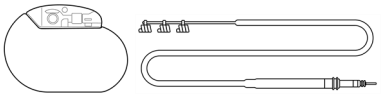
VNS Therapy™

PHYSICIAN'S MANUAL

VNS Therapy™ Generator and Lead Manual for Epilepsy



Pulse™ Generator— Model 102

Pulse Duo™ Generator— Model 102R

Demipulse™ Generator— Model 103

Demipulse Duo™ Generator— Model 104

AspireHC™ Generator— Model 105

AspireSR™ Generator— Model 106

SenTiva™ Generator— Model 1000

SenTiva Duo™ Generator— Model 1000-D

Lead — Model 302

PerenniaDURA™ Lead — Model 303

PerenniaFLEX™ Lead — Model 304

December 2023

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CHAPTER 1

Introduction to the VNS Therapy System

Links to the following documents are found at www.livanova.com.

- Model-specific programming system manuals
- VNS Therapy System Glossary
- LivaNova Neuromodulation Symbols and Definitions

This topic includes the following concepts:

1.1. System—Brief Description

The LivaNova VNS Therapy system, used for vagus nerve stimulation, consists of an implantable generator, lead, and external programming system used to change stimulation settings. The generator and lead make up the implantable portion of the VNS Therapy system.

1.1.1. Generator

The generator is an implantable, multi-programmable pulse generator that delivers electrical signals to the vagus nerve via the lead. The generator is housed in a hermetically sealed titanium case and is powered by a single battery.

NOTE: For detailed technical information, see "Technical Information—Generators" on page 60.

1.1.2. Lead

The lead, which delivers the electrical signal from the generator to the vagus nerve, is insulated with silicone. It has two helical electrodes and an anchor tether, which are coiled around the left vagus nerve. The lead is available in multiple sizes to ensure optimal electrode fit on different size nerves. The connector end of the lead is tunneled subcutaneously to the generator pocket.

NOTE: For detailed technical information, see "Technical Information—Leads" on page 64.

1.1.3. Programming System

The external programming system includes a tablet and programming software (Programmer), and a programming wand (Wand). The physician uses the programming system to interrogate and adjust generator settings and obtain system integrity information. The software includes a System Diagnostics feature that is used to assess lead impedance, battery status, and output current.

1.2. System—Compatibility

The following table provides compatibility information for generators, surgical accessories, programming systems, and programming modes and features. For detailed descriptions of programming modes and features, see "System Modes and Features" on page 71.

Table 1. System Compatibility

Generator Model	Compatible Lead (Header)	Surgical Accessories	Programming Modes and Features	Wand	Programmer
Model 1000	Model 304 Model 303 Model 302	Model 502 Model 402	• Normal Mode • AutoStim Mode • Magnet Mode • Guided Titration (Guided Programming) • Scheduled Titration (Scheduled Programming) • Day-Night Programming • Low Heart Rate Detection • Prone Position Detection	Model 2000*	Model 3000
				Model 2000 v1.1.2	Model 3100 v1.1
Model 1000-D	Model 300	Model 502 Model 402	• Normal Mode • AutoStim Mode • Magnet Mode • Guided Titration (Guided Programming) • Scheduled Titration (Scheduled Programming) • Day-Night Programming • Low Heart Rate Detection • Prone Position Detection	Model 2000* v1.1+	Model 3000 v1.6 +
				Model 2000 v1.1.2	Model 3100 v1.1
Model 106	Model 304 Model 303 Model 302	Model 502 Model 402	• Normal Mode • AutoStim Mode • Magnet Mode	Model 201	Model 250 v11.0
				Model 2000*	Model 3000
			• Guided Programming	Model 2000*	Model 3000
Model 105 **Model 103** **Model 102**	Model 304 Model 303 Model 302	Model 502 Model 402	• Normal Mode • Magnet Mode	Model 201	Model 250 v11.0
				Model 2000 *	Model 3000
			• Guided Programming	Model 2000*	Model 3000

Table 1. System Compatibility (continued)

Generator Model	Compatible Lead (Header)	Surgical Accessories	Programming Modes and Features	Wand	Programmer
Model 104 Model 102R	Model 300	Model 502 Model 402	• Normal Mode • Magnet Mode	Model 201	Model 250 v11.0
				Model 2000*	Model 3000
			• Guided Programming	Model 2000*	Model 3000

* Model 2000 v1.1.2 is only compatible with Model 3000 v1.6.2.

1.3. System—Package Contents

Table 2. System—Package Contents

Components	Package Contents
Generators	1 generator 1 hex screwdriver
Leads	1 lead 4 tie-downs
Tunneler	1 tunneler shaft 1 tunneler bullet tip 1 small-diameter sleeve (for single pin leads) 1 large-diameter sleeve (for dual pin leads)
Accessory Pack	1 hex screwdriver 1 single pin test resistor 1 dual pin test resistor 4 tie-downs
Wand Model 201	1 Wand with attached serial cable 1 9-Volt battery
Wand Model 2000	1 Wand with detached USB cable 2 AA batteries
Programmer (Model 250 and Model 3000)	1 commercial tablet (pre-installed software) 1 power supply 1 adapter
Programmer (Model 3100)	1 commercial tablet 1 wall / USB charger 1 USB cable
Patient Kit	2 magnets (≥ 35 Gauss) 1 watch strap 1 clip

1.4. Education, Training, and Services

LivaNova employs highly trained representatives and engineers located throughout the world to serve you and provide training to prescribers and implanters of LivaNova products. Physicians must contact LivaNova before a VNS Therapy system is prescribed or implanted for the first time. In addition to the information provided herein, training material includes, but is not limited to, surgeon or prescriber physician training slide presentation, surgical video, training block and demo lead, etc. The required training (elements, duration, and frequency) to use LivaNova products depend on the product and physician. Needs can be discussed and arranged with your local LivaNova representative, or contact "Technical Support" on page 223.

CHAPTER 2

Indications, Warnings and Precautions

This topic includes the following concepts:

2.1. Intended Use and Indications

The VNS Therapy system is indicated for use as an adjunctive therapy in reducing the frequency of seizures in patients 4 years of age and older with partial onset seizures that are refractory to antiepileptic medications.

VNS Therapy may be approved for other indications in your market. All VNS Therapy labeling is located at www.livanova.com.

2.2. Contraindications

Unless otherwise specified, all indications, contraindications, and possible complications and adverse events are applicable to all implantable parts of the VNS Therapy system.

Vagotomy

The VNS Therapy system cannot be used in patients with a bilateral or left cervical vagotomy.

Diathermy

- Do not use shortwave diathermy, microwave diathermy, or therapeutic ultrasound diathermy (hereafter referred to as diathermy) on patients implanted with a VNS Therapy system. Energy delivered by diathermy may be concentrated into or reflected by implanted products such as the VNS Therapy system. This concentration or reflection of energy may cause the system to heat.
- Tests indicate that diathermy can cause the VNS Therapy system to heat well above temperatures required for tissue destruction. The heating that results from diathermy can cause temporary or permanent nerve, tissue, or vascular damage. This damage may result in pain or discomfort, loss of vocal cord function, or possible death if there is damage to blood vessels.
- Because diathermy can concentrate or reflect its energy off any size implanted object, the hazard of heating is possible when any portion of the VNS Therapy system remains implanted, including just a small portion of the lead or electrode. Injury or damage can occur during diathermy treatment whether the system is turned "ON" or "OFF".
- Diathermy is further prohibited because it may also damage the VNS Therapy system components and result in loss of therapy, which requires additional surgery for system explantation and replacement. All risks associated with surgery or loss of therapy (loss of seizure control) would then be applicable.
- Advise your patients to inform all their healthcare professionals that they should not be exposed to diathermy treatment.

2.3. Warnings ⚠

Unless otherwise specified, all indications, contraindications, and possible complications and adverse events are applicable to all implantable parts of the VNS Therapy system.

2.3.1. Warnings—All Implants

Use

This device is a permanent implant. The VNS Therapy system should only be prescribed and monitored by physicians who have specific training and expertise in the management of seizures and the use of this device. It should only be implanted by physicians who are trained in surgery of the carotid sheath and have received specific training in the implantation of this device.

Not a Cure

Physicians should warn patients that VNS Therapy is not a cure for epilepsy. Since seizures may occur unexpectedly, patients should consult with a physician before they engage in unsupervised activities that could harm them or others (e.g., drive, swim, bathe, participate in strenuous sports).

Safety and Efficacy Not Established

The safety and efficacy of the VNS Therapy system have not been established for uses outside its approved indications for use. The safety and efficacy of VNS Therapy *have not been shown* for people with these conditions:

- Cardiac arrhythmias or other abnormalities
- History of dysautonomias
- History of previous therapeutic brain surgery or CNS injury
- History of respiratory diseases or disorders, including dyspnea and asthma
- History of ulcers (gastric, duodenal, or other)
- History of vasovagal syncope
- Only one vagus nerve
- Other concurrent forms of brain stimulation
- Pre-existing hoarseness
- Progressive neurological diseases other than epilepsy
- Primary generalized seizures
- Under 4 years of age

Dysfunctional Cardiac Conduction Systems

The safety and effectiveness of the VNS Therapy system in patients with predisposed dysfunction of cardiac conduction systems (re-entry pathway) have not been established. Evaluation by a cardiologist is recommended if the family history, patient history, or electrocardiogram suggests an abnormal cardiac conduction pathway. Serum electrolytes, magnesium, and calcium should be documented before implantation. Additionally, postoperative bradycardia can occur among patients with certain underlying cardiac arrhythmias. Post-implant electrocardiograms and Holter monitoring are recommended if clinically indicated.

Bradycardia or Asystole During Implantation

It is important to follow recommended implantation procedures and intra-operative product tests described in the "Implantation Procedure Overview" on page 99. During the intra-operative System Diagnostics infrequent incidents of bradycardia and/or asystole have occurred. If asystole, severe bradycardia (heart rate < 40 bpm), or a clinically significant change in heart rate is encountered during a System Diagnostics or during initiation of stimulation, physicians should be prepared to follow guidelines consistent with Advanced Cardiac Life Support (ACLS).

Additionally, postoperative bradycardia can occur among patients with certain underlying cardiac arrhythmias. If a patient has experienced asystole, severe bradycardia (heart rate < 40 bpm), or a clinically significant change in heart rate during a System Diagnostics test at the time of initial device implantation, the patient should be placed on a cardiac monitor during initiation of stimulation.

The safety of this therapy has not been systematically established for patients that experience bradycardia or asystole during VNS Therapy system implantation.

External Defibrillation or Cardioversion (electrical)

External defibrillation or cardioversion (electrical) procedures may damage the generator and can temporarily or permanently damage the nerve. Follow these recommendations to minimize the flow of current through the generator and lead system:

- Position defibrillation patches or paddles perpendicular to the generator and lead system, and as far from the generator as possible.
- Use the lowest clinically appropriate energy output (watt-seconds).
- Confirm generator function after any internal or external defibrillation, or cardioversion treatment.

Magnetic Resonance Imaging (MRI)

Patients with the VNS Therapy system, or any part of the system, implanted should have MRI procedures performed **only as described in the MRI Guidance instructions for use**.

MR Unsafe Devices

The Wand, Programmer, and patient magnet are MR Unsafe devices. These devices are projectile hazards and must not be brought into the MR scanner room.

Excessive Stimulation

Excessive stimulation is the combination of an excess duty cycle (i.e., one that occurs when ON time is greater than OFF time) and high frequency stimulation (i.e., stimulation at ≥ 50 Hz). Excessive stimulation has resulted in degenerative nerve damage in laboratory animals. Furthermore, excess duty cycle can be produced by continuous or frequent magnet activation (> 8 hours). While LivaNova limits the maximum programmable frequency to 30 Hz, it is recommended that you do not stimulate with excess duty cycle. Further, physicians should warn patients about continuous or frequent magnet use as this could lead to early battery depletion.

Device Manipulation

Patients who manipulate the generator and lead through the skin (Twiddler's Syndrome) may damage or disconnect the lead from the generator and/or possibly cause damage to the vagus nerve. For patients with the Model 1000/ Model 1000-D, recalibration of Prone Position detection may be required. Patients, parents, and caregivers should be warned against manipulating the generator and lead.

Swallowing Difficulties

Dysphagia (difficulty swallowing) may occur with active stimulation, and aspiration may result from the increased swallowing difficulties. Patients with pre-existing swallowing difficulties and those with a history of drooling or hypersalivation are at greater risk for aspiration. Appropriate aspiration precautions should be taken for such patients. Use of the magnet to temporarily stop stimulation while eating may mitigate the risk of aspiration.

Dyspnea or Shortness of Breath

Dyspnea (shortness of breath) may occur with active VNS Therapy. Any patient with underlying pulmonary disease or insufficiency, such as chronic obstructive pulmonary disease or asthma, may be at increased risk for dyspnea and should have their respiratory status evaluated prior to implantation and monitored following initiation of stimulation.

Obstructive Sleep Apnea (OSA)

Patients with obstructive sleep apnea (OSA) may have an increase in apneic events during stimulation. Lowering stimulus frequency or prolonging "OFF" time may prevent exacerbation of OSA. Vagus nerve stimulation may also cause new onset sleep apnea in patients who have not previously been diagnosed with this disorder. It is recommended that patients being considered for VNS Therapy who demonstrate signs or symptoms of OSA, or who are at increased risk for developing OSA, should undergo the appropriate evaluation prior to implantation.

Device Malfunction

Device malfunction could cause painful stimulation or direct current stimulation. Either event could cause nerve damage and other associated problems. Instruct patients, parents, and caregivers to use the magnet to stop stimulation if they suspect a malfunction, and then to contact their physician immediately for further evaluation. Prompt surgical intervention may be required if a malfunction occurs.

Device Trauma

Blunt trauma to the neck and/or any area of the body beneath which the lead is implanted could possibly cause damage to the lead.

Sudden Unexplained Death in Epilepsy (SUDEP)

Through August 1996, 10 sudden and unexpected deaths (definite, probable, and possible) were recorded among the 1,000 patients implanted and treated with the VNS Therapy device. During this period, these patients had accumulated 2,017 patient-years of exposure.

Some of these deaths could represent seizure-related deaths in which the seizure was not observed, at night, for example. This number represents an incidence of 5.0 definite, probable, and possible SUDEP deaths per 1,000 patient-years.

Sudden Unexplained Death in Epilepsy (SUDEP)

Although this rate exceeds that expected in a healthy (nonepileptic) population matched for age and sex, it is within the range of estimates for epilepsy patients not receiving vagus nerve stimulation, ranging from 1.3 SUDEP deaths for the general population of patients with epilepsy, to 3.5 (for definite and probable) for a recently studied antiepileptic drug (AED) clinical trial population similar to the VNS Therapy system clinical cohort, to 9.3 for patients with medically intractable epilepsy who were epilepsy surgery candidates.

2.3.2. Warnings—Generators

2.3.2.1. Generators with AutoStim

NOTE: For a full description of AutoStim, see "AutoStim Mode" on page 72.

Cardiac Arrhythmia

Model 1000 Model 1000-D Model 106	The AutoStim Mode feature should not be used in patients with clinically meaningful arrhythmias currently being managed by devices or treatments that interfere with normal intrinsic heart rate responses (e.g., pacemaker dependency, implantable defibrillator, beta adrenergic blocker medications). Patients also should not have a history of chronotropic incompetence commonly seen in patients with sustained bradycardia (heart rate < 50 bpm). See also "Operation of Other Implanted Devices" on page 31.

Pre-Surgical Surface Assessment

Model 1000 Model 1000-D Model 106	For anticipated use of the AutoStim feature, it is important to follow the recommended pre-surgical surface assessment described in the implantation procedure. For the device to detect heart rate, patients must have a peak-to-peak R-wave amplitude ≥ 0.4 mV on ECG measured from the proposed electrode location in the neck to the proposed generator location in the chest via surface ECG electrodes in the body positions described in "Determine Acceptable Implant Locations" on page 95.

2.3.2.2. Model 106 (Serial Numbers < 80000 Only)

Potential Interruption of Therapy

For Model 106 (Serial Numbers < 80000), there is a potential for interruption of therapy. Magnet Mode output current should always be set at least 0.125 mA higher than AutoStim Mode output current. When Magnet Mode output current is less than or equal to AutoStim Mode output current, repeated magnet applications may trigger a device safety feature that disables stimulation. While stimulation is disabled the generator will not provide therapy and must be programmed by the physician to resume treatment. If stimulation output becomes disabled (0 mA), stimulation can be reinstated at the next office visit by programming stimulation output current on.

2.3.2.3. Model 1000 (Serial Numbers <100,000 Only)

Potential Erroneous High Impedance Warning

Some Model 1000 generators (serial numbers < 100,000) report higher impedance values compared to prior models, due to a change in the timing of the impedance measurement during the diagnostic test pulse. This timing difference will not impact the battery longevity or the ability to safely deliver therapy. However, it may result in an erroneous high impedance warning:

- **Potential erroneous high impedance warning during implantation surgery**
  Erroneous high impedance is more likely for replacement generator surgeries compared to new implants due to fibrosis of the lead. Follow troubleshooting steps in the programming system physician's manual to resolve common sources of true high impedance (confirm lead pin insertion, setscrew tension, electrode placement on the nerve, irrigation of the nerve, and generator diagnostics indicative of normal function). If high lead impedance (≥ 5300 Ω) is still reported, consider lead or generator replacement.
- **Potential erroneous high Impedance Warning at follow-up or titration visit**
  If high lead impedance is observed (≥ 5300 Ω), perform a chest and neck x-ray (anteroposterior and lateral views) and contact "Technical Support" on page 223. Surgery is warranted if improper lead pin insertion or lead break is present in the x-ray. For implanted Model 1000 (serial numbers < 100,000), advise patients to use the magnet daily to verify that stimulation is felt and report any change in perceived clinical symptoms related to stimulation (e.g., increase in seizures, painful stimulation, changes in perception of stimulation). In the absence of device-related complications (e.g., magnet stimulation is perceived, no changes in clinical symptoms), higher than expected lead impedance is not an indication of generator or lead malfunction. Continue to perform System Diagnostics at each visit to monitor for further increases in impedance.

2.4. Precautions ⚠

Physicians should inform patients about all potential risks and adverse events discussed in the VNS Therapy system directions for use.

2.4.1. Precautions—All Implants

General Precaution

Unless otherwise specified, all indications, contraindications, and possible complications and adverse events are applicable to all implantable parts of the VNS Therapy system.

Physician Training

Appropriate physician training is very important.
Physicians who prescribe should be experienced in the diagnosis and treatment of epilepsy and should be familiar with the programming and use of the VNS Therapy system. See also "Education, Training, and Services" on page 16.
Physicians who implant the VNS Therapy system should be experienced with surgery within the carotid sheath and capable of performing the surgical technique used to implant the VNS Therapy system. See also "Surgeon Training" on page 92.

Use During Pregnancy

The safety and effectiveness of the VNS Therapy system have not been established for use during pregnancy. There are no adequate and well-controlled studies of VNS Therapy in pregnant women. Reproductive studies have been performed on female rabbits stimulated with a commercially available VNS Therapy system at stimulation dose settings similar to those used for humans. These animal studies have revealed no evidence of impaired fertility or harm to the fetus due to VNS Therapy. Because animal reproduction studies are not always predictive of human response and animal studies cannot address developmental abnormalities, VNS Therapy should be used during pregnancy only if clearly needed.

Effects on Other Medical Devices

The VNS Therapy system may affect the operation of other implanted devices (e.g., cardiac pacemakers, implanted defibrillators). Possible effects include sensing problems and inappropriate device responses. If the patient requires concurrent implantable pacemaker, defibrillator therapy, or other types of stimulators, careful programming of each system may be necessary to optimize the patient's benefit from each device. Furthermore, when the VNS Therapy system and another stimulator are implanted in the same patient, the two stimulators should be placed at least 10 centimeters (4 inches) apart to avoid communication interference. Users should refer to the product labeling for the concurrent device to determine if there are additional precautions that should be observed.

Device Reset

Model 1000 Model 1000-D Model 106 Model 105 Model 104 Model 103	When the generator is reset, its stimulation output is disabled; however, all settings and device history are preserved. After a successful reset, the generator stimulation output may be re-enabled to resume operation at the previously programmed settings.
Model 102 Model 102R	A reset of the device will program the device OFF (output current = 0 mA).

Device History Loss

Model 102 Model 102R	A reset of the device causes all device history information to be lost. The device history information (e.g., programmed patient initials, implant date, device serial number) should be documented before it is reset.

2.4.2. Precautions—Generator and Lead

2.4.2.1. Generators

Unintended Stimulation	
Model 1000 Model 1000-D Model 106	For devices that sense changes in heart rate, false positive detection may cause unintended stimulation. Examples of instances where heart rate may increase include exercise, physical activity, and normal autonomic changes in heart rate, both awake and asleep, etc. Depending on the amount of unintended stimulation, adjustments to the AutoStim feature's detection threshold should be considered. If necessary, the feature can be disabled.
Battery Depletion or Drain	
Model 1000 Model 1000-D Model 106	Talk to your patient about the AutoStim feature. Use of this feature will result in reduced battery longevity leading to more frequent replacements. Since the AutoStim feature can significantly affect the generator battery life, patients should return to their physician at appropriate intervals to evaluate whether they are receiving benefit from the current AutoStim settings. See "Generators with AutoStim" on page 79.
Model 102 Model 102R	**Do not use frequencies of 5 Hz or below for long-term stimulation.** These frequencies generate an electromagnetic trigger signal, which results in excessive battery depletion of the implanted generator. Therefore, use these low frequencies for short periods of time only.

2.4.2.2. Optional Generator Features

NOTE: For a full description of optional features, see "System Modes and Features" on page 71.

Low Heart Rate / Prone Detection	
Model 1000 Model 1000-D	These features are for informational purposes only. Do not use detected events for alarms or medical diagnosis.
Scheduled Programming	
Model 1000 Model 1000-D	Since this feature allows the generator to apply therapy increases at scheduled intervals, it may not be appropriate for use in patients who are nonverbal or are unable to use the patient magnet to stop undesired stimulation. Similarly, exercise caution for use of this feature in patients with a history of obstructive sleep apnea, shortness of breath, coughing, swallowing difficulties, or aspiration.

Day-Night Programming	
Model 1000 Model 1000-D	Consider risk and benefits of altering a patient's known efficacious settings before this feature is used or when parameter adjustments are made. Assess patient tolerability of the alternate parameter set before the patient leaves the office visit. Inform your patients about when to expect a setting change (i.e., when Daytime settings transition into Nighttime settings).

Time-Based Features	
Model 1000 Model 1000-D	Day-Night Programming and Scheduled Programming do not automatically adjust for Day Light Savings or time zone changes. Tell the patient to follow-up with the physician for reprogramming, if needed.

2.4.2.3. Leads

Do Not Use a Lead Other Than a VNS Therapy Lead

Use a VNS Therapy single-pin lead with the single-receptacle generator or a VNS Therapy dual-pin lead with the dual-receptacle generator because use of other leads may damage the generator or injure the patient.

Lead Size

The lead is available in multiple sizes. Since it is not possible to predict in patients what size lead will be needed, **it is recommended that at least one alternate lead size be available in the operating room**. In addition, backups for leads should be available in the event of compromised sterility or damage induced during surgery. For lead size availability, see "Technical Information—Leads" on page 64.

Lead Related Adverse Events

Possible adverse events specifically related to the lead include migration, dislodgement, breakage, and corrosion.

Potential Effects of Lead Breaks

Lead fractures of the VNS Therapy system may prevent patients from receiving therapy. It may also prevent or interfere with tachycardia detection, if the feature is enabled. Children (4–11 years of age) may be more likely to exhibit certain risk factors for lead failures including a higher activity level and a higher likelihood to manipulate the lead. If a lead fracture is suspected, perform diagnostic testing to evaluate continuity within the system. If diagnostics suggest that a fracture is present, consider turning the generator to zero milliamps (0 mA) of output current. Continuing stimulation with a fractured lead may result in dissolution of the conductor material resulting in adverse events (e.g., pain, inflammation, and vocal cord dysfunction). The benefits and risks of leaving the generator ON (active stimulation) when a lead fracture is present should be evaluated and monitored by the medical professional treating the patient.
For details on diagnostic tests, see "Device Diagnostics" in the model specific programming system manual posted at www.livanova.com.

2.4.3. Precautions—Related to Implantation

2.4.3.1. Operative

Vagus Nerve Placement

The VNS Therapy system is indicated for use only in stimulating the left vagus nerve in the neck area inside the carotid sheath, **below where the superior and inferior cervical cardiac branches separate from the vagus nerve**. The safety and efficacy of the VNS Therapy system have not been established for stimulation of the right vagus nerve or of any other nerve, muscle, or tissue.

Reversal of Lead Polarity

Reversal of lead polarity has been associated with an increased chance of bradycardia in animal studies. It is important that the electrodes are attached to the left vagus nerve in the correct orientation. It is also important to make sure that leads with dual connector pins are correctly inserted (white marker band / serial number to + connection) into the generator receptacle.

Device Placement

Model 1000 Model 1000-D Model 106	For the AutoStim feature, the physical location of the device critically affects its ability to properly sense heart beats. Therefore, care must be taken to follow the implant location selection process outlined in the Implantation Procedure. Note that this implant location selection procedure may be performed pre-operatively as part of the patient's surgical work-up.

Line-Powered Equipment

Exercise extreme caution if line-powered equipment is used to test the lead because leakage current can injure the patient.

Setscrew

Do not insert a lead in the generator receptacle until you visually **verify that the setscrew is sufficiently retracted** to allow insertion. Do not back the setscrew out further than needed for lead insertion.

Hex Screwdriver

Ensure that the hex screwdriver is fully inserted in the setscrew and then push in on the hex screwdriver and turn it clockwise until it clicks. To avoid a dislodged setscrew plug or damage to the setscrew, insert the hex screwdriver into the center of the setscrew plug and keep it perpendicular to the generator.

Infection Control

It is important to follow infection control procedures. Infections related to any implanted device are difficult to treat and may require that the device be explanted. The patient should be given antibiotics pre-operatively. The surgeon should ensure that all instruments are sterile prior to the operation. Frequent irrigation of both incision sites with generous amounts of bacitracin or equivalent solution should be performed prior to closure. To minimize scarring, these incisions should be closed with cosmetic closure techniques. Also, antibiotics should be administered postoperatively at the discretion of the physician. Children (4–11 years of age) may have a greater risk for infection when compared to adolescent and adult patients (≥12 years). Careful monitoring for site infection as well as the avoidance of manipulation of the surgical site post implant should be stressed.

2.4.3.2. Post-Operative

Lead Stabilization

The patient can use a neck brace for the first week to help ensure proper lead stabilization.

Programming After Surgery

Do not program the VNS Therapy system to an ON or periodic stimulation treatment for at least 14 days after the initial or replacement implantation. Failure to observe this precaution may result in patient discomfort or adverse events.

Vagus Nerve Damage

Some complications may be associated with damage to the vagus nerve:

- Hoarseness may be caused by device malfunction, nerve constriction, or nerve fatigue. Nerve constriction should be apparent within a few days after implantation and may require explantation of the lead. Nerve fatigue usually occurs after intense stimulation parameters have been used and might not be associated with any other adverse event. If fatigue is suspected, the generator should be turned off for several days until hoarseness subsides.
- Persistent hoarseness *not* associated with stimulation suggests possible nerve irritation and should be immediately investigated.
- Trauma to the vagus nerve at the implantation site could result in permanent vocal cord dysfunction.

Laryngeal Irritation

Laryngeal irritation may result from stimulation. Patients who smoke may have an increased risk of laryngeal irritation.

2.4.4. Precautions—Hospital and Medical Environments

Patients should exercise reasonable caution in avoiding devices that generate a strong electric or magnetic field. If a generator ceases operation while in the presence of electromagnetic interference (EMI), moving away from the source may allow it to return to its normal mode of operation.

VNS Therapy System Operation

Always perform device diagnostics after any of the procedures mentioned herein. Additional precautions for these procedures are described below.

Routine Diagnostic Procedures

Most routine diagnostic procedures (e.g., fluoroscopy, radiography) are not expected to affect system operation.

Mammography

To obtain clear images, patients may need to be specially positioned for mammography procedures because of the location of the generator in the chest.

Therapeutic Radiation

Therapeutic radiation may damage the generator's circuitry. Sources of such radiation include therapeutic radiation, cobalt machines, and linear accelerators. The radiation effect is cumulative, with the extent of damage determined by the total dosage. The effects of exposure to such radiation can range from a temporary disturbance to permanent damage and may not be detectable immediately.

Electrosurgery

Use of electrosurgery [i.e., electrocautery or radio frequency (RF) ablation devices] may damage the generator. During the implantation procedure, do not use electrosurgical equipment after the generator is introduced to the sterile field. To minimize the current that flows through the generator and lead system when other surgical procedures are performed, follow these precautions:

- Position the electrosurgery electrodes as far as possible from the generator and lead.
- Avoid electrode placement that puts the generator or lead in the direct path of current flow or within the part of the body being treated.
- Confirm that the generator functions as programmed after electrosurgery.

Electrostatic Discharge (ESD)

ESD may damage the generator. Do not touch the metal shaft of the hex screwdriver when it is engaged with the generator setscrew. This shaft can serve as a path to conduct electrostatic discharges into the device circuitry.

Extracorporeal Shockwave Lithotripsy

Extracorporeal Shockwave Lithotripsy may damage the generator. If therapeutic ultrasound is required, do not position the area of the body where the generator is implanted in the water bath or in any other position that would expose it to ultrasound therapy. If that position cannot be avoided, program the generator output to 0 mA for the treatment, and then after therapy, reprogram the generator to the original parameters.

Treatment That Involves Electrical Currents

If the patient receives medical treatment for which electric current is passed through the body (e.g., from a TENS unit), either the generator output should be set to 0 mA or the function of the generator should be monitored during the initial stages of treatment.

Therapeutic Ultrasound

Routine therapeutic ultrasound could damage the generator and may be inadvertently concentrated by the device, causing harm to the patient.

NOTE: Diagnostic ultrasound has no known adverse effects on the generator or lead.

2.4.5. Precautions—Home Occupational Environments

Patients should exercise reasonable caution in avoiding devices that generate a strong electric or magnetic field. If a generator ceases operation while in the presence of electromagnetic interference (EMI), moving away from the source may allow it to return to its normal mode of operation.

No Effect to Generator Expected

Microwave ovens, electrical ignition systems, power transmission lines, theft-prevention devices, and metal detectors that operate properly are not expected to affect the generator. However, because of their higher energy levels, sources such as transmitting antennas may interfere with the VNS Therapy system. It is suggested that the generator be moved away from equipment—typically at least 1.8 meters (6 feet)—that may cause interference.

CAUTION: The patient should seek medical advice before they enter environments that are protected by a warning notice that prevents entry by patients implanted with a cardiac pacemaker or defibrillator.

Cellular Phones

Based on current test data, RF emissions from cellular phones have no effect on generator operation. Cellular phones may contain magnets (see "Other Electro-Mechanical Devices" below.)

Electronic Article Surveillance (EAS) System Tag Deactivators

EAS System tag deactivators can interfere with VNS Therapy when they are operated in proximity of the generator. Potential effects include inhibited stimulation and accidental activations (Magnet or AutoStim). Patients should be cautioned to stay at least 60 centimeters (2 feet) away from EAS System tag deactivators to avoid potential interference.

Other Electro-Mechanical Devices

Strong magnets, tablet computers and their covers, hair clippers, vibrators, loudspeaker magnets, cellular phones, smart watches, wearable devices, and other similar electrical or electro-mechanical devices, which have a strong static or pulsing magnetic field, can cause accidental magnet activation or stimulation inhibition. Patients should be cautioned to keep such devices at least 20 centimeters (8 inches) away from the generator.

2.4.6. Precautions—Generator and EMI Effects on Other Devices

Patients should exercise reasonable caution in avoiding devices that generate a strong electric or magnetic field. If a generator ceases operation while in the presence of electromagnetic interference (EMI), moving away from the source may allow it to return to its normal mode of operation.

Interference During Stimulation

During stimulation, the generator may interfere with devices that operate in the 30 kHz to 100 kHz range (e.g., pocket transistor radios and hearing aids). This interference is a theoretical possibility, and no effects on hearing aids have been reported, although the generator can interfere with a transistor radio. No specific tests have been done to date, and no definite information on effects is available. The patient should move—typically at least 1.8 meters (6 feet)—away from equipment with which it may interfere.

Interference During Programming or Interrogation

Programming or interrogation of the generator may momentarily interfere with other sensitive electronic equipment nearby. The generator is not expected to trigger airport metal detectors or theft-protection devices that are further than about 1.8 meters (6 feet).

Operation of Other Implanted Devices

The generator and the patient magnet may affect the operation of **other implanted devices**, such as cardiac pacemakers and implantable defibrillators. Possible effects include sensing problems and inappropriate generator responses. If the patient requires concurrent implantable pacemaker and/or defibrillator therapy, careful programming of each system is necessary to optimize the patient's benefit from each device.

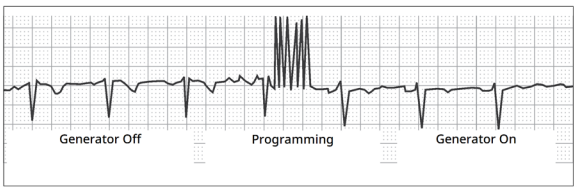
Items Affected by Strong Magnetic Fields

The magnet provided for activation or inhibition of the generator may damage **televisions, computer disks, credit cards, and other items affected by strong magnetic fields**.

Effects on ECG monitors

Generator data communication produces an ECG artifact as shown below.

Figure 1. ECG Artifact Produced by Generator Communication



Interactions With Fetal Monitors

The ranges of operation for the VNS Therapy system and fetal monitors are dissimilar and no interaction would be expected. However, tests have not been performed and the potential may exist for interaction between the VNS Therapy system and fetal monitoring systems.

2.4.7. Precautions—Sterilization

The generator, lead, accessory pack, and tunneler have been sterilized with hydrogen peroxide (H_2O_2 or HP) gas plasma and are supplied in a sterile pack to permit direct introduction into the operating field.

NOTE: Either ethylene oxide (EO/EtO) gas or HP gas plasma may have been used on sterile devices previously distributed.

A use by date and method of sterilization is marked on each package. A sterilization process indicator is located on the inner sterile pack and is only used as an internal manufacturing process aid.

Do Not Re-Sterilize

Do not resterilize any VNS Therapy product. Return any opened devices to LivaNova.

2.4.8. Precautions—Storage

Liquids and Moisture

Do not store any components of the system where they may be exposed to water or other liquids. Moisture can damage the seal integrity of the package materials.

Nonpyrogenic

The implantable portions of the system are nonpyrogenic.

Temperature and Humidity

Store the devices in the system at the ranges indicated below. Conditions outside this range can damage components.

Table 3. Storage Temperature and Humidity Range

Device Type or Model	Temperature Range	Relative Humidity Range
Generators		
All Models	-4 °F (-20 °C) – +131 °F (+55 °C)	N/A
Leads		
All Models	-4 °F (-20 °C) – +131 °F (+55 °C)	N/A

Table 3. Storage Temperature and Humidity Range (continued)

Device Type or Model	Temperature Range	Relative Humidity Range
Surgical Accessories		
Model 402 Model 502	-4 °F (-20 °C) – +131 °F (+55 °C)	N/A
Programming System		
Model 201	-4 °F (-20 °C) – +131 °F (+55 °C)	5% – 95%
Model 2000	-4 °F (-20 °C) – +131 °F (+55 °C)	Up to 95% includes condensation
Model 250	-4 °F (-20 °C) – +131 °F (+55 °C)	10% – 90%
Model 3000 Model 3100	-4 °F (-20 °C) – +131 °F (+55 °C)	10% – 90% non-condensing
Magnet		
Model 220	-4 °F (-20 °C) – +131 °F (+55 °C)	N/A

2.4.9. Precautions—Handling

2.4.9.1. Before Use / Implant

Dropped Device

Do not implant or use a sterile device if the device has been dropped. Dropped devices may have damaged internal components.

Use By Date

Do not implant or use a sterile device if the use by date has expired. This can adversely affect the device's longevity and sterility.

Sterile Device Integrity

Do not implant or use a sterile device if the integrity of the outer or inner sterile barrier has been pierced or altered.

Do Not Ultrasonically Clean

Do not ultrasonically clean any VNS Therapy system components. Ultrasonically cleaning the generator may cause damage.

Do Not Re-implant an Explanted Device

Components of the VNS Therapy system provided sterile are single-use only devices. **Do not re-implant an explanted generator or lead for any reason**, because sterility, functionality, and reliability cannot be ensured, and infections may occur.

2.4.9.2. After Explant

Do Not Incinerate the Generator

The generator contains a sealed chemical battery, and an explosion could result if subjected to incineration or cremation temperatures.

Return Explanted Generators and Leads

Explanted generators and leads are medical waste and should be handled in accordance with local laws. They should be returned to LivaNova for examination and proper disposal, along with a completed Return Product Form. Before device components are returned, disinfect them with Betadine®, Cidex® soak, or other similar disinfectant, and double seal them in a pouch or other container properly labeled with a biohazard warning. For directions, see "Return Product Form " on page 223.

CHAPTER 3

Epilepsy Information—Clinical Studies

This topic includes the following concepts:

3.1. Clinical Studies—Safety

NOTE: For intended use / indications, see "Intended Use and Indications" on page 18.

The VNS Therapy system was implanted in 454 patients in five clinical studies involving 611 devices (some patients had generator replacements). As of August 1996, total VNS Therapy exposure in these 454 patients was 901 device-years. Individual patient exposure averaged 24 months, with a range of eight days to 7.4 years.

A total of nine patients died during these five studies. One patient died from each of the following: thrombotic thrombocytopenic purpura, drowning, aspiration pneumonia, pneumonia, and renal failure associated with drug and alcohol ingestion. No cause of death was apparent for the other four deaths, which may be classified as Sudden Unexplained Death in Epilepsy (SUDEP). None of these deaths were attributed by the investigators to the VNS Therapy system.

3.1.1. Device Performance

The VNS Therapy system performed according to its specifications. Most device issues were communication difficulties resolved by repositioning the programming Wand or replacing the programming Wand batteries. One high lead impedance occurred requiring replacement; a lead break due to fatigue at the electrode bifurcation was noted. Most device complaints were resolved on the day of the initial complaint.

3.1.2. Adverse Events Observed in Studies

Included among the five clinical trials were two randomized, blinded, active control trials (Study E03 and E05), which involved 314 patients and the implantation of 413 devices, yielding a VNS Therapy system exposure (inclusive of long-term follow up) of 591 device years. These trials form the basis of the rates of observed adverse events.

The table below contains only a partial list of the more common and expected observed adverse events associated with the VNS Therapy system. A comprehensive listing of adverse events observed in studies is available by study from the Clinical Research department at LivaNova.

The table below reports the adverse events from these studies during the randomized phase (approximately a 14-week observation period) and randomized phase plus long-term follow up (> 3 months) through August 1996. The most common side effect associated with stimulation was hoarseness (voice alteration), which, depending on device settings, can be severe to barely perceptible. Hoarseness is reported to occur primarily during the ON period of stimulation.

Table 4. Observed Adverse Events

N=413 devices in 314 patients, 152 patients in the HIGH treatment group, 591 device years						
Randomized + Long-term Follow Up (> 3 Months) N=314 Patients, 591 Device-years					Randomized Phase, HIGH Only N=152 Pts	
Adverse Events (AE)	Number of Patients*	% of Patients†	Number of Events	Events / Device-Year	Number of Patients	% of Patients
Serious AEs‡						
Surgically related	13	4.1	13	0.022	N/A	N/A
Stimulation related	4	1.2	4	0.007	1	0.7
Non-serious AEs						
Voice alteration	156	50	720	1.218	91	60
Increased coughing	129	41	456	0.772	57	38
Pharyngitis	84	27	182	0.308	36	24
Paresthesia	87	28	377	0.638	32	21
Dyspnea	55	18	55	0.093	32	21
Dyspepsia	36	12	98	0.166	22	15
Nausea	59	19	154	0.261	21	14
Laryngismus	10	3.2	30	0.051	9	5.9

* Number of patients reporting the event at least once.
† Percentage of patients reporting the event at least once.
‡ Included infection, nerve paralysis, hypoesthesia, facial paresis, left vocal cord paralysis, left facial paralysis, left hemidiaphragm paralysis, left recurrent laryngeal nerve injury, urinary retention, and low-grade fever.

3.1.2.1. Status Epilepticus

Valid estimates of the incidence of treatment-emergent status epilepticus among VNS Therapy system treated patients are difficult to obtain because Investigators participating in clinical trials did not all employ identical rules for identifying cases. At a minimum, two of 441 adult patients had episodes that could be described unequivocally as “status.” In addition, a number of reports were made of variably defined episodes of seizure exacerbation (for example, seizure clusters and seizure flurries).

3.1.2.2. Rebound After Stimulation was Stopped

Seizure frequency was monitored for one to four weeks after stimulation was stopped because of battery depletion in 72 instances (68 patients) in Study E03. Of these instances, 11 of the 72 (15%) had a greater than 25 percent increase above baseline, and 42 of the 72 (58%) had a greater than 25 percent decrease in seizure rate. The seizure rate increased by more than 1.5 standard deviations above baseline in 10 percent of instances (compared with the 7 percent expected).

3.1.2.3. Potential Adverse Events

Adverse events reported during clinical studies as statistically significant are listed below:

- Ataxia (loss of the ability to coordinate muscular movement)
- Dyspepsia (indigestion)
- Dyspnea (difficulty breathing, shortness of breath)
- Hypoesthesia (impaired sense of touch)
- Increased coughing
- Infection
- Insomnia (inability to sleep)
- Laryngismus (throat, larynx spasms)
- Muscle movement or twitching generally associated with stimulation
- Nausea
- Pain
- Paresthesia (prickling of the skin)
- Pharyngitis (inflammation of the pharynx, throat)
- Voice alteration (hoarseness)
- Vomiting

Other potential Adverse Events possibly associated with surgery or stimulation include, but are not limited to, the following:

- Aspiration (fluid in the lungs)
- Blood clotting
- Choking sensation
- Damage to nerves or vasculature in the surgical area, including the carotid artery and jugular vein
- Device (generator and/or lead) migration or extrusion
- Dizziness
- Dysphagia (difficulty swallowing)
- Duodenal ulcer, gastric ulcer
- Ear pain
- Facial flushing (may be more likely in children aged 4-11 years)
- Facial paralysis, paresis
- Foreign body reaction to implants, including possible tumor formation

- Formation of fibrous tissue, pockets of fluid
- Heart rate and rhythm changes
- Hiccuping
- Incision site pain
- Irritability
- Laryngeal irritation (sore, painful throat)
- Left hemidiaphragm paralysis
- Left recurrent laryngeal nerve injury
- Left vocal cord paralysis
- Low-grade fever
- Muscle pain
- Neck pain
- Nerve injury
- Painful or irregular stimulation
- Seroma
- Skin, tissue reaction
- Stomach discomfort
- Tinnitus (ringing in the ears)
- Tooth pain
- Unusual scarring at the incision site
- Urinary retention
- Vagus nerve paralysis
- Weight change / Loss of appetite (potential for increased risk in children and adolescents)
- Worsening of asthma and bronchitis

⚠ CAUTION: Patients who manipulate the generator and lead through the skin may damage or disconnect the lead from the generator and/or possibly cause damage to the vagus nerve.

3.1.2.3.1. Analysis of Medical Device Reports Submitted to the FDA—Epilepsy Indication for the VNS Therapy System From July 1, 1997 Through October 8, 2004

Summary

Once a medical device is approved for commercial distribution, the United States Food and Drug Administration (FDA) regulations require certain parties, including manufacturers of medical devices, to report to the FDA deaths and serious injuries to which a device has or may have caused or contributed. The required report is referred to as a medical device report (MDR).

As part of the approval for a new indication in 2005, the FDA Office of Biometrics and Surveillance analyzed all MDRs submitted for the VNS Therapy system from July 1, 1997 through October 8, 2004. During this period,

the VNS Therapy system had a single approved indication, epilepsy. The analysis included 2,887 reports, 2,453 of which were reported from sites within the United States. By the end of the period analyzed, there were 32,065 VNS Therapy device implants and 80,144 device-years of implant experience. It is important to emphasize that, although the events occurred during treatment with the VNS Therapy system, the submission of an MDR does not necessarily mean the product caused or contributed to the event being reported.

Deaths

A total of 524 deaths were reported to the FDA during the period from July 1, 1997 through October 8, 2004. By the end of the period, there were 32,065 VNS Therapy device implants and 80,144 device-years of implant experience. Of the 524 deaths, 102 (20%) were of an "unknown cause," including 24 deaths of unknown cause that occurred during sleep (5% of total deaths). Of those deaths with a reported cause, the following were the most common etiologies:

- Seizure disorder (152 reports; 29% of total deaths), including sudden unexplained death in epilepsy and status epilepticus
- Respiratory events (99 reports; 19% of total deaths), including pneumonia, pulmonary edema, and hypoxia
- Cardiac events (51 reports; 10% of total deaths), including cardiopulmonary arrest, infarction, and arrhythmias
- Neurovascular events (24 reports; 5% of total deaths), including stroke and cerebral hemorrhage
- Malignancy (19 reports; 3% of total deaths), including brain and colon
- Suicide (9 reports; 2% of total deaths)

Serious injuries

A total of 1,644 serious injuries were reported to the FDA during the period from July 1, 1997 through October 8, 2004. By the end of the period, there were 32,065 VNS Therapy device implants and 80,144 device-years of implant experience. The most frequently reported serious injury was infection (525 reports). Approximately 40% of these were known to have required device explantation. The second most common serious injury reported was increased seizure activity (324 reports). Others included:

- Vagus nerve injury (181 reports), including vocal cord paralysis (109) and hoarseness (71)
- Respiratory injuries (141 reports), including sleep apnea (33), dyspnea (50), and aspiration (14)
- Cardiac events (123 reports), including tachycardia, bradycardia, palpitations, hypertension, hypotension, syncope, and asystole
- Pain (81 reports), including chest and neck pain
- Gastrointestinal events (60 reports), including dysphagia (24) and weight loss (24)
- Depression (21 reports)

Of the 1,644 reports of serious injury, 694 (42%) were associated with subsequent device explantation in that subject.

Device malfunctions

A total of 708 device malfunctions were reported to the FDA during the period from July 1, 1997 through October 8, 2004. By the end of the period, there were 32,065 VNS Therapy device implants and 80,144 device-years of implant experience. Some of the most common malfunctions reported were high lead impedance (351), lead breakage (116), device failure (44), and device migration (20).

3.2. Clinical Studies—Effectiveness

Five acute-phase clinical studies involving the VNS Therapy system have been conducted (see below). These studies enrolled 537 patients, of whom 454 were implanted with the VNS Therapy system. A total of 611 devices were implanted, and patient exposure totaled 901 device-years, with an individual mean patient exposure of 24 months (ranging from eight days to 7.4 years). A total of 45 centers participated in these studies: 40 in the United States, 2 in Germany, and 1 each in Canada, The Netherlands, and Sweden.

NOTE: References to "partial onset seizures" have been changed to "focal onset seizures" to align with updated official seizure type terminology; however, the functional definition of the condition remains the same.

Table 5. Description of Clinical Studies

All patients enrolled in all clinical studies, N=537						
	Longitudinal			Parallel		
Study	E01	E02	E04	E03	E05	Total
Type of study	pilot longitudinal	pilot longitudinal	open longitudinal	randomized parallel, high/low	randomized parallel, high/low	–
Number of patients enrolled	11	5	133	126	262	537
Number of centers*	3	2	24	17	20	45
Reference period (baseline)	weeks 2 to 4	weeks 3 to 6	weeks -4 to 0	weeks -12 to 0	weeks -12 to 0	–
Seizure type	focal	focal	all types	focal	focal	–
Number of AEDs	1 to 2	1 to 2	not specified	0 to 3	1 to 3	–

* Total includes Non-U.S. centers (Canada, The Netherlands, Germany-2, and Sweden); several U.S. centers participated in more than one study.

3.2.1. Purpose

The purpose of the studies was to determine whether adjunctive use of optimal stimulation of the left vagus nerve could reduce seizure frequency in patients with refractory seizures.

3.2.2. Methods

In the two randomized, blinded, active control trials (E03 and E05), patients were randomly assigned to either of two treatment groups: HIGH (believed to be therapeutic) or LOW (believed to be less therapeutic). Patients enrolled in the study were seen every four weeks during the baseline period (weeks -12 to 0). Patients meeting eligibility were implanted with the generator and lead (see below).

Two weeks after implantation, patients were randomized to the HIGH or LOW stimulation group, and the generator was activated. Patients in the HIGH groups received a higher frequency, greater pulse width, and higher duty cycle of stimulation. The randomized treatment period that followed activation of the generator lasted 14 weeks (the last 12 weeks of which were used in the efficacy analysis—the first two weeks for a treatment ramp-up period).

Table 6. Description of Patients

All patients implanted in all clinical studies, N=454						
	Longitudinal			Parallel		
Study	E01	E02	E04	E03	E05	Total
Number of patients implanted	11	5	124	115	199	454
Number of patients stimulated	10	5	123	115	198	451
Age in years (range)	32 (20–58)	33 (18–42)	24 (3–63)	33 (13–57)	33 (13–60)	32 (3–63)
Number of females (%)	4 (36%)	2 (40%)	57 (46%)	43 (37%)	104 (52%)	210 (46%)
Years with epilepsy (range)	22 (13–32)	20 (5–36)	17 (0.8–48)	21 (4–47)	23 (2–52)	21 (0.8–52)
Average number of AEDs	1.0	1.0	2.2	2.1	2.1	2.1
Median number of seizures per day at baseline	0.6	0.42	0.65	0.70 high/ 0.85 low	0.58 high/ 0.51 low	–

3.2.3. Results

3.2.3.1. Primary Efficacy Endpoint

The primary efficacy endpoint (percent reduction in seizure rate) was measured over 12 weeks (see below). Adverse events were assessed at each patient visit.

Table 7. Principal Efficacy and Safety Results

All patients in efficacy analyses in all clinical studies, N=441						
	Longitudinal			Parallel		
Study	E01	E02	E04	E03	E05	Total
Number of patients in efficacy analysis	10	5	116	114	196	441
Median reduction in seizures/day	32%*	48%	22%*	23% high*/6% low	23% high†/21% low†	–

Table 7. Principal Efficacy and Safety Results (continued)

All patients in efficacy analyses in all clinical studies, N=441						
	Longitudinal			Parallel		
Study	E01	E02	E04	E03	E05	Total
Mean reduction in seizures/day	24%†	40%	7%‡	24% high‡/6% low	28% high†/15% low†	–
Difference in mean (high/low)	–	–	–	17%§ (3%/31%)	13%‖ (2%/23%)	–
% with > 50% response	30%	50%	29%	30% high/14% low	23% high/16% low	–
Principal Safety Results Through Long-term Follow Up						
Exposure (pt-yr)	45	20	245	456	135	901
SAEs¶	9%/-	0%/-	6%/-	5%/0%	7%/9%	–
Discontinued (LOE / AE)#	0/1	0/0	2/3	0/2	1/3	3/9
Number of explants**	2	2	15	9	5	33
Deaths SUDEP/total††	0/0	0/0	3/4	0/3	1/2	4/9

Within group broad analyses:
* P ≤0.05, by Wilcoxon sign rank.
† P <0.0001, by anova.
‡ P ≤0.05, by Student's t-test.

Between group broad analyses:
§ P ≤0.02, by Wilcoxon rank sum; P ≤0.02, by Student's t-test.
‖ P <0.04, by aligned ranks test; P <0.02, by Student's t-test; P <0.03, by anova.

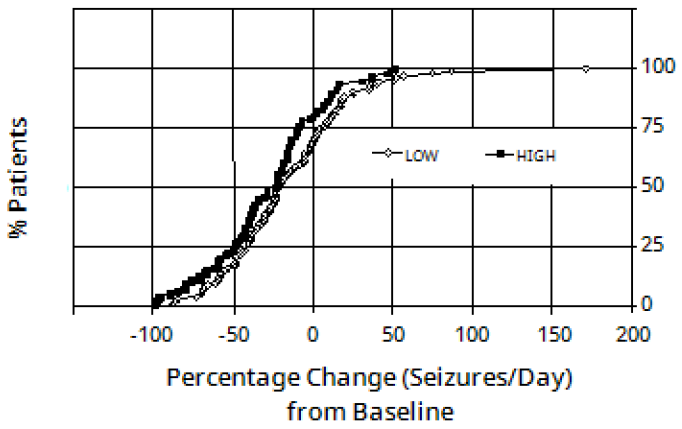
Safety information:
¶ SAEs = serious adverse events.
# Discontinuing for lack of efficacy (LOE)/ adverse events (AE) at one year, excluding deaths.
** Number of explants through August 1996, excluding deaths.
†† All deaths occurred by the long-term follow-up closing date of August 1996.

3.2.3.2. Change in Seizure Frequency, Patient Distribution

The graph and corresponding table below show the results from Study E05, the largest and most recent of the randomized, blinded, active control studies:

Figure 2. Change in Seizure Frequency, Patient Distribution (With Corresponding Table)

All E05 Patients that Completed Effectiveness Evaluation, N=196



All patients in E05 effectiveness analyses, N=196			
Principal Effectiveness Statistics (E05)			
Percentage Change (Seizures/Day) from Baseline			
Statistics	High (94)	Low (102)	Difference
Median	-23%	-21%	N/A
25%, 75% Quartiles	-8.9%, -49%	4.0%, -43%	N/A
95% Confidence intervals	-35%, -21%	-23%, -7.7%	-23%, -2.3%
Range	-100%, 52%	- 89%, 171%	-23%, -2.3%
(min, max) Mean ± SD	-28% ± 34%	-15% ± 39%	-13%* ± 37%

*Difference is statistically significant ($P < .05$) by analysis of variance ($P = .032$) and by Cochran-Mantel-Haenszel aligned ranks ($P = .040$).

Patient response to VNS Therapy was examined using statistical modeling (examining group characteristics) and an evaluation of individual patients. No useful predictors were found of an increase or a decrease in seizure frequency.

3.2.4. Conclusions

Patients with refractory focal onset seizures treated with HIGH VNS Therapy had a statistically significant decrease in frequency of seizures, compared with the baseline and compared with patients treated with LOW (active control) VNS Therapy. As shown in "Change in Seizure Frequency, Patient Distribution (With

Corresponding Table) " above, most patients had a reduction in seizure frequency; some, however, had either no change or an increase in seizure frequency. The most common treatment-related adverse events were voice alteration and dyspnea. Treatment was well tolerated, with 97 percent (306 of 314) of the implanted patients continuing into the long-term follow-up phase of the study.

3.2.5. Long-Term Data from Uncontrolled Follow-Up

Long-term data (> 3 months' stimulation) were collected on all available E01 through E04 study patients (see below). At the time the VNS Therapy system Premarket Approval Application was considered by the U. S. Food and Drug Administration, long-term data on most Study E05 patients were not available. These long-term follow-up data are uncontrolled because they come from an open-label protocol in which both the antiepileptic drug medications and the VNS Therapy device settings were allowed to be changed.

Ninety-five percent (95%) of patients were continuing one year after their original implant; 82 percent were still receiving stimulation at two years; and 69 percent were receiving stimulation at three years. Some E04 patients had not yet had the opportunity to reach two or three years of stimulation and therefore were not used in the calculations. Additionally, 28 E03 patients were implanted outside the United States in countries that later received commercial approval, and data were available through one year of stimulation only.

Table 8. Patient Summary Chart

Patients continuing treatment as of 8/22/96					
Study	E01	E02	E03	E04	Total
No. of patients randomized / stimulated	10	5	115	123	253
No. of patients entering long-term phase	10	5	113	123	251
No. of continuing patients being treated for up to 1 year / No. started	10/10	5/5	111/115	112/121*	238/251
No. of continuing patients being treated for up to 2 years / No. started	9/10	4/5	71/87†	58‡/70	142/172
No. of continuing patients being treated for up to 3 years / No. started	7/10	3/5	57/87	21§/24	88/126

* Two E04 Study patients had not been implanted long enough to reach the one-year date after implantation.
† Twenty-eight (N=28) commercial European patients were excluded from follow up after one year of treatment because of the commercial release of the VNS Therapy system in those countries.
‡ As of 8/22/96, only 70 patients had been implanted long enough to reach the two-year treatment period; 58 of the 70 were continuing.
§ As of 8/22/96, only 24 patients had been implanted long enough to reach the three-year treatment period; 21 of the 24 were continuing.

The table below shows the number of patients included in the efficacy analysis. It is apparent from the table that not all continuing patients were used in the efficacy analysis. This difference was mostly because of

missing data (some patients kept only sporadic records over the long term), although two patients were not used because they had lobectomy surgery, which affected their seizure rates.

Table 9. Patients Used for Efficacy Analysis

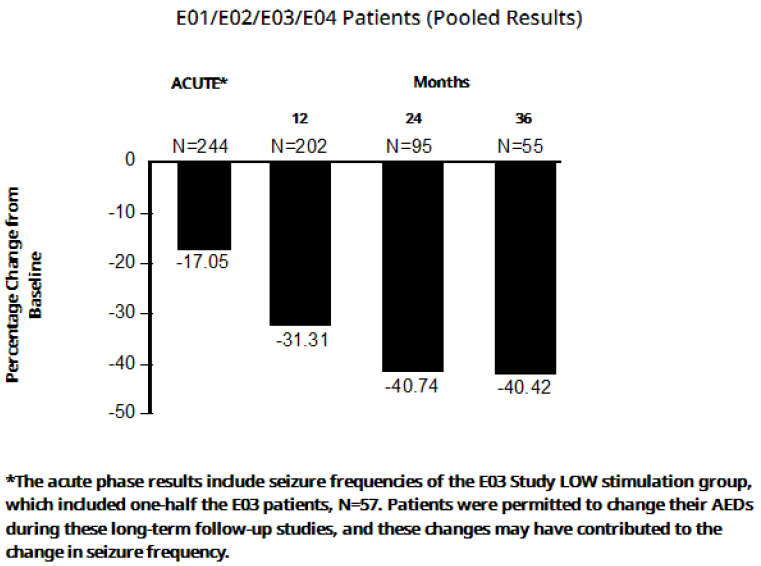
Study	E01	E02	E03	E04	Total
No. of patients randomized / stimulated	10	5	115	123	253
No. of patients entering long-term phase	10	5	113	123	251
No. of patients used in 1-year efficacy analysis / No. stimulated	10/10	5/5	102/111	86/112	202/238
No. of patients used in 2-year efficacy analysis / No. stimulated	8/9	2/4	51/71*	34/58†	95/142
No. of patients used in 3-year efficacy analysis / No. stimulated	4/7	2/3	49/57	0‡	55/67

* Of the 71 patients continuing, efficacy data were available for only 51.
† Of the 58 patients, efficacy data were available for only 34.
‡ No data were available at the three-year time for the E04 patients.

3.2.5.1. Long-Term Results

Available long-term data from uncontrolled, open-label protocols during which antiepileptic drug and VNS Therapy device setting changes were allowed suggest improved efficacy over the first 24 months of treatment, with stabilization of this improvement after two years (see below). As evident from the table above, these long-term data are limited at years two and three, with no patients being represented in the three-year analysis from Studies E04 or E05. There can be no assurances that the efficacy of the VNS Therapy treatment will continue to improve or will not decline over time, nor can there be assurances that additional long-term data will not reveal new adverse information presently unknown to LivaNova. However, currently available long-term data do not suggest an increase or a worsening of adverse events, or a decline in efficacy.

Figure 3. Median Percentage Change in Seizure Frequency



***The acute phase results include seizure frequencies of the E03 Study LOW stimulation group, which included one-half the E03 patients, N=57. Patients were permitted to change their AEDs during these long-term follow-up studies, and these changes may have contributed to the change in seizure frequency.**

3.2.5.2. Other Information

Unlike the two randomized studies, Study E04, an open-label safety study, included patients 12 years old and younger, and patients with generalized seizures. Sixteen patients under age 12, ranging from 3.6 to 12 years old, were evaluated. (Two additional patients had unevaluable seizure data.) These patients were found to have a 17.9 percent median decrease in seizures during the acute phase, with 31 percent of the patients experiencing a greater than 50 percent decrease.

Additionally, 25 patients with generalized seizures were evaluated. (Two additional patients had unevaluable seizure data.) These patients were found to have a 46.6 percent median decrease in seizures during the acute phase, with 44 percent experiencing a greater than 50 percent decrease. The E04 results (N=116 analyzed), including patients younger than 12 and those with generalized seizures, showed a 22 percent median decrease during the acute phase, with 29 percent of the patients experiencing a greater than 50 percent decrease.

The E04 results (N=86 analyzed), excluding patients younger than 12 and those with generalized seizures, showed an 18.3 percent median decrease in seizures during the acute phase, with 27.9 percent of the patients experiencing a greater than 50 percent decrease.

3.2.5.3. Mechanism of Action

The precise mechanism(s) by which the VNS Therapy system exerts its anticonvulsant action is unknown. In animal models designed to examine anticonvulsant activity, vagus nerve stimulation prevented seizures or seizure spread in these models: maximum electroshock (MES), pentylenetetrazol (PTZ) tests,

3-mercaptopropionic acid (3-MPA), alumina gel, potassium penicillin, strychnine, and kindling. With the exception of the alumina gel model, vagus nerve stimulation did affect the heart and respiratory rate, which may have contributed to the alteration in seizure activity.

Localization of vagus-initiated activity in the brain has been observed through animal studies of *fos*[1] immunoreactivity, regional brain glucose metabolism, and positron emission tomography (PET) imaging in human patients.

An [^{15}O] H_2O PET study in 10 patients demonstrated that vagus nerve stimulation by the VNS Therapy system does increase blood flow in the rostral medulla, right thalamus, and right anterior parietal cortex, and bilaterally in the hypothalamus, anterior insula, and inferior cerebellum. Decreases in blood flow were detected bilaterally in the hippocampus, amygdala, and posterior cingulate gyrus.

[1] A nuclear protein that is expressed under conditions of high neuronal activity.

3.3. Clinical Studies—Pediatric Safety and Effectiveness

Pre-market clinical and post-market surveillance data were used to extrapolate the safety and effectiveness of VNS Therapy from adolescents and adults (≥ 12 years) to children (4-11 years) to support the approval of VNS Therapy in patients 4–11 years of age.

3.3.1. Extrapolation Methods

Extrapolation is the leveraging process whereby an indication for use of a device in a pediatric population can be supported by existing clinical data from a studied population. Extrapolation of the safety and effectiveness of VNS Therapy for patients 4–11 years of age was conducted using a Bayesian hierarchical model to estimate the 50% responder rate in patients 4–11 years of age following 12 months of treatment utilizing existing clinical data across several data sources. Data from a prospective, open label, post-approval study of all consecutive patients treated with VNS Therapy in Japan was the primary data source. Historical data from E03, E04, E05, and E06 were used as prior data in the Bayesian model. The Bayesian hierarchical model borrows data from prior studies to the degree the current study data matches the previous studies' data.

3.3.2. Data Sources

The following data sources were included in the analysis:

- Pre-market data from the E03, E04, and E05 clinical trials
- E06: Randomized, parallel group, comparative study to compare the efficacy of VNS Therapy to antiepileptic drug (AED) treatment in reducing the frequency of seizures in children (age 17 or less). The study was initiated in October 2004 and completed in January 2010.
- Japan Post-Approval Study (PAS): Prospective, open label, post-approval study of all consecutive patients treated with VNS Therapy in Japan. Patients were implanted between July 2010 and December 2012.
- LivaNova Post-Market Surveillance Database: Passively reported adverse events and device tracking data from patients implanted with the VNS Therapy system from November 1988 to September 2015. When assessing device relatedness, post-market data was restricted to reports starting in November 2006 when the post-market coding system was updated to include device relatedness.

3.3.3. Data Sets Analyzed

The safety population included all patients 4 years of age and older who underwent implantation with the VNS Therapy system who:

- participated in the E03, E04, E05, or E06 clinical trial,
- participated in the Japanese PAS (initial implants only), or
- had a record in the LivaNova Post-Market Surveillance database.

Clinical study data from 847 patients were included in the safety population. Of these, 13.8% (n=117) of patients were 4–11 years of age, 23.5% (n=199) of patients were 12-21 years of age, and 62.7% (n=531) were > 21 years of age. Post-market surveillance data with information on device relatedness for adverse events were available from 40,926 patients. Of these 18.9% of patients were 4-11 years (n=7,729), 22.9% (n=9,389) of patients were 12-21 years of age, and 58.2% (n=23,808) were > 21 years of age.

Patients in the efficacy population included all patients in the safety population with refractory focal onset seizures who had at least 1 seizure recorded at baseline. Patients who were only in the post-market surveillance database were excluded from the efficacy analysis. In total, clinical study data from 663 patients were included in the efficacy analysis. Of these, 582 patients had 12-month efficacy outcome data (n=54 patients 4–11 years, n=126 patients 12-21 years, and n=402 patients > 21 years of age).

Pediatric patients under 12 years of age participated in the E04, E06, and Japan PAS. The E03 and E05 studies consisted of patients > 12 years of age. Baseline characteristics by age group are reported in Table 8. Both groups had similar rates of prior brain or epilepsy surgery (35.0% of patients 4–11; 34.3% of patients ≥ 12), however pediatric patients 4–11 years of age in the safety population were more likely to have only generalized seizures (49.6% of patients 4–11; 16.2% of patients ≥ 12 years). Note that the efficacy evaluation is limited to patients with focal onset seizures.

Table 10. Demographics (Safety Population)

	4–11 Years	≥ 12 Years	Overall
Gender [n=(%)]			
N	117	730	847
% Female	45.3% (53/117)	44.1% (322/730)	44.3% (375/847)
Age (years)			
N	117	730	847
Average ± SD (Range)	8.4 ± 2.2 (4.0-11.9)	30.6 ± 11.5 (12.0-73.0)	27.6 ± 13.2 (4.0-73.0)
Age at Epilepsy Onset (years)			
N	117	719	836
Average ± SD (Range)	1.7 ± 1.9 (0.0-7.8)	10.5 ± 10.6 (0.0-63.7)	9.2 ± 10.4 (0.0-63.7)
Time to VNS Since Diagnosis (years)			
N	117	719	836
Average ± SD (Range)	6.7 ± 2.5 (1.2-11.6)	20.1 ± 10.6 (0.1-61.0)	18.2 ±10.9 (0.1-61.0)
Prior Brain or Epilepsy Surgery			
N	117	727	844
% Prior Surgery	35.0% (41/117)	34.3% (249/727)	34.4% (290/844)
Baseline Seizure Type			
N	117	730	847

Table 10. Demographics (Safety Population) (continued)

	4–11 Years	≥ 12 Years	Overall
Focal Onset	49.6% (58/117)	83.7% (611/730)	79.0% (669/847)
Generalized Only	49.6% (58/117)	16.2% (118/730)	20.8% (176/847)
Zero Baseline Seizures	0.9% (1/117)	0.1% (1/730)	0.2% (2/847)

3.3.4. Primary Endpoints

3.3.4.1. Primary Safety Endpoint

The primary safety endpoint was the incidence rate of device-related treatment emergent adverse events through 12 months of treatment. Adverse event rates for patients 4–11 years were compared to that of patients 12–21 years (comparable with respect to physiological development) via a 95% confidence interval for the incidence rate ratio. Adverse events with statistically significant incidence rate ratios greater than 1 indicate that the incidence rate for patients 4–11 years of age is greater than the incidence rate for patients 12–21 years of age. This analysis was performed separately for the shorter-term clinical study data and the longer term, larger post-market surveillance data to assess consistency of results.

3.3.4.2. Primary Efficacy Endpoint

The primary effectiveness endpoint is the proportion of patients 4–11 years of age in the Japan PAS with at least a 50% reduction in the frequency of seizures following 12 months of treatment. The pre-established efficacy threshold was set to a 30% responder rate with a corresponding 10% non-inferiority (NI) margin. A Bayesian hierarchical model was used to model the 12-month rates for each study.

3.3.5. Safety

Based on the clinical data, the overall incidence rate of device related treatment emergent adverse events was not different for patients 4–11 years of age compared to patients 12–21 years of age (Incidence Rate Ratio (IRR): 0.44, 95% CI: 0.20, 1.04). There were no device-related treatment emergent adverse events that had a statistically higher incidence rate in the 4–11 year age group when compared to 12–21 year age group. Two adverse events, myalgia and paresthesia, had statistically lower incidence rates in the 4–11 age group when compared to the 12–21 age group.

Table 11. Primary Safety Analysis (Clinical Data)

Device-Related, Treatment-Emergent Adverse Events by Age based on Clinical Data (Overall and statistically significant differences)					
Adverse Event	4-11 years (N=117 patients, 113 person years)		12-21 years (N=199 patients, 194 person years)		Incidence Rate Ratio* (IRR) (95% CI)
	Number of AE Reports	Incidence Rate / PY (95% CI)	Number of AE Reports	Incidence Rate / PY (95% CI)	
Overall Rate	75	66.6% (32.2%-145%)	293	151% (109%-207%)	0.44 (0.20-1.04)
Statistically Significant Difference in Incidence Rates (IRR <1)					
Myalgia	1	0.9% (0.0%-5.4%)	11	5.7% (0.0%-33.8%)	0.16 (0.00-0.90)
Paraesthesia	1	0.9% (0.0%-5.1%)	23	11.9% (5.8%-22.1%)	0.07 (0.00-0.79)

Based on post-market surveillance data, the overall incidence rate of device related treatment emergent adverse events was lower for patients 4–11 years of age compared to patients 12-21 years of age (IRR: 0.82, 95% CI: 0.77, 0.88). Infection and extrusion of lead had a statistically greater incidence rate in patients 4–11 years of age. Younger patients may have a greater risk for wound infection when compared to adolescent and adult patients; therefore, the importance of monitoring for site infection as well as the avoidance of manipulation of the surgical site post implant in children should be stressed.

Table 12. Primary Safety Analysis (Post-Market Data)

Device-Related, Treatment-Emergent Adverse Events by Age based on Post-Market Data (Overall and Statistically Significant Differences)							
Adverse Event	4–11 years (N=7,729 patients, 31,220 person years)			12–21 years (N=9,389 patients, 37,647 person years)			Incidence Rate Ratio (95% CI)
	Number of AE Reports	Incidence Rate/Person Year (95% CI)	% of Total Reports	Number of AE Reports	Incidence Rate/Person Year (95% CI)	% of Total Reports	
Overall	1328	4.25% (4.03%, 4.49%)	100%	1948	5.17% (4.95%, 5.41%)	100%	0.82 (0.77, 0.88)
Statistically Significant Difference in Incidence Rates (IRR > 1)							
Infection	85	0.27% (0.22%, 0.34%)	6.40%	67	0.18% (0.14%, 0.23%)	3.44%	1.53 (1.11, 2.11)

Table 12. Primary Safety Analysis (Post-Market Data) (continued)

Device-Related, Treatment-Emergent Adverse Events by Age based on Post-Market Data (Overall and Statistically Significant Differences)							
Adverse Event	4–11 years (N=7,729 patients, 31,220 person years)			12–21 years (N=9,389 patients, 37,647 person years)			Incidence Rate Ratio (95% CI)
	Number of AE Reports	Incidence Rate/Person Year (95% CI)	% of Total Reports	Number of AE Reports	Incidence Rate/Person Year (95% CI)	% of Total Reports	
Extrusion of Lead	15	0.05% (0.03%, 0.08%)	1.13%	5	0.01% (0.00%, 0.03%)	0.26%	3.62 (1.31, 9.95)
Statistically Significant Difference in Incidence Rates (IRR < 1)							
Painful Stimulation	83	0.27% (0.21%, 0.33%)	6.25%	200	0.53% (0.46%, 0.61%)	10.27%	0.50 (0.39, 0.65)
Pain	60	0.19% (0.15%, 0.25%)	4.52%	150	0.40% (0.34%, 0.47%)	7.70%	0.48 (0.36, 0.65)
Voice Alteration	66	0.21% (0.16%, 0.27%)	4.97%	122	0.32% (0.27%, 0.39%)	6.26%	0.65 (0.48, 0.88)
Stimulation Not Perceived	37	0.12% (0.08%, 0.16%)	2.79%	99	0.26% (0.21%, 0.32%)	5.08%	0.45 (0.31, 0.66)
Coughing	47	0.15% (0.11%, 0.20%)	3.54%	88	0.23% (0.19%, 0.29%)	4.52%	0.64 (0.45, 0.92)
Migration of Generator	12	0.04% (0.02%, 0.07%)	0.90%	48	0.13% (0.09%, 0.17%)	2.46%	0.30 (0.16, 0.57)
Dysphagia	14	0.04% (0.02%, 0.08%)	1.05%	40	0.11% (0.08%, 0.14%)	2.05%	0.42 (0.23, 0.78)
Cognitive Changes	16	0.05% (0.03%, 0.08%)	1.20%	35	0.09% (0.06%, 0.13%)	1.80%	0.55 (0.31, 1.00)
Erratic Stimulation Perceived	4	0.01% (0.00%, 0.03%)	0.30%	15	0.04% (0.02%, 0.07%)	0.77%	0.32 (0.11, 0.97)
Continuous Stimulation Perceived	3	0.01% (0.00%, 0.03%)	0.23%	13	0.03% (0.02%, 0.06%)	0.67%	0.28 (0.08, 0.98)
Syncope	1	0.00% (0.00%, 0.02%)	0.08%	11	0.03% (0.01%, 0.05%)	0.56%	0.11 (0.01, 0.85)

3.3.6. Efficacy

Baseline seizure frequency for patients in the ITT population with 12-month efficacy data by age group is reported in the table below. The median baseline seizure rate per month across all studies is 21.3 seizures / month. The median baseline seizure rate for patients 4–11 years of age (85.7 seizures / month) was higher when compared to adolescent and adult patients (30.4 and 17.4 seizures / month, respectively). Due to the differences in baseline seizure frequency rates by age group, this variable was evaluated as potential covariate in the hierarchical model; however, there was no evidence that baseline seizure frequency is associated with the probability of being a responder (% seizure reduction ≥ 50%).

Table 13. Baseline Seizure Frequency Per Month

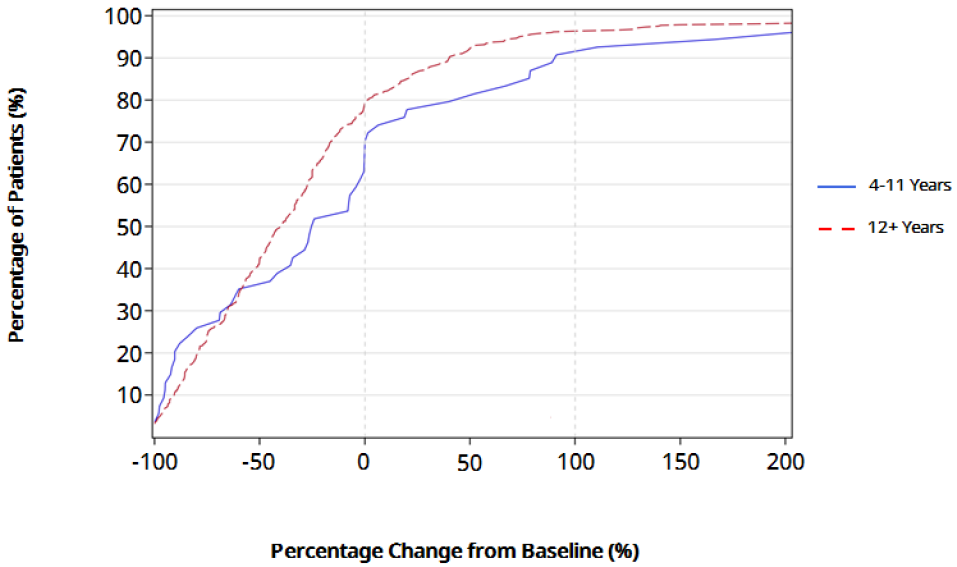
Age Group	4–11 Years	≥ 12 Years		Overall
N	54	528		582
Median	85.7	19.5		21.3
Age Group	4–11 Years	12–21 Years	≥ 22 Years	Overall
N	54	127	401	582
Median	85.7	30.4	17.4	21.3

Median percent reduction in seizure frequency from baseline to 12 months by age category is reported in the table below. Following 12 months of treatment, there was no statistically significant difference in the median percent seizure reduction when comparing patients 4–11 years (-24.7%) with patients > 12 years of age (-40.4%) (*P* = .142). The figure below shows the cumulative change in seizure frequency following 12 months of treatment for the ITT population by age group (4–11, ≥ 12 years).

Table 14. Median Percent Change in Seizure Frequency at 12 Months, by Age Group

Age Group	4–11 Years	> 12 Years
N	54	528
Median	-24.7%	-40.4%
95% CI	-45.1% to 0%	-45.6 to -33.3%
P Value, Mann-Whitney	0.142	

Figure 4. Change in Seizure Frequency, Patient Distribution by Age Group



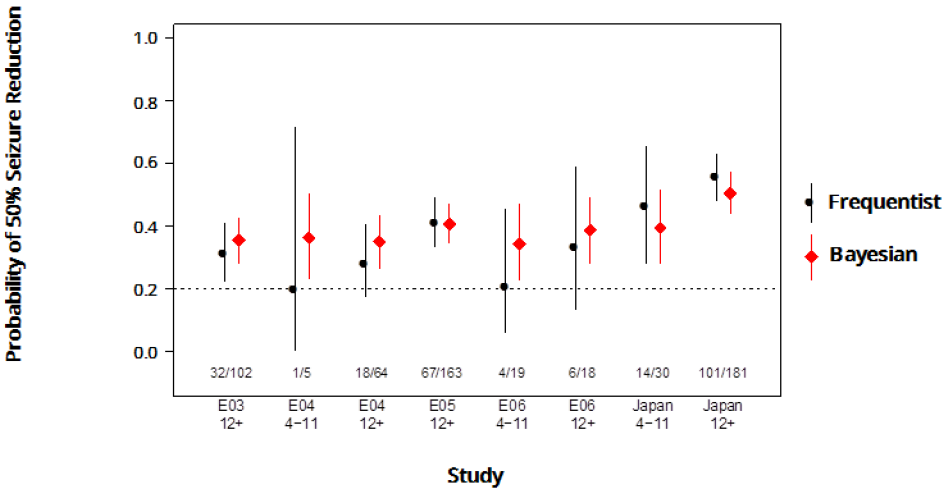
The Bayesian hierarchical model, which borrows from previous study data, estimated the 12 month responder rate for patients 4–11 years of age with focal onset seizures in the Japan PAS as 39% (95% credible interval: 28%, 52%). Since the entire 95% credible interval is greater than 20%, the primary efficacy endpoint was met. Across all studies, the Bayesian hierarchical model estimate for responder rate in patients 4–11 years of age is 37% (95% credible interval: 26%, 48%). (See the graph and table below.)

Table 15. Primary Efficacy Analysis (50% Response Rates at 12 Months)

Study	Age Group	Responders	Frequentist Estimate	95% Exact Binomial CI	Bayesian Estimate	95% Credible Interval
E-03	12+	32/102	31%	23–41%	35%	28–43%
E-04	4–11	1/5	20%	1–72%	36%	23–50%
E-04	12+	18/64	28%	18–41%	35%	27–44%
E-05	12+	67/163	41%	33–49%	41%	34–47%
E-06	4–11	4/19	21%	6–46%	34%	23–47%
E-06	12+	6/18	33%	13–59%	39%	28–49%
Japan	4–11	14/30	47%	28–66%	39%	28–52%
Japan	12+	101/181	56%	48–63%	50%	44–57%
Overall	4–11	19/54	35%	23–49%	37%	26–48%
Overall	12+	224/528	42%	38–47%	39%	33–46%

Note: VNS may be less effective in children who have previously undergone epilepsy surgery.

Figure 5. Probability of ≥ 50% Seizure Reduction at 12 Months



3.3.7. Overall Study Conclusions

The results of the extrapolation study demonstrate that VNS Therapy is a safe and effective treatment for the reduction of focal onset seizures in pediatric patients 4–11 years of age with refractory epilepsy. Based on the Bayesian hierarchical model, the 12-month responder rate for pediatric patients 4–11 years of age with focal onset seizures in the Japan PAS is 39% (95% credible interval: 28%-52%). There were no unanticipated adverse device effects observed in pediatric patients 4–11 years of age. However, infection and extrusion of lead had a statistically greater incidence rate in patients 4–11 years of age. Younger patients may have a greater risk for wound infection when compared to adolescent and adult patients; therefore, the importance of monitoring for site infection as well as the avoidance of manipulation of the surgical site post implant in children should be stressed. Otherwise, treatment-emergent adverse events in patients 4–11 years of age were consistent with patients ≥ 12 years of age treated with VNS Therapy and no new risks were identified.

3.4. Clinical Study Bibliography

A bibliography of animal, clinical, and mechanism of action studies is available from LivaNova on request.

CHAPTER 4

Technical Information

This topic includes the following concepts:

4.1. Technical Information—Generators

4.1.1. Physical Characteristics

The titanium case of the VNS Therapy generator is hermetically sealed and leak-rate tested. Specially designed feedthrus that use platinum conductors make the electrical connection from the connector blocks to the circuitry through the hermetically sealed enclosure. The table below provides physical characteristics for all generator models.

Table 16. Generator Physical Characteristics

Model	Lead Receptacle	Dimensions*	Weight	Connector Retention Strength with Lead
Model 1000 Model 103	3.2 mm (0.126 in.) (single-pin lead)	45 mm x 32 mm x 6.9 mm (1.8 in. x 1.3 in. x 0.27 in.)	16 g (0.56 oz)	> 10 N
Model 106 Model 105 Model 102	3.2 mm (0.126 in.) (single-pin lead)	52 mm x 52 mm x 6.9 mm (2.0 in. x 2.0 in. x 0.27 in.)	25 g (0.88 oz)	> 10 N
Model 104 Model 1000-D	5 mm (0.2 in.) (dual-pin lead)	45 mm x 39 mm x 6.9 mm (1.8 in. x 1.6 in. x 0.27 in.)	17 g (0.63 oz)	> 10 N
Model 102R	5 mm (0.2 in.) (dual-pin lead)	52 mm x 58.4 mm x 6.9 mm (2.0 in. x 2.3 in. x 0.27 in.)	27 g (0.95 oz)	> 10 N

*Measurements (typical) – all dimensions nominal

4.1.2. Biological Compatibility

Materials exposed to the subcutaneous environment are biologically compatible. All of these materials have a long history in medical implants and have been found to be tissue compatible. The table below provides a list of component materials for all generator models.

Table 17. Generator Biological Compatibility

Component	Material
Case	Titanium, hermetically sealed
Header	Polyurethane—Tecothane™ TT-1075D-M Thermoplastic
Lead Connector Block	Stainless steel
Setscrew Plug	Silicone*

* No component of the system is made with natural rubber latex.

4.1.3. Power Source

The table below contains battery characteristics for the generator.

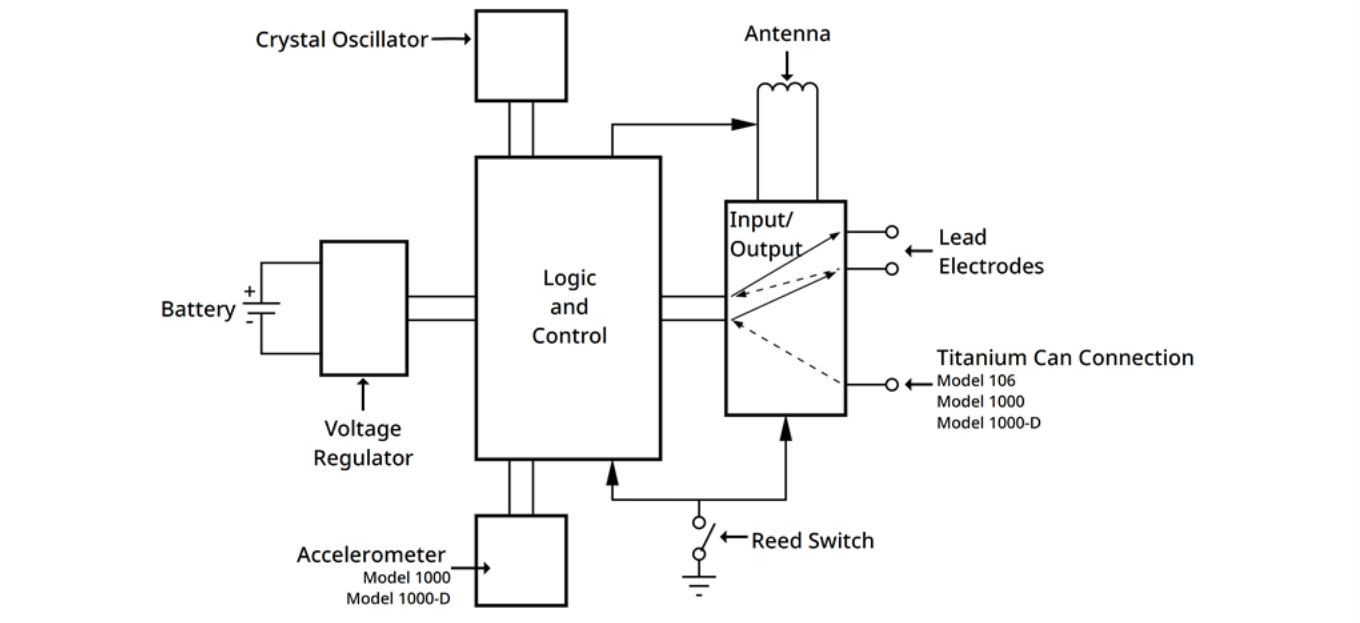
Table 18. Battery Characteristics

Model	Battery Manufacturer & Model	Battery Chemistry	Open Circuit Voltage	Maximum Capacity	Self Discharge	Battery Voltage Drop at End of Service (EOS)
Model 1000 Model 1000-D Model 104 Model 103	Wilson Greatbatch Ltd. Model 2183	lithium carbon monofluoride	3.3	1 Amp-hour	reduces capacity by < 1% per year	gradual drop in voltage at EOS
Model 106 Model 105 Model 102 Model 102R	Wilson Greatbatch Ltd. Model 2075	lithium carbon monofluoride	3.3	1.7 Amp-hours	reduces capacity by < 1% per year	gradual drop in voltage at EOS

4.1.4. Circuitry

The generator uses complementary metal oxide semiconductor (CMOS) integrated circuits, including a microprocessor. The circuitry is schematically represented below.

Figure 6. Generator Circuitry



For descriptive purposes, the generator circuitry is divided into functional sections as shown in the table below.

Table 19. Generator Circuitry Functionality

	Model 1000 Model 1000-D	Model 106	Model 105 Model 104 Model 103 Model 102 Model 102R
Voltage Regulator	Regulates the system power supply.	Regulates the system power supply.	Regulates the system power supply.
Crystal Oscillator	Provides a timing reference.	Provides a timing reference.	Provides a timing reference.
Logic and Control	Controls overall generator function.	Controls overall generator function.	Controls overall generator function.
	Receives and implements programming commands	Receives and implements programming commands	Receives and implements programming commands
	Collects and stores telemetry information, processes sensory input, and controls scheduled and sensory-based therapy outputs	Collects and stores telemetry information, processes sensory input, and controls scheduled and sensory-based therapy outputs	Collects and stores telemetry information, processes sensory input, and controls scheduled and sensory-based therapy outputs
Antenna	Receives programming signals.	Receives programming signals.	Receives programming signals
	Transmits telemetry information to the programming Wand	Transmits telemetry information to the programming Wand	Transmits telemetry information to the programming Wand
Reed Switch	Provides a mechanism to place the generator in Magnet Mode or to inhibit its output	Provides a mechanism to place the generator in Magnet Mode or to inhibit its output	Provides a mechanism to place the generator in Magnet Mode or to inhibit its output
Input / Output	Develops and modulates signals delivered to the lead	Develops and modulates signals delivered to the lead	Develops and modulates signals delivered to the lead
	Allows the traditional VNS Therapy electrodes to serve as both therapy outputs and sensing input connections	Allows the traditional VNS Therapy electrodes to serve as both therapy outputs and sensing input connections	Allows the traditional VNS Therapy electrodes to serve as both therapy outputs and sensing input connections
	Provides amplification of cardiac signals	Provides amplification of cardiac signals	
Accelerometer	Provides information related to patient posture	N/A	N/A

4.1.5. Identification

The generator can be identified on an x-ray by the tag codes provided below. The serial number and model number of the generator are marked on its titanium case, but do not appear on the x-ray.

The serial number and model number are identified when the generator is interrogated with the programming system.

Table 20. Generator Identification

Model	Possible X-ray Tag Codes	Further Identification by Serial Number
Model 1000 **Model 1000-D**	LIVN VNS	N/A
Model 106 **Model 105**	CYBX	N/A
Model 104 **Model 103**	CYB A VNS A	N/A
Model 102	CYBX CYBX-J-XX (XX = year, e.g. 10 for 2010)	Serial numbers <1000000
Model 102R	CYBX CYBX-J-XX (XX = year, e.g. 10 for 2010)	Serial numbers ≥1000000

4.1.6. Heartbeat Detection Performance

Applicable Models:	Model 1000	Model 1000-D	Model 106

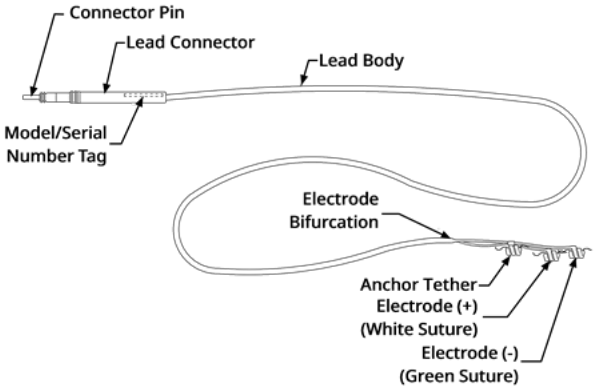
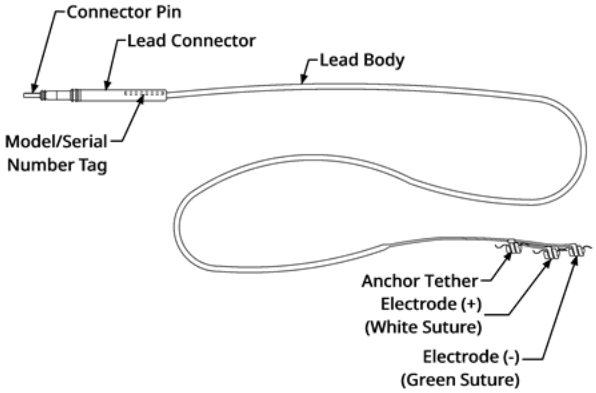
Models capable of AutoStim have a heartbeat detection sensitivity of 98% and Positive Predictive Value (PPV) of 98%.

Improper implant location and/or inadequate heartbeat detection configuration could negatively impact R-wave detection performance results. For details on how to determine implant location and configure heartbeat detection, see "Determine Acceptable Implant Locations" on page 95.

4.2. Technical Information—Leads

Applicable Models:	PerenniaFLEX™ Model 304	PerenniaDURA™ Model 303	Model 302

Figure 7. Leads

Model 304 Model 302	Model 303
	

4.2.1. Physical Characteristics

Table 21. Lead Physical Characteristics

Components	Dimensions*	Connector Assembly	Retention Strength With Generator
Lead Connector	3.2 mm (0.127 in.) D	One (1)	> 10 N
Connector Pin	1.27 mm (0.05 in.) D	N/A	N/A
Connector Ring	2.67 mm (0.105 in.) D	N/A	N/A
Lead Body	2 mm (0.08 in.) D 43 cm (17 in.) L	N/A	N/A
Electrodes and Anchor Tether	**Helical**: 2 mm (0.08 in.) ID **Helical:** 2.5 mm (0.1 in.) ID (Model 304 only) **Helical:** 3 mm (0.12 in.) ID **Separation**: 8 mm (0.31 in.) center to center	N/A	N/A
Tie-Down	5.7 mm x 7.7 mm (0.22 in x 0.30 in.)	N/A	N/A

* All dimensions nominal; diameter (D); inner diameter (ID); Length (L)

Table 22. Lead Body Physical Characteristics

Model	Conductor Coil Construction	Resistance (pin / ring to electrode)
Model 302 Model 304	Helical, quadfilar	120 to 180 Ω
Model 303	Helical, trifilar	180 to 250 Ω

4.2.2. Biological Compatibility

Materials exposed to the subcutaneous environment are biologically compatible. All of these materials have a long history in medical implants and have been found to be tissue compatible.

Table 23. Lead Biological Compatibility

Components	Material
Lead Connector	Silicone*
Connector Pin	300 series Stainless Steel
Connector Ring	300 series Stainless Steel
Lead Body	Conductor: MP-35N alloy Insulation: Silicone*
Electrodes and Anchor Tether	Helical: Silicone* elastomer Conductor: Platinum/Iridium alloy Suture: Polyester
Tie-Down	Material: Radio-opaque silicone*

* No component of the system is made with natural rubber latex.

4.2.3. Lead Lifespan and Replacement

The lead's lifespan is undetermined at this time. A lead would require replacement if a lead fracture were suspected through diagnostic tests.

Events that can shorten the life expectancy of the lead are as follows:

- Blunt trauma to the neck and/or any area of the body beneath which the lead is implanted
- Patient twists or picks at either the implanted lead or generator
- Improper surgical implantation of the VNS Therapy system (e.g., inadequate strain relief loop, sutures placed directly on the lead body, tie-downs not used, sutured to muscle)

⚠ CAUTION: **Lead replacement or removal due to lack of efficacy** is a medical judgment based on the patient's desires and health status and must be carefully weighed against the known and unknown risks of surgery. At present, there are no known long-term hazards or risks associated with leaving the lead implanted, beyond those already mentioned.

CHAPTER 5

Generator Directions for Use

This topic includes the following concepts:

5.1. Stimulation Parameters and Available Parameter Settings

Stimulation Parameters and Available Parameter Settings		
Stimulation Parameters	Model 1000 Model 1000-D	Model 106
Output Current	0–2.0 mA in 0.125-mA steps (± 0.1 mA or ± 10%; whichever is greater); 2–3.5 mA in 0.25-mA steps (± 0.1 mA or ± 10%; whichever is greater)	0–2.0 mA in 0.125-mA steps (± 0.1 mA or ± 10%; whichever is greater); 2–3.5 mA in 0.25-mA steps (± 0.1 mA or ± 10%; whichever is greater)
Signal Frequency	1, 2, 5, 10, 15, 20, 25, 30 Hz ± 6%	1, 2, 5, 10, 15, 20, 25, 30 Hz ± 6%
Pulse Width	130, 250, 500, 750, 1000 µsec ± 10%	130, 250, 500, 750, 1000 µsec ± 10%
Signal ON Time	Normal Mode—7, 14, 21, 30, 60 sec AutoStim Mode—30, 60 sec Magnet Mode—7, 14, 21, 30, 60 sec	Normal Mode—7, 14, 21, 30, 60 sec (+ 7 sec/ - 15%) AutoStim Mode—30, 60 sec (+ 15%/ - 7 sec) Magnet Mode —7, 14, 21, 30, 60 sec (+ 15%/ - 7 sec)
Signal OFF Time	0.2, 0.3, 0.5, 0.8, 1.1, 1.8, 3 min, and 5 to 180 min (5 to 60 in 5-min steps; 60 to 180 in 30-min steps) ± 4.4 sec or ± 1%, whichever is greater ⓘ NOTE: The programming software may limit the selection of certain OFF times. For details, see the model-specific programming system manual posted at www.livanova.com.	0.2, 0.3, 0.5, 0.8, 1.1, 1.8, 3 min, and 5 to 180 min (5 to 60 in 5-min steps; 60 to 180 in 30-min steps) ± 4.4 sec or ± 1%, whichever is greater
Magnet Activation	Provided by magnet application (output current, pulse width, and signal ON time may be independently programmed for this purpose)	Provided by magnet application (output current, pulse width, and signal ON time may be independently programmed for this purpose)
Reset Parameters	Settings are unchanged, but output is disabled (0 mA)	Settings are unchanged, but output is disabled (0 mA)
Detection Configuration Parameters		
Tachycardia Detection	Enabled or Disabled; When enabled, allows the device to perform heartbeat sensing and tachycardia detections.	Enabled or Disabled; When enabled, allows the device to perform heartbeat sensing and tachycardia detections.

Stimulation Parameters and Available Parameter Settings		
Stimulation Parameters	Model 1000 Model 1000-D	Model 106
AutoStim Threshold	Threshold for heart rate increase which triggers Automatic Stimulation (AutoStim). Setting range is from 20% to 70%. 20% is most sensitive. 70% is least sensitive.	Threshold for heart rate increase which triggers Automatic Stimulation (AutoStim). Setting range is from 20% to 70%. 20% is most sensitive. 70% is least sensitive.
Heartbeat Detection (Sensitivity)	Sensitivity parameter for heartbeat detection, ranging from 1 to 5, with "1" being the least sensitive and "5" being the most sensitive setting. NOTE: Model 1000/Model 1000-D can detect heart beats between 28 and 180 bpm (± 10% or 5 bpm, whichever is greater). The tachycardia detection algorithm (AutoStim feature) only considers heart rates up to 180 bpm. A heart rate above 180 bpm will not trigger tachycardia detection.	Sensitivity parameter for heartbeat detection, ranging from 1 to 5, with "1" being the least sensitive and "5" being the most sensitive setting. NOTE: Model 106 can detect heart beats between 32 and 240 bpm (± 10% or 5 bpm, whichever is greater). The tachycardia detection algorithm (AutoStim feature) only considers heart rates up to 180 bpm. A heart rate above 180 bpm will not trigger tachycardia detection.
Verify Heartbeat Detection	Feature on the programming software that when activated, configures the generator to emit a pulse signal when a heartbeat is detected (for 2 minutes). May be used to check heartbeat detection performance at the currently programmed Heartbeat Detection setting.	Feature on the programming software that when activated, configures the generator to emit a pulse signal when a heartbeat is detected (for 2 minutes). May be used to check heartbeat detection performance at the currently programmed Heartbeat Detection setting.
Low Heart Rate Threshold	Threshold for low heart rate that triggers logging of the event if it occurs after AutoStim Mode or Magnet Mode stimulation. Available selections include OFF, 30, 40, 50, and 60 bpm. **Note**: "OFF" turns off detection for low heart rate events.	N/A
Prone Position Detection	ON or OFF; When ON, configures the Model 1000/ Model 1000-D to perform detection for prone posture events after an AutoStim Mode or Magnet Mode stimulation.	N/A

Stimulation Parameters and Available Parameter Settings		
Stimulation Parameters	Model 1000 Model 1000-D	Model 106
Day-Night Programming		
Day-Night Programming	Enabled or Disabled; When enabled, allows user to program the generator to deliver 2 independent sets of stimulation parameters at different times during a 24-hour period.	N/A
Nighttime Period	Time period for which Nighttime values are active; 1-23 hours in 30-minute increments	N/A
Nighttime Values	Programmable parameters for Nighttime stimulation include the following: • Normal Mode, AutoStim Mode, and Magnet Mode output current • Normal Mode frequency • Normal Mode, AutoStim Mode, and Magnet Mode pulse width • Normal Mode, AutoStim Mode and Magnet Mode ON time • Normal Mode OFF time •Nighttime AutoStim Threshold Nighttime AutoStim Mode and Magnet Mode frequency will default to the same value as the Nighttime Normal Mode frequency.	N/A
Scheduled Titration (Scheduled Programming) Parameters		
Scheduled Titration (Scheduled Programming)	Enabled or Disabled — When enabled, allows user to schedule automated increases in output current using a protocol of up to 7 steps	N/A
Interval Between Steps	Default value: 14 days; range is from 7 days to 28 days	N/A
Step Values	Step values are selected through the programming software. For details, see the model-specific programming system manual posted at www.livanova.com. NOTE: Scheduled Programming for depression devices are available on the Model 3000 Programmer only.	N/A

Stimulation Parameters and Available Parameter Settings			
Stimulation Parameter	Model 105	Model 104 Model 103	Model 102 Model 102R
Output Current	0-3.5 mA in 0.25-mA steps (± 0.1 mA or ± 10%; whichever is greater)	0–3.5 mA in 0.25-mA steps* ± 0.25 ≤ 1 mA, ± 10% > 1 mA	0–3.5 mA in 0.25-mA steps* ± 0.25 ≤ 1 mA, ± 10% > 1 mA
Signal Frequency	1, 2, 5, 10, 15, 20, 25, 30 Hz ± 6%	1, 2, 5, 10, 15, 20, 25, 30 Hz ± 6%	1, 2, 5, 10, 15, 20, 25, 30 Hz ± 6%
Pulse Width	130, 250, 500, 750, 1000 μsec ± 10%	130, 250, 500, 750, 1000 μsec ± 10%	130, 250, 500, 750, 1000 μsec ± 10%
Signal ON Time	Normal Mode—7, 14, 21, 30, 60 sec (+ 7 sec/ - 15%) Magnet Mode —7, 14, 21, 30, 60 sec (+ 15%/ - 7 sec)	7, 14, 21, 30, 60 sec[†] ± 15% or + 7 sec, whichever is greater (± 15% or ± 7 sec in Magnet Mode)	7, 14, 21, 30, 60 sec[†] ± 15% or + 7 sec, whichever is greater (± 15% or ± 7 sec in Magnet Mode)
Signal OFF Time	0.2, 0.3, 0.5, 0.8, 1.1, 1.8, 3 min, and 5 to 180 min (5 to 60 in 5-min steps; 60 to 180 in 30-min steps), + 4.4/- 8.4 sec or ± 1% whichever is greater	0.2, 0.3, 0.5, 0.8, 1.1, 1.8, 3 min, and 5 to 180 min (5 to 60 in 5-min steps; 60 to 180 in 30-min steps), + 4.4/- 8.4 sec or ± 1% whichever is greater	0.2, 0.3, 0.5, 0.8, 1.1, 1.8, 3 min, and 5 to 180 min (5 to 60 in 5-min steps; 60 to 180 in 30-min steps), + 4.4/- 8.4 sec or ± 1% whichever is greater
Magnet Activation	Provided by magnet application (output current, pulse width, and signal ON time may be independently programmed for this purpose)	Provided by magnet application (output current, pulse width, and signal ON time may be independently programmed for this purpose)	Provided by magnet application (output current, pulse width, and signal ON time may be independently programmed for this purpose)
Reset Parameters	Settings are unchanged, but output is disabled (0 mA)	Settings are unchanged, but output is disabled (0 mA)	0 mA, 10 Hz; 500 μsec; ON time, 30 sec; OFF time, 60 min

*For output currents ≤ 1 mA, the tolerance is ± 0.25 mA. Maximum output is 12.5 ± 2.5 V with the exception of 10 Hz, 7 seconds On Time, in which case the maximum output is 4.4 V and 0.25 mA tolerance. This 0.25 mA tolerance also applies to 15 Hz, 7 seconds On Time, 0.5 mA output current.

[†]For signal ON time > 7 sec, there is no ramp-down at 15 Hz with 0.5 mA and at 10 Hz with 0.5-1.75 or 2.75 mA. For signal ON time at 30 sec, actual ON time is 40 sec for 10 Hz with 0.25 mA and 38 sec for 15 Hz with 0.25 mA.

5.2. System Communication

5.2.1. Programming System

A compatible VNS Therapy programming system is required to communicate with and program the generator.

5.2.2. Communication

The generator “listens” for a communication signal from the Wand. Communication usually initiates between 1 and 4 seconds (between 3 and 10 seconds for Model 102 and Model 102R) but may be prolonged or interrupted in the presence of electromagnetic interference (EMI). Complete communication, which may take up to one minute, depends on the type and amount of information to be transferred between the generator and the Wand. The download of additional information may take more time.

The generator listens for and implements interrogations, parameter programming instructions, requests for diagnostics testing, and device history inquiries. In response, the generator transmits information on the stimulation parameter settings, changes its parameter settings, responds to requests for diagnostics testing, and provides device histories, respectively. Each time these data are transmitted by the generator, they are saved by the programming software to a database.

In addition to the programming system, a magnet that activates a reed switch in the electronic circuitry can be used for one-way communication to the generator. The magnet can be used to initiate stimulation, temporarily inhibit stimulation, perform Magnet Mode Diagnostics, and reset the generator.

5.3. System Modes and Features

NOTE: For a compatibility table for generator models, modes and features, see "System—Compatibility" on page 13.

5.3.1. Modes

5.3.1.1. Normal Mode

After the generator has been programmed, the stimulation repeats in accordance with the programmed ON and OFF cycle (Normal Mode) until the generator receives communication from the programming system, is inhibited or activated with a magnet, or an AutoStim occurs. Immediately after successful programming, the generator delivers a programmed stimulation that allows you to evaluate patient response. If programming is performed during stimulation, stimulation will be terminated. After programming, stimulation starts again with the revised settings.

5.3.1.2. Magnet Mode

Magnet Mode produces on-demand stimulation for the programmed magnet ON time. To initiate stimulation, apply or pass the magnet over the generator for 1–2 seconds and then immediately remove it from the area over the generator. Magnet Mode stimulation is delivered after the magnet is removed. The Magnet Mode uses the same frequency as the Normal Mode, but the output current, pulse width, and signal ON time are independently programmable.

The magnet may also be used to inhibit stimulation. To do so, place the magnet over the generator and keep it in place. The generator will not stimulate until the magnet is removed.

5.3.1.3. AutoStim Mode

Applicable Models:	Model 1000	Model 1000-D	Model 106

AutoStim Mode is an optional feature that monitors heart rates during stimulation OFF times and detects rapid, relative heart rate increases (≥20%) that may be associated with seizures.

If AutoStim is enabled, stimulation initiates automatically upon detection of heart rate increases that exceed the selected threshold for AutoStim. This threshold is adjustable from 20% to 70% to accommodate diverse physiological conditions among patients.

Tachycardia Detectionrequires that the generator accurately measures heart rate. Therefore, its heartbeat detection accuracy should be verified by the physician at implant and at each office visit. If heartbeat detection is inaccurate, adjustments of the Heartbeat Detection setting may be needed.

NOTE: For troubleshooting, see "Detection Issues" on page 163.

5.3.1.3.1. Tachycardia Detection Algorithm Performance—ROC Curves

NOTE: The Tachycardia Detection Algorithm in Model 1000 / Model 1000-D was tested *in silico* and determined to be functionally equivalent to Model 106. Therefore, no new clinical evaluation for algorithm performance was conducted for Model 1000 / Model 1000-D and the Model 106 results are applicable.

The "Receiver Operating Characteristic (ROC) Curve for Tachycardia Detection Associated with Seizures " on the next page uses data collected in an epilepsy monitoring unit (EMU) setting from two previously conducted clinical studies (E36 and E37).

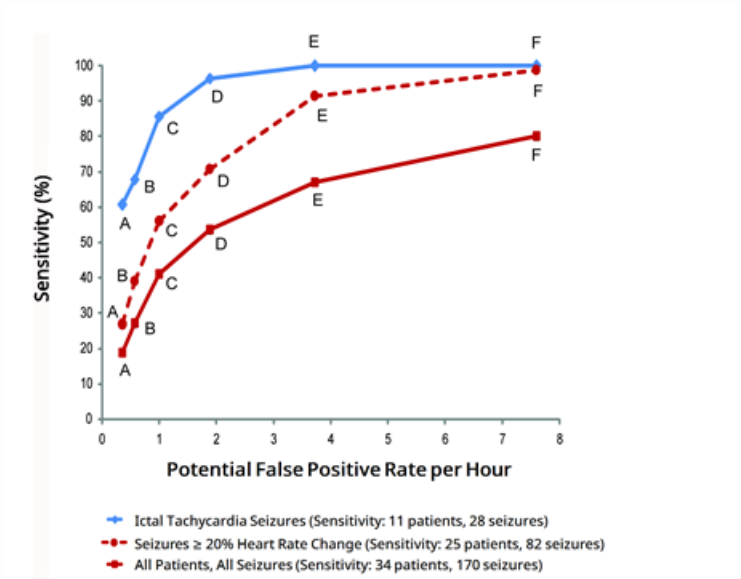
- Curve 1 (blue) includes only seizures that met the criteria for ictal tachycardia (defined as an increase in heart rate during a seizure to a rate that was greater than 100 bpm and was at least a 55% increase or 35 bpm increase from baseline [resting] heart rate).
- Curve 2 (dashed red) includes all seizures with greater than 20% increase in heart rate during an ictal event and represents the performance for all seizures which may be detected based on the design of the Tachycardia Detection Algorithm.
- Curve 3 (solid red) includes all seizures from all study patients, irrespective of the heart rate change.

The curves illustrate a trade-off between sensitivity and specificity (potential false positive rate per hour) as the AutoStim Threshold setting is adjusted. As one decreases the AutoStim threshold, the sensitivity increases, but at the expense of specificity.

The following limitations should be considered when interpreting the data in the ROC curve (shown below), as an EMU may not be reflective of real-world use:

- The EMU represents a controlled setting and thus, the types of seizures and number of seizures associated with tachycardia may vary from those in real-world use.
- During the EMU only the AutoStim feature was enabled and the Normal Mode was disabled. Use of AutoStim in conjunction with Normal Mode stimulation and Magnet Mode stimulation may affect tachycardia detections.
- In real world use, physical activities that increase heart rate, including but not limited to exercise, could result in detection of tachycardia that may not be associated with a seizure.

Figure 8. Receiver Operating Characteristic (ROC) Curve for Tachycardia Detection Associated with Seizures



A AutoStim Threshold 70%

B AutoStim Threshold 60%

C AutoStim Threshold 50%

D AutoStim Threshold 40%

E AutoStim Threshold 30%

F AutoStim Threshold 20%

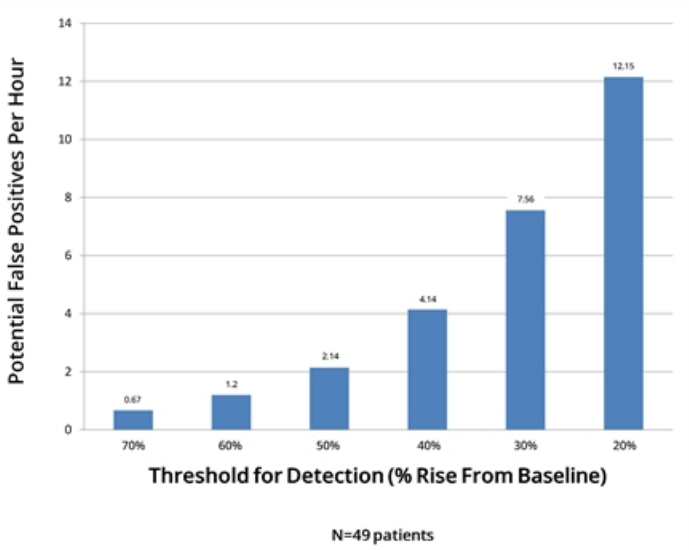
NOTE: Note: Potential False Positive Rate based on 50 patients, 4516 hours.

5.3.1.3.2. Tachycardia Detection Algorithm Performance— AutoStim Potential False Positives

NOTE: The Tachycardia Detection Algorithm in Model 1000 / Model 1000-D was tested *in silico* and determined to be functionally equivalent to Model 106. Therefore, no new clinical evaluation for algorithm performance was conducted for Model 1000 / Model 1000-D and the Model 106 results are applicable.

ECG data were collected in a previously conducted clinical study of healthy normal volunteers (E-34) during sub-maximal exercise testing and sleep. The graph below shows the impact of exercise (i.e., stair stepping and moderate treadmill) and other activities (i.e., Valsalva maneuvers and sleep) on the AutoStim Potential False Positive rate.

Figure 9. Non-seizure Heart Rate Challenges



5.3.1.3.3. Sensitivity and Potential False Positive Rates per AutoStim Threshold

The following table is applicable for generators with the AutoStim feature only and supplements the "Receiver Operating Characteristic (ROC) Curve for Tachycardia Detection Associated with Seizures " on the previous page.

Table 24. Mean Values and 95% Confidence Intervals (CI) from the E36 and E37 Clinical Study Performance Data

Threshold for AutoStim	Mean Sensitivity (%) (95% CI)*			Potential False Positives per Hour (95% CI)*
	Ictal Tachycardia Seizures Only (—♦—) n=11 pts, 28 sz	Seizures ≥ 20% Heart Rate Change (- -●- -) n=25 pts, 82 sz	All Patients (pts), All Seizures (sz) (—■—) n=34 pts, 170 sz	Applies to All Categories n=50 pts, 4516 hrs
70% Threshold	60.7 (40.0, 81.8)	26.8 (14.2, 42.9)	18.8 (10.5, 34.4)	0.4 (0.3, 0.5)
60% Threshold	67.9 (46.9, 88.0)	39.0 (23.8, 53.9)	27.1 (12.9, 41.0)	0.6 (0.5, 0.8)
50% Threshold	85.7 (70.4, 96.0)	56.1 (38.1, 73.0)	41.2 (20.9, 50.9)	1.0 (0.8, 1.3)

Table 24. Mean Values and 95% Confidence Intervals (CI) from the E36 and E37 Clinical Study Performance Data (continued)

Threshold for AutoStim	Mean Sensitivity (%) (95% CI)*			Potential False Positives per Hour (95% CI)*
	Ictal Tachycardia Seizures Only (—♦—) n=11 pts, 28 sz	Seizures ≥ 20% Heart Rate Change (- -●- -) n=25 pts, 82 sz	All Patients (pts), All Seizures (sz) (—■—) n=34 pts, 170 sz	Applies to All Categories n=50 pts, 4516 hrs
40% Threshold	96.4 (86.2, 100)	70.7 (52.5, 84.4)	53.5 (28.9, 61.3)	1.9 (1.5, 2.3)
30% Threshold	100†	91.5 (78.6, 97.5)	67.1 (39.0, 71.2)	3.7 (3.2, 4.5)
20% Threshold	100†	98.8 (94.4, 100)	80.0 (56.0, 82.1)	7.6 (6.6, 8.8)

* 95% confidence intervals constructed using 3000 bootstrap samples
† Confidence Intervals cannot be calculated when mean sensitivity equals 100%

5.3.2. Features

5.3.2.1. Low Heart Rate / Prone Detection

Applicable Models: Model 1000 | Model 1000-D

⚠ CAUTION: Low heart rate and prone position events are for informational purposes only. Detected events are not to be used for alarms or medical diagnosis.

Clinical data suggest that events of cardiac arrest and/or respiratory arrest, possibly aggravated by the prone position, are precursors to instances of Sudden Unexplained Death in Epilepsy (SUDEP)[1] . The generator can detect and log low heart rate and prone position events if they are of interest to the physician. These events are detected after AutoStim Mode or Magnet Mode stimulation, and Tachycardia Detection must be enabled in order to log low heart rate and prone position events.

[1]Ryvlin, Philippe et al. Incidence and mechanisms of cardiorespiratory arrests in epilepsy monitoring units (MORTEMUS): a retrospective study. The Lancet Neurology, Volume 12 , Issue 10 , 966 - 977

5.3.2.2. Scheduled Titration (Scheduled Programming)

Applicable Models: Model 1000 Model 1000-D

⚠ CAUTION: This feature may not be appropriate for use in patients who are nonverbal or are unable to use the patient magnet to stop undesired stimulation. Similarly, exercise caution for use of this feature in patients with a history of obstructive sleep apnea, shortness of breath, coughing, swallowing difficulties, or aspiration.

Scheduled Titration (Scheduled Programming) is an optional feature that allows you to program the generator so that it automatically increases stimulation therapy parameters while the patient is in the comfort of his or her home. This feature is intended to be used during the titration phase and could potentially lessen the number of office visits the patient will need to travel to and from the clinic for programming increases.

5.3.2.3. Day-Night Programming

Applicable Models: Model 1000 Model 1000-D

Day-Night programming is an optional feature that programs the VNS device to deliver two alternate sets of therapy parameters within 24 hours. This feature allows you to choose unique Daytime and Nighttime settings and define the time each parameter set is active.

After therapy parameters reach a target level, use Day-Night to customize the therapy for the individual patient's needs. Ensure that the patient can tolerate both sets of parameters and communicate to the patient and caregiver when to expect a setting change. As with any therapy setting change, the risks and benefits of altering a patient's known efficacious settings should be considered when adjustments are made.

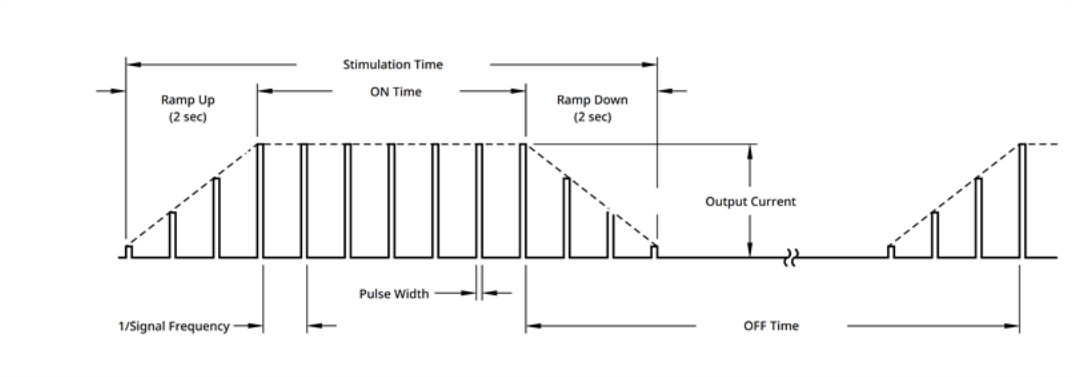
⚠ CAUTION: Time-based features do not automatically adjust for daylight saving time or time zone changes. Tell the patient to follow up with their physician for reprogramming if needed.

5.4. Stimulation Parameters and Duty Cycle

5.4.1. Programmable Parameters

The graphic representation of stimulation shown below depicts the relationship of the programmable parameters.

Figure 10. Stimulation



NOTE: Frequencies < 10 Hz do not ramp.

Each parameter can be independently programmed, thereby offering multiple setting combinations from which the physician may select optimal stimulation for the patient.

The stimulation graphic shows that the output pulse can be varied both by amplitude (output current) and duration (pulse width). The number of output pulses delivered per second determines the frequency.

5.4.2. Duty Cycle

The percentage of time the generator stimulates is called a duty cycle. To calculate a duty cycle, divide the stimulation time (programmed Normal Mode ON time plus, if frequency is ≥ 10 Hz, 2 seconds of ramp-up time and 2 seconds of ramp-down time) by the sum of the ON time and OFF time.

For details on available parameters, see "Stimulation Parameters and Available Parameter Settings" on page 67.

WARNING: Excessive stimulation is the combination of an excess duty cycle (i.e., one that occurs when ON time is greater than OFF time) and high frequency stimulation (i.e., stimulation at ≥ 50 Hz). Excessive stimulation has resulted in degenerative nerve damage in laboratory animals. Furthermore, excess duty cycle can be produced by continuous or frequent magnet activation (> 8 hours). While LivaNova limits the maximum programmable frequency to 30 Hz, it is recommended that you do not stimulate with excess duty cycle. Further, physicians should warn patients about continuous or frequent magnet use as this could lead to early battery depletion.

The table below shows duty cycles for typical ON time and OFF time settings.

Table 25.

Duty Cycles for Various ON Time and OFF Time Settings

ON Time (sec)	OFF Time (min)								
	10	5	3	1.8	1.1	0.8	0.5	0.3	0.2
	Duty Cycles* (% ON Time)								
7	2	4	6	10	15	20	30	44	58
14	3	6	9	15	23	29	41	56	69
20	4	8	12	19	29	36	49	64	76
30	5	10	16	25	35	44	57	71	81
60	10	18	27	38	51	59	71	82	89

** Duty cycle = (ON time + 2 sec ramp-up + 2 sec ramp-down) / (ON time + OFF time)*.
Note: The duty cycles in gray are *not recommended* as they represent parameter combinations with ON time > OFF time.

NOTE: If Tachycardia Detection is enabled and AutoStim output current is >0 mA, Normal Mode OFF times < 1.1 minutes are not available for programming.

5.5. Generator Battery Longevity

5.5.1. All Generators

The anticipated longevity of the generator battery depends on the programmed setting choices. Higher output currents, frequencies, pulse widths, and duty cycles generally deplete the battery over a shorter period of time than lower settings. Generally, the increase in battery depletion rate is proportional to the increase in the programmed setting in the absence of detection.

CAUTION: *Undeliverable output currents*: Programming the generator to a high output current that cannot be delivered due to a high lead impedance may disproportionately increase the battery depletion rate and should be avoided.

Other factors, such as lead impedance, magnet usage, or use of optional features (e.g., AutoStim Threshold settings, AutoStim) also affect the anticipated battery longevity. The anticipated battery longevity decreases as lead impedance increases. Although 1.5 kΩ to 3 kΩ may be a typical lead impedance at implantation, the impedance may increase to 3 kΩ to 5 kΩ during the life of the implant.

The "Battery Longevity Tables" on page 167 provide estimated generator battery lifetimes under a variety of stimulation conditions.

Because of the number of possible parameter combinations, it is impractical to provide the projected life for all possible combinations. The longevity tables should not be used to predict battery EOS, but they give some

indication of the effect of various parameter changes on battery life and can be used to assist in the selection of parameter settings. They also indicate that battery life can be maximized at low duty cycles and low frequencies (e.g., 20 Hz) for stimulation.

NOTE: For details, see the model-specific programming system manual posted at www.livanova.com.

5.5.2. Generators with AutoStim

Applicable Models:	Model 1000	Model 1000-D	Model 106

When a combination of parameter settings for stimulation is selected, the physician should also consider that some combinations decrease battery life faster than others. Tachycardia Detection and/or additional features will also decrease the battery life.

NOTE: See "All Generators" on the previous page.

The table below shows the longevity impact that the AutoStim Mode feature has on generators capable of AutoStim with a typical lead impedance (3 kΩ) and the parameter values listed in the table.

Table 26. Estimated Longevity With and Without Sensing and AutoStim

	Model 1000 Model 1000-D				Model 106			
Normal Mode settings: 2 mA output current, 20 Hz signal frequency, 30 sec ON, 5 min OFF								
AutoStim Feature	Expected Life (yrs) at 250 µsec		Expected Life (yrs) at 500 µsec		Expected Life (yrs) at 250 µsec		Expected Life (yrs) at 500 µsec	
Tachycardia Detection / AutoStim OFF	11.4		8.5		>12		>10	
	AutoStim ON Time				AutoStim ON Time			
Tachycardia Detection / AutoStim ON (2 mA output current)	30 sec	60 sec	30 sec	60 sec	30 sec	60 sec	30 sec	60 sec
AutoStims Per Hour	Expected Life (yrs) at 250 µsec		Expected Life (yrs) at 500 µsec		Expected Life (yrs) at 250 µsec		Expected Life (yrs) at 500 µsec	
1	7.7	7.5	6.2	5.9	8.8	8.7	6.5	6.9
7	7.1	6.1	5.5	4.5	8.4	7.5	6.5	5.5
15	6.5	5.0	4.8	3.4	7.8	6.5	6.0	4.4

5.5.3. Battery Status Indicators

The programming software displays the generator battery status and the approximate battery capacity that remains. The software also displays recommended actions if the generator battery requires additional monitoring (i.e., IFI), is near end of service (NEOS) or at end of service (EOS).

NOTE: For details, see the model-specific programming system manual posted at www.livanova.com.

CAUTION: *Battery evaluation at cold temperatures*: Low storage temperatures may affect the battery status indicators. In such cases, keep the generator at room or body temperature for 30 minutes, then use the System Diagnostics or Generator Diagnostics to re-evaluate the battery status indicators.

5.6. Generator Replacement

All VNS Therapy generators will eventually require surgical replacement due to battery depletion. Generator replacement does not, of itself, require lead replacement unless a lead discontinuity is suspected. Generator replacement or removal requires dissection to the generator's pocket, with care being taken not to damage or cut the lead. The entire surgical procedure generally requires about 1 hour.

NOTE: See "Revision, Replacement, and Removal Procedure " on page 132 for details.

5.6.1. Signs of End of Service

The most common reason for the absence of stimulation is battery depletion, although there may be other reasons. When end of service (EOS) occurs, the generator will disable stimulation and no output will be delivered. If the generator is not explanted or replaced at end of service (EOS), the battery voltage will continue to gradually decrease and communication with the generator may not be possible.

CAUTION: Generator end of service (EOS) may result in increased frequency, intensity, or duration of signs and symptoms of the patient's disorder, in some cases to levels greater than those reported before stimulation.

5.6.2. Replacement Based on Battery Status Indicators

The generators and the programming system have battery status indicators (see "Battery Status Indicators" above). These indicators let you know that a generator battery should be monitored more frequently (i.e., IFI), is near end of service (NEOS), or has reached end of service (EOS). When these indicators appear, see recommendations in the model specific programming system manual posted at www.livanova.com.

CAUTION: *Prompt generator replacement* – LivaNova recommends prompt replacement of the generator at or before end of service (EOS). Prompt replacement may help minimize any possible relapse. See "System Removal" on page 142 for additional information about explanted devices.

CAUTION: *Explanted generator* – A generator explanted for any reason should not be re-implanted. Return explanted generators to LivaNova. For instructions, see Return Product Form.

5.7. Magnet

5.7.1. Magnet Uses

Magnets are supplied by LivaNova. There are four possible uses for the magnet:

- Provide on-demand stimulation as an attempt to abort or de-intensify an oncoming seizure. During an aura or at the start of a seizure, the patient, a companion, or the physician can initiate magnet activation with the magnet. To do so, apply or pass the magnet over the generator to activate the reed switch in the generator's electronic circuitry. This action changes the generator from Normal Mode to Magnet Mode.
- Temporarily inhibit stimulation
- Reset the generator (in combination with the programming system)
- To test the generator function, it is recommended that patients be instructed to use the magnet to activate stimulation. Note that this indirectly tests the generator through the ability of the patient to perceive Magnet Mode stimulation. Since patient may become accustomed to their stimulation settings over time, it is recommended that physicians always use the Diagnostic tests available in the programming software in order to formally test the implanted system.

  WARNING: Excessive stimulation is the combination of an excess duty cycle (i.e., one that occurs when ON time is greater than OFF time) and high frequency stimulation (i.e., stimulation at ≥ 50 Hz). Excessive stimulation has resulted in degenerative nerve damage in laboratory animals. Furthermore, excess duty cycle can be produced by continuous or frequent magnet activation (> 8 hours). While LivaNova limits the maximum programmable frequency to 30 Hz, it is recommended that you do not stimulate with excess duty cycle. Further, physicians should warn patients about continuous or frequent magnet use as this could lead to early battery depletion.

NOTE: See also the *Patient Magnet Directions for Use* posted at www.livanova.com.

5.7.2. On Demand Stimulation

To initiate stimulation, apply or pass the magnet over the generator for 1–2 seconds and then immediately remove it from the area over the generator. Removal of the magnet causes the generator to operate in Magnet Mode and delivers a single stimulation with the programmed magnet pulse width, magnet current, and magnet signal ON time settings. The frequency is the programmed value for Normal Mode. A Magnet Mode stimulation will always override any Normal Mode programmed stimulation. If Magnet Mode stimulation is not desired, the Magnet Mode output current may be programmed to 0 mA.

It is recommended that tests of the magnet output be performed while the patient is still in the physician's office to ensure tolerability of the magnet output.

5.7.3. Magnet Activation Technique

The proper orientation and motion for magnet activation is shown below. If difficulty is encountered with a single pass of the magnet, an optional cross-pattern may be used by the patient or caregiver to activate the Magnet Mode.

Figure 11. Standard Magnet Activation

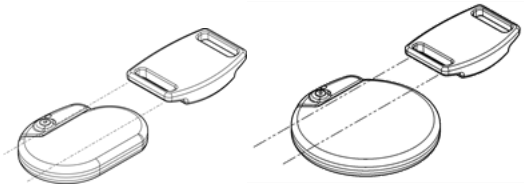
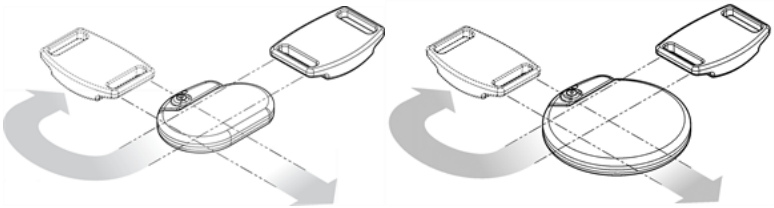


Figure 12. Optional Cross-pattern Magnet Activation



⚠ CAUTION: To activate or stop stimulation, the label side of the magnet should face the generator.

⚠ CAUTION: The cross-pattern activation technique may cause duplicate magnet activation entries to be shown in the programming software database. This is an expected occurrence due to device design and is not considered a device malfunction.

5.7.4. Inhibit Stimulation

A magnet held in place over the generator temporarily stops any ongoing stimulation. To inhibit the entire stimulation cycle, the magnet must be held in place over the generator for the minimum required time listed in the table below. After the magnet is removed, normal operation will resume after one complete OFF time.

Table 27. Time Needed to Terminate Stimulation

Model	Time
Model 1000 Model 1000-D	10 sec
Model 106	5 sec
Model 105 Model 104 Model 103 Model 102 Model 102R	65 sec

⚠ CAUTION: If stimulation becomes painful, the patient should be instructed to stop the stimulation with the magnet.

In the unlikely event of continuous stimulation or other malfunction, advise the patient to apply the magnet, secure it in place, and immediately notify their physician.

ⓘ NOTE: For details on adverse events, see "Potential Adverse Events" on page 38.

5.8. Effects of the Daily Reset of the Internal Clock

The Model 102 and Model 102R generators contain an internal clock that rolls over (i.e., restarts) every 24 hours. This daily rollover of the internal clock is a normal device function. Every time the clock restarts, a stimulation cycle beginning with the programmed ON time is delivered. Patients may notice a shorter OFF time between the last stimulation cycle just prior to the clock restart and the first stimulation cycle after the clock restart.

ⓘ NOTE: The time that the clock restarts each day corresponds with the time of day the most recent programming event occurred. Holding the magnet over the generator for an extended period of time will put all timekeeping functions on hold and will delay the time that the internal clock rolls over each day.

Some patients may be more sensitive to this shorter OFF time and may exhibit common stimulation related side effects (e.g., coughing, voice changes). These side effects will only occur once a day at the time of the daily clock restart. In the rare reported instances in which side effects occurred with the daily clock restart, it

was noted that the most common programmed duty cycle was 30 seconds ON time and 3 minutes OFF time along with a high output current (> 2 mA).

NOTE: For a complete list of side effects, see "Potential Adverse Events" on page 38

As with any normal side effect, adjusting settings for tolerability (i.e., decreasing pulse width, signal frequency, and/or output current) has been shown to be successful in resolving stimulation related side effects associated with the 24-hour rollover event. However, since this 24-hour rollover event is directly related to the programmed ON time and OFF time, adjusting the duty cycle may be a better option. Optimizing the patient's benefit from therapy should be considered when making the decision as to which parameter should be adjusted. For example, if the patient is responding well clinically at a particular output current, adjusting a different parameter or duty cycle may be considered. The table below shows several ON time and OFF time combinations that may be better options when trying to resolve stimulation related side effects associated with the daily clock restart.

Table 28. Optimize Therapy for Patients Affected by the Internal Clock Cycle

ON Time (sec)	OFF Time (min)
7	0.3
14	0.5
21	0.5
7	0.8
14	1.1
30	1.1
60	1.1
30	1.8
7	3.0
14	3.0
60	5.0
14	10.0

NOTE: For details on Duty Cycle, see "Duty Cycle" on page 77.

5.9. Device History

The generator device history consists of the generator serial number, model number, patient ID, implantation date, and other information pertinent to diagnostic events.

Use the programming software to access and view device history information. For details, see the model-specific programming system manual posted at www.livanova.com.

5.10. Device Diagnostics

5.10.1. Device Diagnostics Introduction

Information from device diagnostic tests can help the physician determine if the following is true:

- Generator output current is delivered at the programmed value
- Generator battery is at a sufficient level
- Lead impedance is within an acceptable range

Use the programming software to access and view Device Diagnostics information.

NOTE: For details, see the model-specific programming system manual posted at www.livanova.com. .

5.10.2. System Diagnostics Test

The System Diagnostics evaluates the lead impedance of the system as well as the generator's ability to deliver the programmed Normal Mode stimulation.

Depending on the generator model and programmed Normal Mode **output current**, different test pulses may be conducted during the test (see table below).

Table 29. System Diagnostics Behavior

Normal Mode Output Current	Model 1000 Model 1000-D	Model 106 Model 105 Model 104 Model 103	Model 102 Model 102R
0 mA	Delivery of programmed output for approximately 4 seconds, followed by one brief pulse at 0.25 mA for less than 130 µsec.*	1 mA, 500 µsec for approximately 14 seconds	1 mA, 500 µsec for approximately 14 seconds
> 0 mA		One brief pulse at 0.25 mA, 130 µsec, followed by delivery of programmed output for the duration of the programmed ON time.	

Table 29. System Diagnostics Behavior (continued)

Normal Mode Output Current	Model 1000 Model 1000-D	Model 106 Model 105 Model 104 Model 103	Model 102 Model 102R
	NOTE: Once programmed ON, lead impedance measurement readings are automatically performed once every 24 hours.	NOTE: Once programmed ON, lead impedance measurement readings are automatically performed once every 24 hours.	N/A

*Minor differences in the system diagnostics test exist for Model 1000 with serial numbers < 100,000. For more information, see Model 1000 (Serial Numbers <100,000 Only).

The programming software reports the lead impedance and whether the programmed stimulus was delivered.

NOTE: For details, see the model-specific programming system manual posted at www.livanova.com.

5.10.3. High Lead Impedance

High lead impedance is defined as any value ≥ 5300 Ω.

5.10.3.1. Reasons for High Lead Impedance Readings

Possible causes of high lead impedance readings are thought to include:

- Lead discontinuity
- Lead disconnection from the generator
- Fibrosis between the nerve and the electrode
- Electrode detachment from the nerve
- Defective generator

5.10.3.2. High Lead Impedance — Possible Implications

High lead impedance (≥ 5300 Ω), in the absence of other device-related complications, is not an indication of a lead or generator malfunction. High lead impedance in combination with the patient's failure to feel even the maximum output stimulus may indicate a lead wire fracture or other type of electrical discontinuity in the lead. Complications with heartbeat sensing may also be indicative of a lead discontinuity.

Patients who experience high lead impedance, no sensation of maximum output stimulation, and an increase in seizure symptoms should be further evaluated for possible lead replacement.

NOTE: For details, see the model-specific programming system manual posted at www.livanova.com.

NOTE: For troubleshooting steps, see "Lead Impedance Issues" on page 152.

For Models:	Model 102	Model 102R

Use the table below to find the DC DC Code displayed by the System Diagnostics screen to determine an estimate of lead impedance in Ohms (Ω). The use of this table with the DC DC Codes from diagnostic screens other than the System Diagnostics and Generator Diagnostics is not appropriate, unless the generator output parameters are the values indicated in the tables. High lead impedance is defined as any DC DC Code greater than or equal to 4 with 1 mA of diagnostic current.

Table 30. DC DC Code Conversion and Estimated Impedance Range Lead Impedance

DC DC Code	Estimated Impedance Range (Lead Impedance Value at 1 mA, 500 µsec)
0	≤ 1700 Ω
1	1800–2800 Ω
2	2900–4000 Ω
3	4100–5200 Ω
4	5300–6500 Ω
5	6600–7700 Ω
6	7800–8900 Ω
7	≥ 9000 Ω

5.10.4. Low Lead Impedance

Low lead impedance is defined as any value ≤ 600 Ω.

5.10.4.1. Reasons for Low Lead Impedance Readings

Possible causes of low lead impedance readings are thought to include:

- Short-circuit condition within the lead
- Defective generator

5.10.4.2. Low Lead Impedance – Possible Implications

Model 1000 Model 1000-D Model 106 Model 105 Model 104 Model 103	Low lead impedance (≤ 600 Ω) likely indicates the existence of a short-circuit condition, although an impedance value of greater than 600 Ω does not exclude the possibility.
Model 102 Model 102R	Low lead impedance (DC DC Code of "0") likely indicates the existence of a short-circuit condition, although an impedance value of greater than 600 Ω does not exclude the possibility. A significant decrease in DC DC Code value on the System Diagnostics (e.g., "3" to "1") from prior System Diagnostics may also indicate a lead problem.

A sudden decrease in impedance value in combination with device-related complications, listed below, may also indicate a short-circuit condition in the lead:

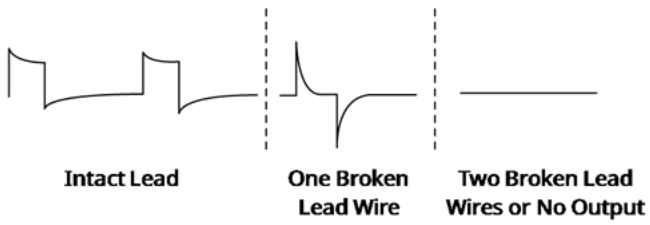
- Increase in seizure symptoms
- Painful stimulation
- Complications with heartbeat detection
- Patient perception of feeling erratic, limited, or no stimulation

NOTE: For troubleshooting steps, see "Lead Impedance Issues" on page 152.

5.10.5. Stimulus Waveform Analysis

Either evoked potential monitoring equipment or an oscilloscope can be used to analyze the stimulus waveform from the neck for verification of an electrical discontinuity. A differentiated waveform with narrowed pulses or no waveform at all can confirm a discontinuity. The figure below shows characteristic waveforms obtained from skin electrodes for a lead that is intact and for a lead that has a fracture in one or both wires. In addition to these approaches, lead discontinuities can sometimes be identified on an x-ray of the implant site.

Figure 13. Typical Waveforms Obtained from Skin Electrodes



5.11. Delivery of Programmed Output Current

5.11.1. Output Current LOW or LIMIT

If the diagnostic tests indicate LOW or LIMIT (Model 102 and Model 102R) output current, the generator may not be delivering the programmed output current. Reasons for failure to deliver the programmed output current include high programmed output current and high lead impedance. The maximum deliverable output current, according to Ohm's Law, equals the maximum output voltage (approximately 12 V) divided by the lead impedance.

5.11.2. Reprogram to a Lower Current

If the generator fails to deliver the programmed output current, you can reprogram the device to a lower output current and attempt to compensate for a decrease in delivered energy by widening the pulse width.

For example, if the output current is at LOW or LIMIT for a generator programmed at 2.5 mA, 30 Hz, 500 µsec with 30 seconds ON time, then lower the output current to 2 mA and widen the pulse width to 750 µsec.

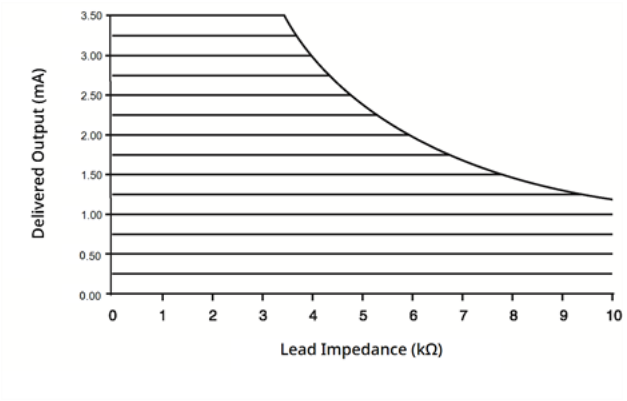
5.12. Charge Delivered per Pulse

The charge delivered per pulse is the most important parameter when stimulation output is evaluated. It is defined as a microcoulomb (µC), which is the product of current and time.

Charge delivered per pulse (µC) = output current (mA) x pulse width (msec[1])

The relationship of programmed output current (mA) to lead impedance for a 1000 µsec pulse with output currents from 0 to 3.5 mA, is shown below.

Figure 14. Relationship of Programmed Output Current to Lead Impedance



[1] Converted from µsec into msec

⚠ CAUTION: Model 100, Model 102 and Model 102R **Do not use frequencies of 5 Hz or below for long-term stimulation.** These frequencies generate an electromagnetic trigger signal, which results in excessive battery depletion of the implanted generator. Therefore, use these low frequencies for short periods of time only.

CHAPTER 6

Implantation

For precautions related to the implantation procedure, see "Precautions—Related to Implantation" on page 27.

This topic includes the following concepts:

6.1. Surgeon Training

Physicians who implant the VNS Therapy system should be experienced with surgery within the carotid sheath and capable of performing the surgical technique used to implant the VNS Therapy system.

All programming should be performed by or under the supervision of a physician familiar with the use and operation of the programming system.

Physicians who implant the VNS Therapy system should be thoroughly familiar with all associated training materials:

- Physician and patient labeling for the VNS Therapy system
- Electrode practice fixture—a device used to practice placing the helices around the vagus nerve

NOTE: Contact "Technical Support" on page 223 to request other training materials and support.

6.2. Components and Surgical Materials — New Implant

Table 31. Components Needed for New Implant

Components Needed for Surgery	New Implant
Generator	1 primary single-receptacle generator 1 backup single-receptacle generator
Lead	1 primary single-pin lead 1 backup single-pin lead
Accessory Pack	1 accessory pack
Programming System	1 programming system
Tunneler	1 tunneler
Sterile Laser Arm Bag or equivalent*	Required
Soft vessel loops or silicone sheet*	Suggested but optional
Commercial ECG monitor and associated instructions for use*†	Required (Able to print out the ECG waveform / amplitudes on the lead I channel)
Standard, 10 mm Ag/AgCl skin electrodes*†	Required

* Not provided by LivaNova
† Used to identify acceptable implant locations for generators with AutoStim. For more information, see "Pre-Surgical Steps" on page 95 .

NOTE: For lead size availability, see "Physical Characteristics" on page 64.

NOTE: For details, see "Pre-Surgical Steps" on page 95. This information is also summarized in the Pre-surgical Evaluation Tool.

6.3. How to Open the Sterile Pack

Before any sterile pack is opened, examine it carefully for evidence of damage or compromised sterility. If the outer or inner sterile barrier has been opened or damaged, LivaNova cannot guarantee sterility of the contents, and it should not be used. An opened or damaged product should be returned to LivaNova.

CAUTION: Do not open the sales pack if it has been exposed to extreme temperatures or if there is evidence of external damage or damage to the package seal. Instead, return it unopened to LivaNova.

CAUTION: Do not implant or use a sterile device if the device has been dropped. Dropped devices may have damaged internal components.

6.3.1. Generator and Lead

To open the sterile pack, complete the following steps:

1. Grasp the tab and peel back the outer cover.
2. Use sterile technique to lift out the sterile inner tray.
3. Grasp the inner tray's tab and carefully peel off the cover to expose the contents without dropping them.

6.3.2. Tunneler

To open the sterile pack, complete the following steps:

1. Grasp the tab and peel back the outer cover.
2. Use sterile technique to lift out the sterile inner tray.
3. Grasp the inner tray's tab and carefully peel off the cover to expose the contents without dropping them.
4. Remove all four pieces in the package (shaft, bullet tip, large-diameter sleeve, small-diameter sleeve).

6.3.3. Accessory Pack

To open the sterile pack, complete the following steps:

1. Grasp the tab and peel back the outer cover.
2. Use sterile technique to lift out the sterile inner tray.
3. Grasp the inner tray's tab and carefully peel off the cover to expose the contents without dropping them.

4. To remove the hex screwdriver, a resistor assembly, or tie-downs, push down on one end of the item and grasp the opposite (raised) end.

6.4. Recommendations for Implantation

In general, implantation of the VNS Therapy system is similar to accepted practice for implantation of a cardiac pacemaker, with the exception of the placement of the helices and the subcutaneous routing of the lead body. The surgical approach and techniques will vary with the preference of the surgeon. To ensure correct lead placement, these instructions provide recommendations for implantation, order of placement of the helical electrodes and anchor tether, and other essential steps.

⚠ CAUTION: To maximize system performance and minimize possible mechanical damage to the nerve or lead, **pay careful attention to helical placement and lead route**.

- For generators with the AutoStim feature, the physical location of the device critically affects its ability to properly sense heartbeats. Therefore, care must be taken to follow the implant location selection process outlined in "Determine Acceptable Implant Locations" on the next page.

  ⓘ NOTE: The implant location selection procedure may be performed pre-operatively as part of the patient's surgical work-up.

- The surgeon should ensure that the generator, lead, and tunneler are compatible. See "System—Compatibility" on page 13.
- It is recommended that the patient be given antibiotics pre-operatively and that both incision sites be irrigated frequently with generous amounts of bacitracin or equivalent solution prior to closure. (These incisions should be closed with cosmetic closure techniques to minimize the development of scars.) Also, antibiotics should be administered post-operatively at the discretion of the physician.

  ⚠ CAUTION: **Infections related to any implanted device are difficult to treat** and explant of the VNS Therapy system may be required.

- Critical to the long-term success of the implant are proper techniques both for the attachment of the electrodes and the anchor tether to the vagus nerve, and for the provision of adequate strain relief below and above the sternocleidomastoid muscle. For details on general placement of the generator and lead, see "Lead and Pocket Location" on page 98.
- Coil the lead body and place it in the chest pocket to the side of the generator.
- Adequate exposure of the vagus nerve (> 3 cm) facilitates placement of the helices on the nerve. The nerve may swell temporarily if the nerve is stretched or allowed to dry during implantation. Constriction of the nerve or other nerve damage may result in vocal cord dysfunction.
- It is recommended that output of the generator and performance of the implanted system be tested at the time of implantation. It is recommended that the appropriate version of the programming software and Wand (placed in a sterile drape) be used for routine system verification. For details, see "Test the System" on page 113.

- After the electrode is placed on the nerve, test the electrode-nerve interface impedance. Connect the lead directly to the generator and perform a System Diagnostics. For details, see "Test the System" on page 113.

6.5. Pre-Surgical Steps

Perform the following before surgery and outside of the sterile field.

6.5.1. Interrogate the Generator

To ensure proper device communication, interrogate the device while still in the sterile pack.

Model 1000 Model 1000-D Model 106 Model 105 Model 104 Model 103	⚠ CAUTION: If you interrogate a generator that has been exposed to low temperatures within the last 24 hours, a low battery status indicator may be displayed. For troubleshooting steps, see"Battery Issues" on page 160.

6.5.2. Program Patient Data

Program the patient identification and implant date into the generator. For details, see the model-specific programming system manual posted at www.livanova.com.

6.5.3. Generators With AutoStim

6.5.3.1. Determine Acceptable Implant Locations

The implant location of generators capable of Tachycardia Detection critically affects their ability to properly sense heartbeats. The following steps describe the recommended process in identifying acceptable implant locations for the generator and lead.

ⓘ NOTE: The implant location selection process is also summarized in the *Pre-Surgical Evaluation Tool* in the generator sales pack.

6.5.3.2. Pre-Surgical Evaluation Materials

The following materials are required to identify acceptable implant locations:

- Commercial ECG monitor — The ECG monitor should have the capability to print out the ECG waveform / amplitudes on the lead I channel. The ECG monitor must be configurable to a lowpass filter setting up to 150 Hz.
- Standard, 10 mm Ag/AgCl skin electrodes

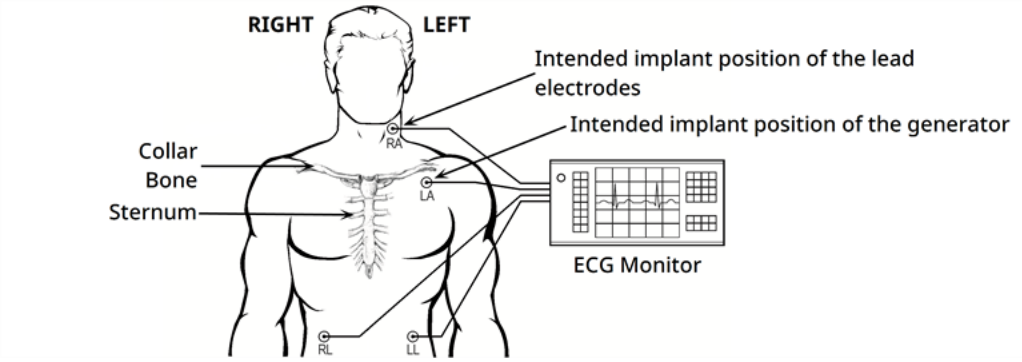
- Commercial ECG Instructions for Use
- Pre-surgical Evaluation Tool posted at www.livanova.com

NOTE: Any commercial ECG system meeting the requirements in the section “Equipment / Materials Required” above is acceptable for use in the identification of potential implant locations procedure. Refer to the commercial ECG system Instructions For Use for proper operation or configuration.

6.5.3.3. Pre-Surgical Evaluation Procedure

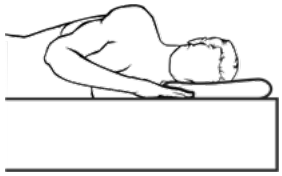
1. Verify that the ECG monitor printing scale is set to 10 mm/mV and the lowpass filter does not exceed 150 Hz.
2. Prepare the patient's skin in the left neck and chest area (e.g., remove excess body hair, perform alcohol wipe) to ensure proper contact with ECG skin electrodes.
3. Place ECG skin electrodes on the patient as follows:
    - One electrode on the left neck, at the approximate intended implant location of the lead electrodes
    - One electrode on the chest, at the approximate intended implant location of the generator
    - One electrode on the right lower abdomen or leg
    - One electrode on the left lower abdomen or leg

Figure 15. Sample Electrode Configuration



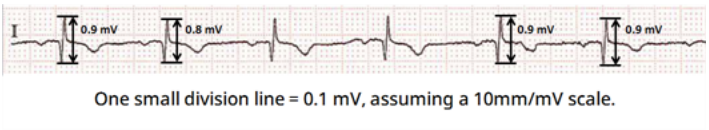
4. Connect the ECG leads to the electrodes:
    - RA – neck
    - LA – chest
    - RL – right lower abdomen or right leg
    - LL – left lower abdomen or left leg
5. Verify that the lead I ECG waveform is showing on the ECG monitor, wait for the ECG signal to stabilize, and collect 10 seconds of ECG data with the patient positioned lying on the left side (first of two positions).

Figure 16. Patient Position - Lying on Left Side



6. Print the ECG strip and label the patient position. On the ECG strip measure the peak-to-peak R-wave amplitude in the lead 1 channel by following the scaling in Step 1. Perform this for at least 4 representative R-waves in the 10 seconds of data and record the minimum amplitude value from the assessed R-waves. This value is representative of the minimum peak-to-peak R-wave amplitude for the patient in the defined body position.

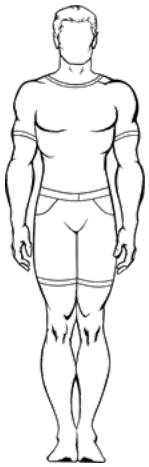
Figure 17. Sample ECG Trace with Peak-to-Peak R-Wave



7. Verify that the minimum peak-to-peak R-wave amplitude measurement in Step 6 is 0.4 mV or greater. If this is the case, then repeat Steps 5–6 with the remaining body position, as shown below, until both body positions have been tested and the minimum peak-to-peak R-wave amplitude measurement for each body position is confirmed to be 0.4 mV or greater.

NOTE: Assuming a 10 mm/mV scale, the peak-to-peak R-wave amplitude measurements must span at least 4 lines on the ECG paper to meet the minimum requirement of 0.4 mV.

Figure 18. Patient Position - Standing, Arms at Side



8. If the minimum peak-to-peak R-wave amplitude measurement for any one position is less than 0.4 mV, pick a new potential implant location for the generator which increases the distance between the neck electrode and the existing chest electrode, and/or is closer to the patient's heart. Place a new electrode on the new potential implant location (the old chest electrode may be removed if it is in the way),

connect it to the LA lead, and repeat Steps 5-7 for both body positions until a location with adequate peak-to-peak R-wave amplitude can be identified.

NOTE: It is preferable to place the generator along the axillary border, at or above anterior rib 4, so the patient can have the maximum flexibility for MRI postoperatively. See MRI Guidance posted at www.livanova.com.

9. When both body positions have been tested and the minimum peak-to-peak R-wave amplitude measurement for each body position is confirmed to be 0.4 mV or greater, the neck and chest electrode locations are acceptable selections for the implant. Mark the spots on the neck and chest where the electrodes are and use these locations as the intended implant location during surgery. The minimum peak-to-peak R-wave amplitude measurements from the different body positions are used to configure Heartbeat Detection and Tachycardia Detection, and post-operatively to optimize the heartbeat detection setting.

   NOTE: For heartbeat detection configuration, see "Heartbeat Detection and Tachycardia Detection Configuration" on page 116.

   NOTE: For how to optimize the heartbeat detection settings, see "Optimize the Heartbeat Detection Setting" on page 128.

If all practical implant locations have been exhausted without identifying a location which yields a peak-to-peak R-wave amplitude of at least 0.4 mV at both body positions, the AutoStim Mode feature is not suitable for the patient.

6.6. Implant Procedure

For precautions related to the implantation procedure, see "Precautions—Related to Implantation" on page 27.

6.6.1. Lead and Pocket Location

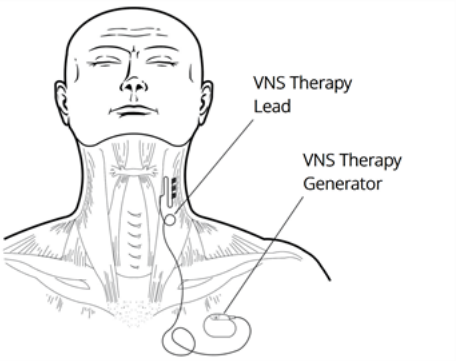
The generator is usually implanted just below the clavicle in a subcutaneous pocket in the left upper chest.

NOTE: It is preferable to place the generator along the axillary border, at or above anterior rib 4, so the patient can have the maximum flexibility for MRI postoperatively.

NOTE: For placement of generators capable of tachycardia detection, see "Determine Acceptable Implant Locations" on page 95.

Suggested placement for the lead is the area of the vagus nerve half-way between the clavicle and the mastoid process, with the lead subcutaneously tunneled between the incision site in the neck and the pocket formed in the upper chest (see below).

Figure 19. Generator and Lead Placement



It is recommended that both the lead body and the generator be positioned on the same side of the body. The VNS Therapy tunneler is recommended for subcutaneous routing of the lead.

NOTE: To ensure device placement follows current MRI guidelines, review the MRI warnings and precautions prior to placement of the system. See MRI Guidance posted at www.livanova.com.

NOTE: For details on the placement of generators capable of Tachycardia Detection, see "Determine Acceptable Implant Locations" on page 95.

6.6.2. Implantation Procedure Overview

CAUTION: This procedural overview is not a substitute for the complete implantation procedure.

NOTE: For generators capable of tachycardia detection, try to implant the lead and generator in the same approximate positions as determined in "Determine Acceptable Implant Locations" on page 95.

1. Expose the left carotid sheath and vagus nerve.
2. Create a pocket in the left upper chest for the generator.
3. Choose the correct size lead.
4. Tunnel the lead subcutaneously from the neck to the generator pocket in the chest.
5. Attach the electrodes and anchor tether to the vagus nerve.
6. Secure the lead parallel to the nerve.
7. Form the strain relief bend and strain relief loop.
8. Connect the lead to the generator.
9. Verify that the connector pin is fully inserted and tighten the setscrew.
10. Perform System Diagnostics.

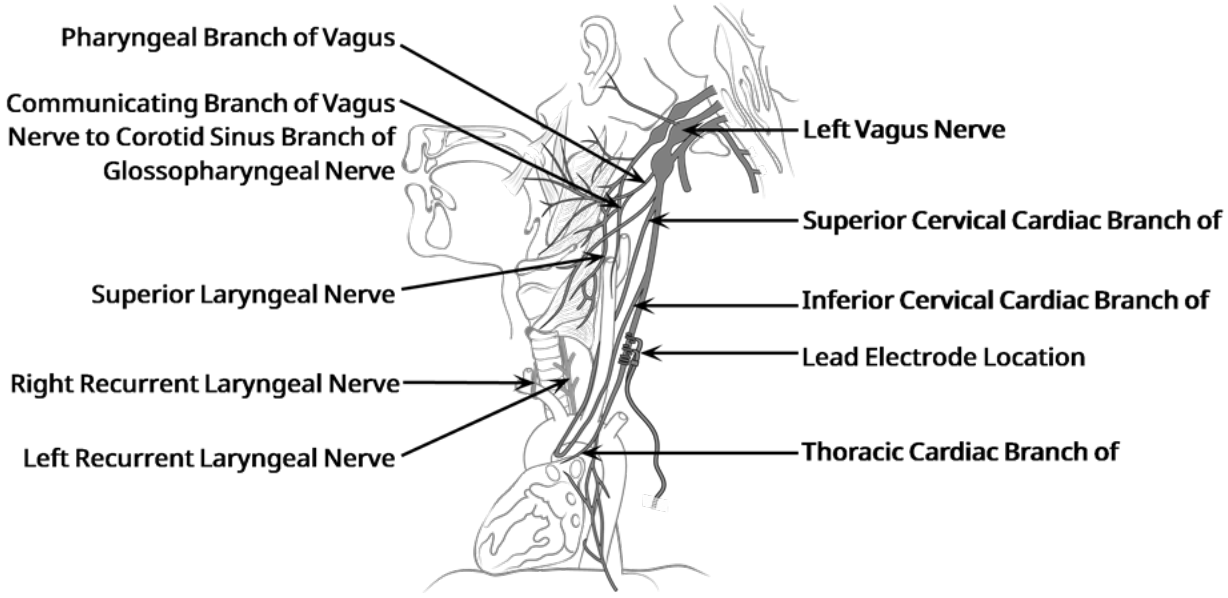
11. Place the generator in the chest pocket, with the extra coiled lead to the side of the generator, not behind it.
12. For generators capable of tachycardia detection, configure detection settings and verify heartbeat.
13. Secure the generator to fascia; do not place sutures directly around or on the lead.
14. Perform the second System Diagnostics.
15. Interrogate the generator to verify current is 0 mA.
16. Irrigate the incision site with bacitracin or other solution.
17. Close the incisions.

6.6.3. Begin the Procedure

6.6.3.1. Anatomy

It is very important that the surgeon who implants the VNS Therapy system be familiar with vagus nerve anatomy, particularly the cardiac branches. The lead electrodes must not be placed on either the superior or the inferior cervical cardiac branches. **Place the lead below where the superior and inferior cardiac branches separate from the vagus nerve.** Stimulation of either of these two branches during the System Diagnostics may cause **bradycardia and/or asystole**. Careful dissection laterally on the vagus nerve should aid the physician in determining proper electrode placement. In most but not all patients, the main vagus nerve is the largest of the three nerves. The image below shows the correct anatomical placement of the helices.

Figure 20. Vagus Nerve Anatomy and Placement of the Lead



⚠ CAUTION: Attachment of lead electrodes must not involve the superior cervical cardiac branch or the inferior cervical cardiac branch of the vagus nerve. Place the electrodes *below* where these two branches separate from the vagus nerve.

⚠ CAUTION: Excessive manipulation of the vagus nerve during placement of the lead can result in noticeable post-operative hoarseness. Under most circumstances, this condition will resolve without additional medical intervention within three to four weeks, depending on the degree of stress applied to the nerve during surgery. LivaNova does not recommend that stimulation treatment be initiated until this condition has resolved, since it could aggravate the condition.

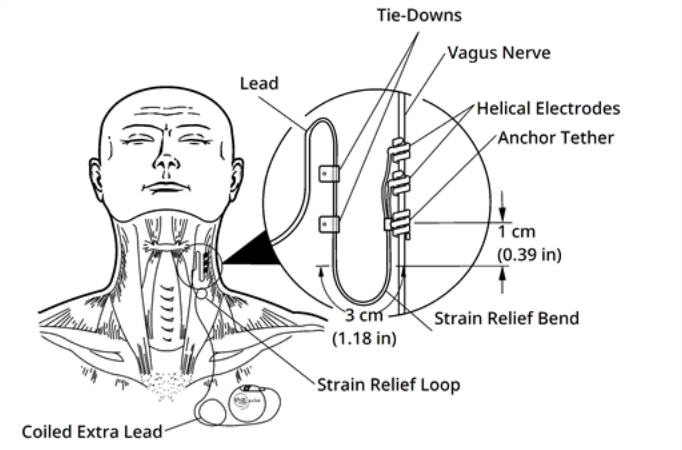
6.6.3.2. Expose the Vagus Nerve

While the specific surgical approach and techniques for lead implantation varies with the implant surgeon, the following detailed instructions are provided for guidance:

1. Administer appropriate anesthesia to the patient.
2. Expose the left carotid sheath as it extends along the anterior border of the sternocleidomastoid muscle.
3. Locate and expose *at least 3 centimeters (1.18 inches)* of the vagus nerve. The recommended stimulation site is a 3-cm section of the vagus nerve, approximately half-way between the clavicle and the mastoid process, where it is clear of branches (below where the superior and inferior cervical cardiac branches separate from the vagus nerve. The nerve usually lies in a posterior groove between the carotid artery and internal jugular vein.

⚠ CAUTION: **Do not allow the vagus nerve to become dry** during surgery, because dehydration of the nerve can result in nerve damage and cause the nerve to swell.

Figure 21. Location for Electrode Placement



6.6.3.3. Create a Generator Pocket

Create a subcutaneous pocket in the chest below the clavicle for the generator. The pocket depth should not be deeper than 1 inch beneath the skin. It is not recommended to implant the generator below muscle. Doing so may contribute to communication difficulties once implanted.

NOTE: It is preferable to place the generator along the axillary border, at or above anterior rib 4, so the patient can have the maximum flexibility for MRI postoperatively.

6.6.4. Implant the Lead

CAUTION: To maximize system performance and minimize possible mechanical damage to the nerve or lead, pay careful attention to the lead route, lead stabilization, and electrode placement.

6.6.4.1. Choose a Lead

Choose the appropriately sized lead carefully. It should fit snugly without constriction of the nerve. The lead (2.0 mm/0.08 in.) should accommodate most nerves.

NOTE: For lead size availability, see "Technical Information—Leads" on page 64.

CAUTION: The lead is available in multiple sizes. Since it is not possible to predict in patients what size lead will be needed, **it is recommended that at least one alternate lead size be available in the operating room.** In addition, backups for leads should be available in the event of compromised sterility or damage induced during surgery.

CAUTION: Do not expose the lead to dust or other similar particulates, because its silicone insulation can attract particulate matter.

CAUTION: Do not soak the lead in saline or similar solution before it is implanted, because this may cause the insulated portions of the connector pin to swell and become difficult to insert into the generator.

6.6.4.2. Pass the Tunneler and Lead

The tunneler is used to tunnel the lead connector and lead body subcutaneously between the neck incision site and the generator in the chest pocket.

NOTE: For a detailed description of the tunneler tool, see the Model 402 Tunneler manual at www.livanova.com.

CAUTION: Never route the lead through muscle.

If necessary, the tunneler can be manually shaped to help direct it through the body.

CAUTION: Do not manually shape the tunneler **more than 25 degrees** because doing so may cause the sleeve to bend or kink.

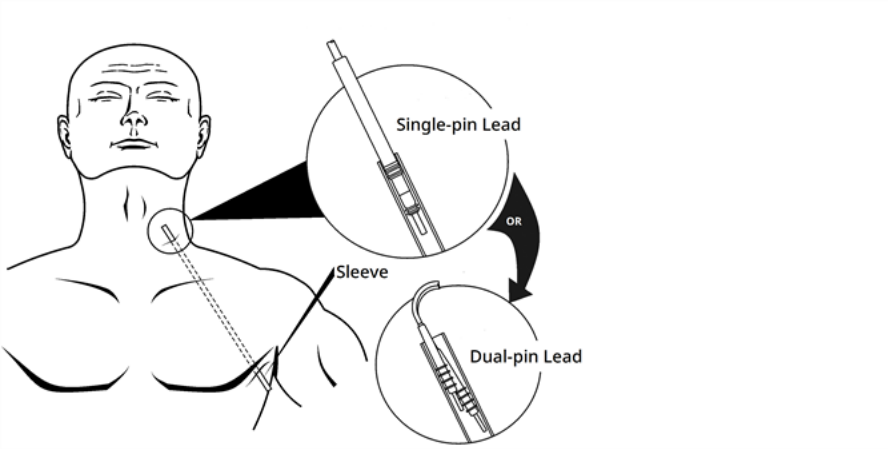
To pass the tunneler follow these steps:

1. Place the bullet-tip end of the tunneler through the neck incision and tunnel subcutaneously toward the chest incision. Exert force on the handle end and direct the tunneler as necessary.

   As an alternative, the lead connector and lead body can be tunneled subcutaneously from the neck incision site to the generator in the chest pocket *after placement of the electrodes and anchor tether on the nerve, and placement of strain relief with the tie-downs*. See "Place the Electrodes" below and "Provide Strain Relief" on page 107, respectively.

2. After the bullet tip has passed from one incision site to the other, unscrew the bullet and withdraw the shaft from the sleeve. Leave the sleeve extended through both incisions.

   Figure 22. Position of Sleeve and Lead Connectors

   NOTE: Insert the lead into the sleeve at the neck.

3. With the sleeve in place between the two incisions, carefully insert the lead connector inside the end of the sleeve at the neck incision until secure. For a dual-pin lead, the second connector will form a slight compression fit between the first lead connector tubing and the inside of the sleeve.
4. Carefully pull the sleeve, along with the lead connector, from the chest incision end until they completely exit the chest incision.
5. Remove the lead connector from the sleeve and leave the electrode array at the neck incision site.
6. Discard the entire tunneler assembly and unused portions after use.

6.6.4.3. Place the Electrodes

NOTE: For a detailed image of the vagus nerve anatomy, see "Anatomy" on page 100.

6.6.4.3.1. Electrode Polarity

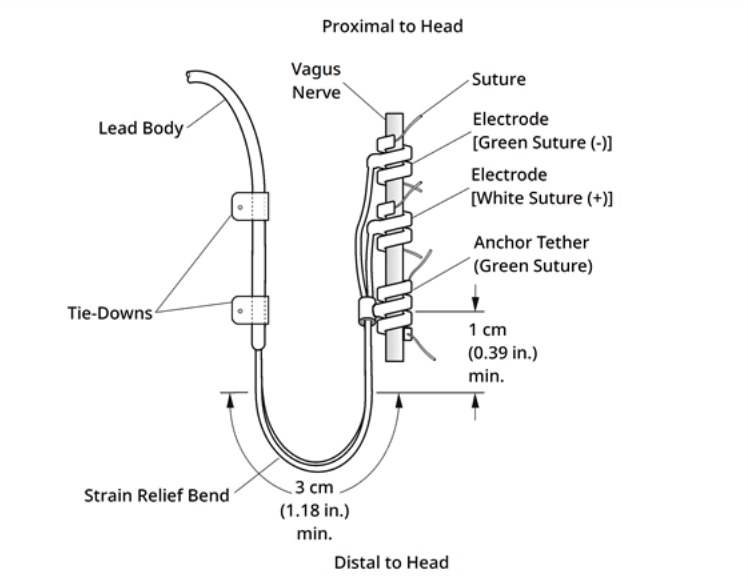
The helical electrodes and anchor tether are coiled around the nerve. Begin with the electrode that is farthest from the lead bifurcation (with a green suture embedded in the helical material). This electrode should be

nearest (proximal to) the patient's head.

Alternately, the surgeon may choose to begin with the anchor tether (distal to head), then the electrode closest to the lead bifurcation (with white suture), and finally the electrode farthest from the lead bifurcation (with green suture).

The polarity of stimulation does not change as long as the electrodes are attached in the final orientation shown below.

Figure 23. Electrode Polarity



6.6.4.3.2. Place the Helices Around the Nerve

⚠ CAUTION: **The lead and helical electrodes are very delicate**; be careful not to stretch, pinch, or crush them when using forceps, and not to over-straighten or stretch the helices when coiling them around the nerve, because doing so may damage the electrode or tether. Use soft rubber vessel loops to raise, or lift, the nerve, if necessary.

⚠ CAUTION: **Proper techniques** for attachment of the electrodes and the anchor tether to the vagus nerve are critical to the long-term success of the implant.

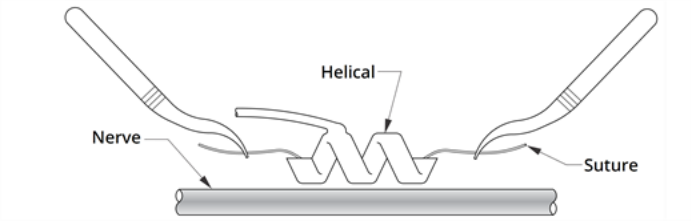
⚠ CAUTION: Sutures that are part of the lead (embedded in the helices of the electrodes and anchor tether) are meant to assist in helical placement around the vagus nerve. These sutures should not be tied to each other or around the nerve, since this may cause nerve damage.

⚠ CAUTION: The suture may become dislodged from the helical if product labeling is not followed (i.e., The elastomer and suture are grasped to manipulate the helical onto the nerve).

Place the helices on the nerve as described below. As an alternative, each helical can be placed underneath the nerve before it is spread. A silicone sheet may be useful to separate the nerve from tissue during the procedure.

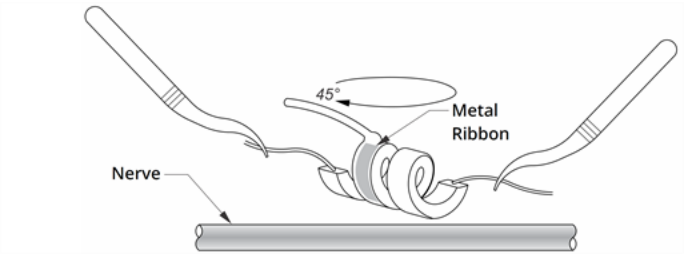
1. Locate the first helical (with green suture).
2. With forceps, gently pull each end of the helical, using the attached sutures to spread the helical.

Figure 24. Spread the Helical



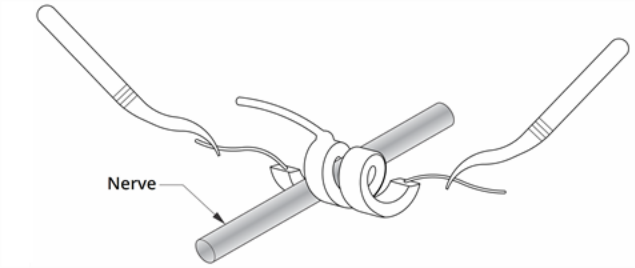
3. Spread the open helical directly above and parallel to the exposed nerve and turn the helical clockwise at a 45 degree angle to the nerve.

Figure 25. Turn the Helical



4. Place the turn of the helical where the lead wire connects to the helical (the section with the metal ribbon) onto the nerve.

Figure 26. Placement of the Turn



5. Pass the *distal* suture portion of the helical under the nerve and back around so that it encircles the nerve.

Figure 27. Initial Placement of the Distal Portion of the Helical

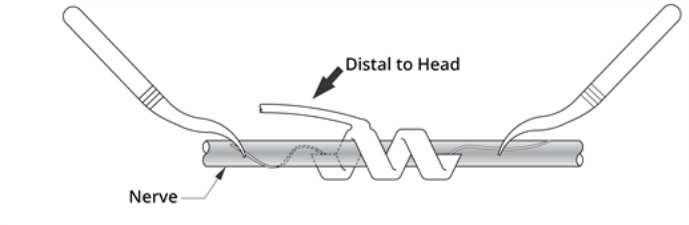
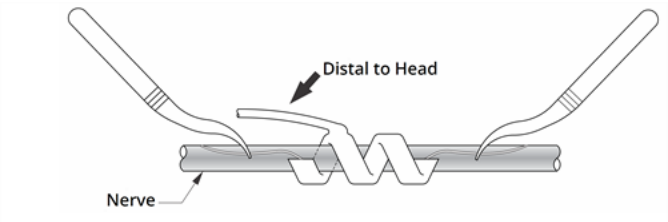
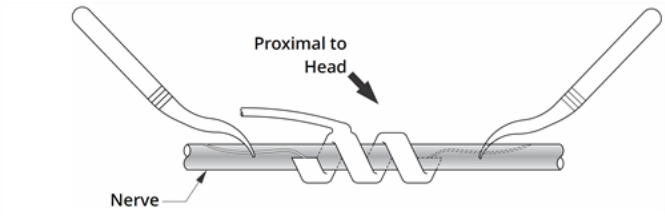


Figure 28. Helical Placement After the Distal Portion Encircles the Nerve



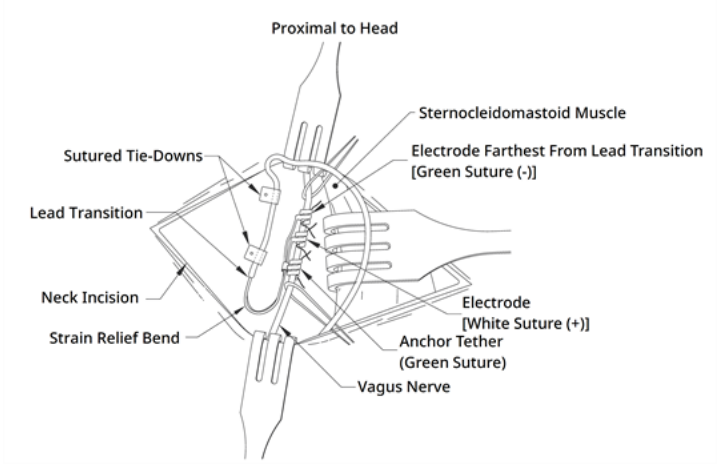
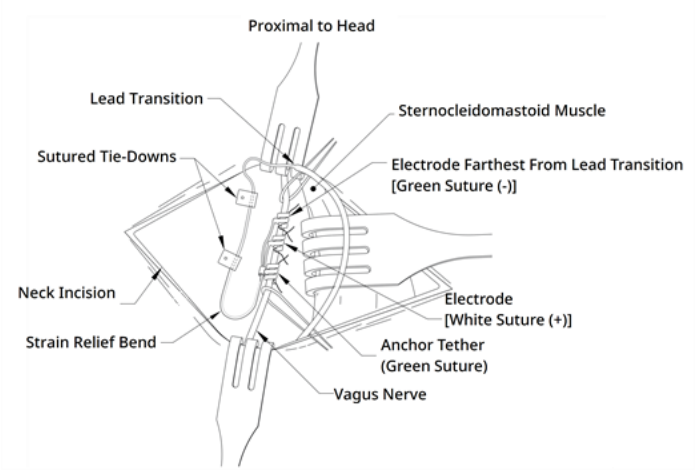
6. Pass the *proximal* suture portion of the helical under the nerve and back around so that it encircles the nerve.

Figure 29. Placement of the Proximal Portion of the Helical



7. Locate the middle helical (with white suture) and repeat steps 2 - 6.
8. Locate the third helical (with green suture) and repeat steps 2 - 6.
9. Verify all three helices have been coiled around the nerve, the lead body exits each helical in the same direction, and the two lead bodies are aligned parallel to each other and the nerve. The correct placement of the two helical electrodes and anchor tether is shown below.

Figure 30. Placement of Electrodes and Anchor Tether

Model 302 Model 304	Model 303
	

6.6.4.3.3. Provide Strain Relief

⚠ CAUTION: **Proper techniques** for providing adequate strain relief below and above the sternocleidomastoid muscle are critical to the long-term success of the implant.

⚠ CAUTION: **The lead wire has a potential for fracture** if the recommended strain relief is not provided as described.

After the two electrodes and anchor tether are attached, form a strain relief bend and a strain relief loop in the lead to provide adequate slack and allow for neck movement.

Form the Strain Relief Bend

⚠ CAUTION: Always use the tie-downs.

⚠ CAUTION: Never suture the lead or lead body to muscle tissue.

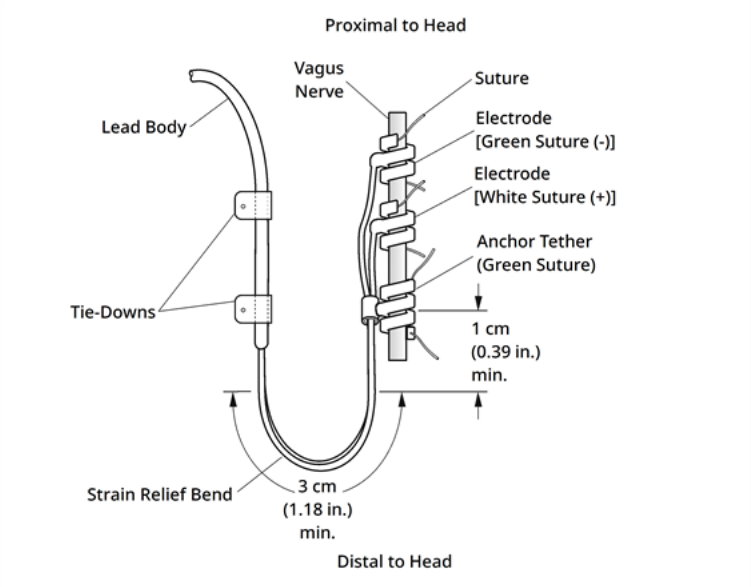
⚠ CAUTION: Do not place the sutures directly around the body of the lead; this could result in insulation failure and system malfunction, and possible lead breakage.

To form the strain relief bend, complete the following steps:

1. Form the lead body into a 3-cm (1.18 in.) strain relief bend with at least 1 cm (0.39 in.) of lead routed parallel to the nerve. The parallel portion can be placed in a pocket formed adjacent to the anchor

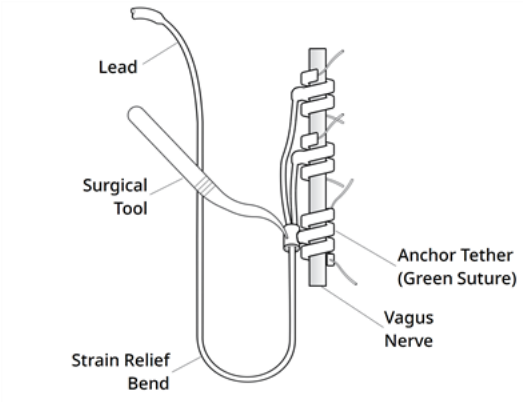
tether.

Figure 31. Strain Relief Bend



Model 303 lead only: Pay careful attention to the previously placed anchor tether and electrodes so they do not come unattached. Slight pressure may be placed against the anchor tether with a surgical instrument to ensure support to the anchor tether while the strain relief bend is formed).

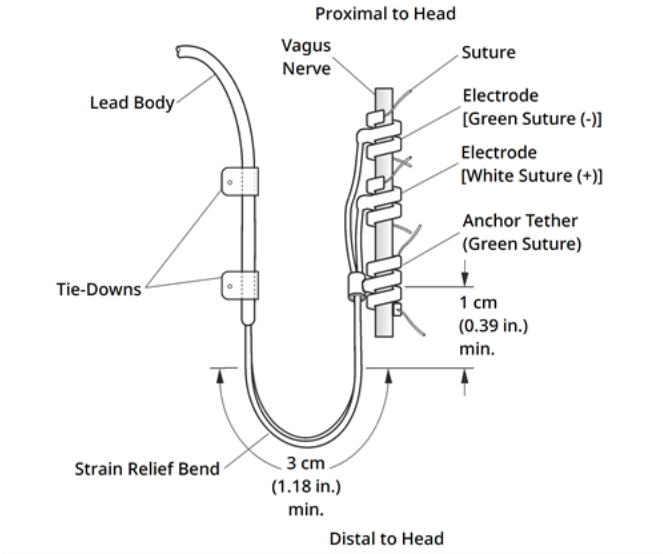
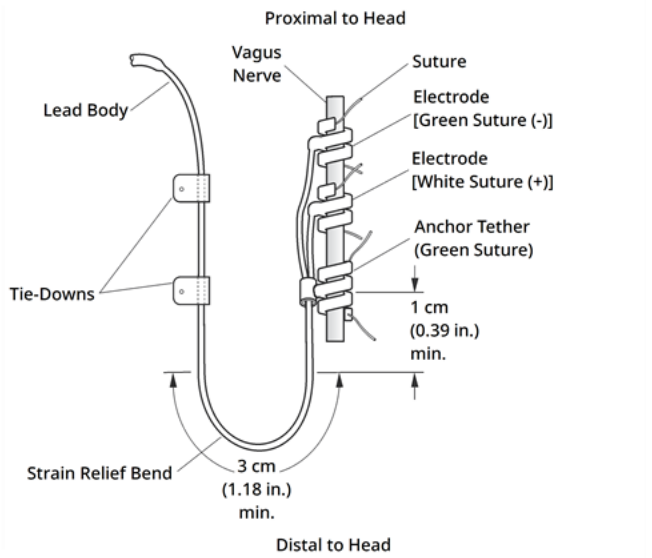
Figure 32. Model 303 Only – Use of surgical tool (e.g., forceps) to support the anchor tether during strain relief formation



2. Loosely attach the 3-cm strain relief bend to the adjacent fascia with tie-downs before you route the lead over the muscle. The first tie-down should be positioned laterally to the anchor tether tie-downs

are provided in the lead sales pack.

Figure 33. Use of Tie-Downs in Electrode Placement

Model 302 Model 304	Model 303
	

Form the Strain Relief Loop

⚠ CAUTION: **Leave enough extra lead** on both sides of the clavicle to prevent damage to the lead caused by tension over the clavicle.

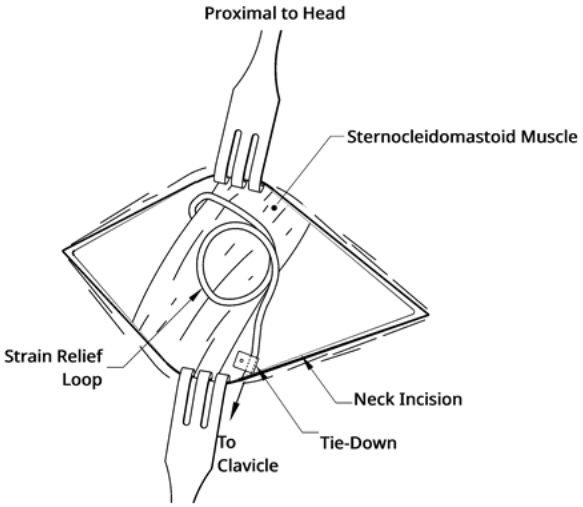
⚠ CAUTION: Do not place the sutures directly around the body of the lead; this could result in insulation failure and system malfunction, and possible lead breakage.

⚠ CAUTION: Use only supplied tie-downs to secure the lead.

To form the strain relief loop above the sternocleidomastoid muscle, complete the following steps:

1. In the neck, form the lead into a large subcutaneous loop.
2. Loosely attach it to fascia with a tie-down before the lead is routed over the clavicle. This strain relief loop should be large enough to provide several inches / centimeters of lead extension when the neck is turned to its maximum stretched position.

Figure 34. Strain Relief Loop



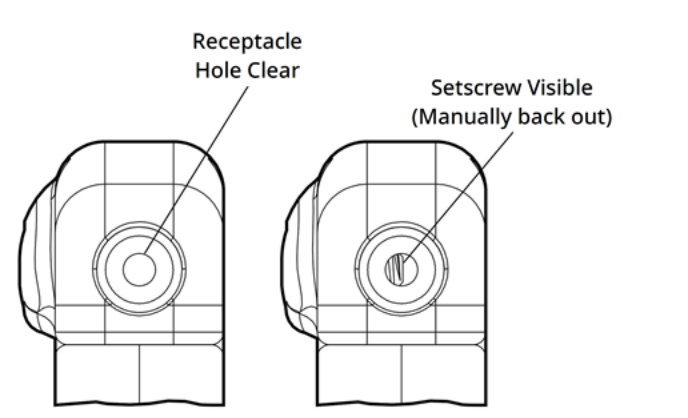
6.6.5. Connect the Lead to the Generator

CAUTION: Do not use electrosurgical equipment after the generator has been introduced to the sterile field. Exposure to this equipment may damage the generator.

NOTE: For the dual-receptacle generator, these directions apply to both receptacles, pins, plugs, and setscrews.

1. Look inside the generator receptacle to verify that no obstruction exists. Ensure that the setscrew is backed out adequately to allow full insertion of the connector pin. Do not back the setscrew out further than needed for lead insertion.

Figure 35. Generator Receptacle and Setscrew



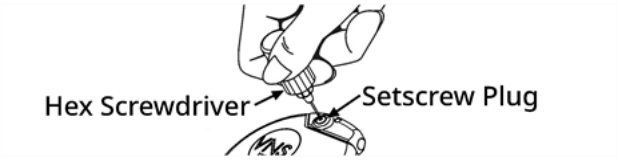
NOTE: Contrast between a clear and a blocked receptacle hole. Applies to single or dual pin headers.

⚠ CAUTION: When you use the hex screwdriver, grasp it by the handle only. Do not grasp any other portion of the hex screwdriver during use, as this may affect its proper function. If the metal shaft is touched while the hex screwdriver is engaged with the set screw, an electrostatic discharge into the device circuitry can be conducted, which can damage the generator.

⚠ CAUTION: In the steps below, ensure that the hex screwdriver is fully inserted in the setscrew and **always push down on the hex screwdriver while you turn it clockwise until it clicks** (begins to ratchet). Also, the hex screwdriver must be inserted into the center of the silicone rubber setscrew plug and kept perpendicular to the generator to avoid stripping the setscrew and/or dislodging the setscrew plug.

2. Keep the hex screwdriver perpendicular to the generator. Insert the hex screwdriver through the center of the setscrew plug to vent back pressure accumulated during lead insertion.

Figure 36. Hex Screwdriver Position



3. When a single-receptacle generator and single-pin lead is used, insert the lead connector pin fully into the generator header. To allow escape of the back pressure created by insertion, leave the tip of the hex screwdriver in the slit in the setscrew plug.

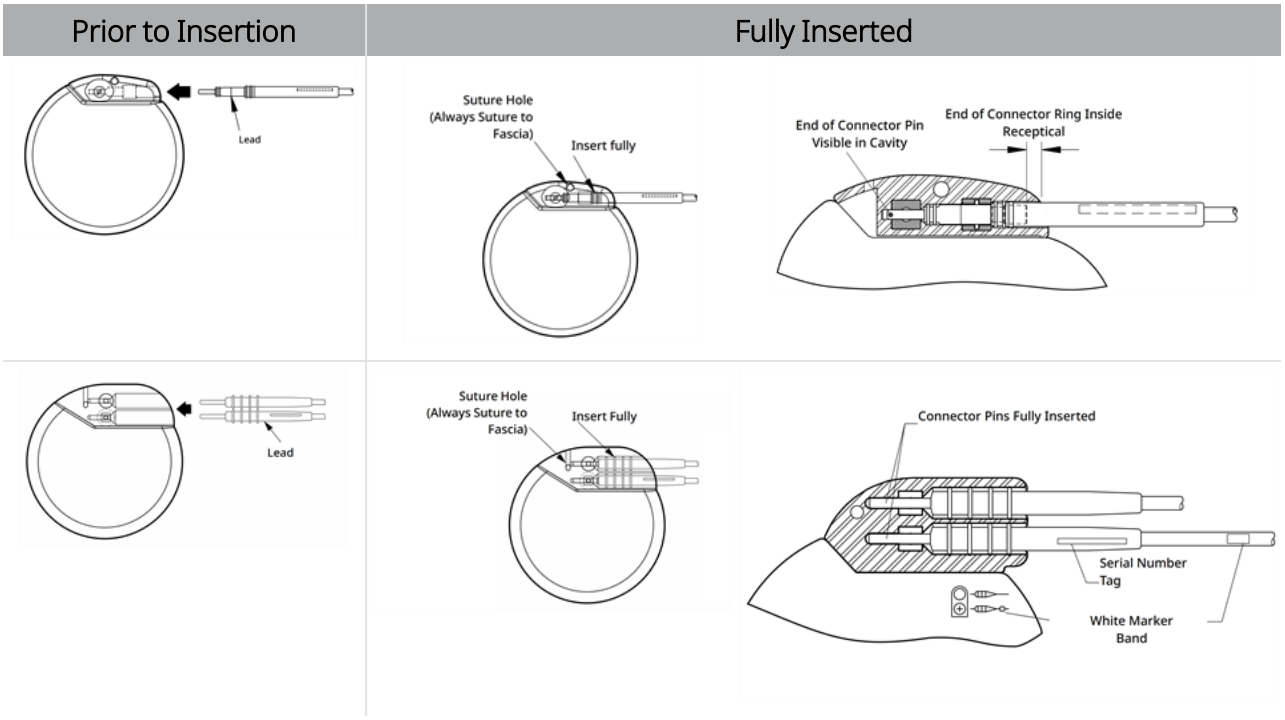
   When a dual-receptacle generator and dual-pin lead are used, insert the lead connector pins fully into the appropriate generator receptacles in the generator header. To allow escape of the back pressure created by insertion, leave the tip of the hex screwdriver in the slit in the setscrew plug of the connector being inserted. Insert the lead connector with the white marker band and with the embedded model number and serial number tag into the generator receptacle labeled “+” (see the dual-receptacle generator portion of the figure below). The other lead connector is inserted into the other generator receptacle.

⚠ CAUTION: Do not back the setscrew out completely. When you loosen during surgery, use no more than two counterclockwise turns.

⚠ CAUTION: **Reversal of lead polarity has been associated with an increased chance of bradycardia** in animal studies. It is important to make sure that the lead connector pins in the VNS Therapy dual-pin lead are correctly inserted (white marker band to + connection) into the generator dual receptacles.

4. With the hex screwdriver still inserted through the setscrew plug, verify that the connector pin is fully inserted. The pin should be visible in the area at the back end of the setscrew connector block. For a dual-receptacle generator, repeat this procedure for each setscrew.

Figure 37. Lead Connectors Prior to Insertion and Fully Inserted



5. If the pin is not visible, remove it. To loosen the setscrew, engage the hex screwdriver into the setscrew, and turn it counterclockwise until the connector pin can be fully inserted. Do not back the setscrew out further than needed for lead insertion. For a dual-receptacle generator, repeat this procedure for each setscrew.
6. After you verify that the connector pin is fully inserted, tighten the setscrew. Engage the hex screwdriver fully, push in, and turn the hex screwdriver clockwise until it begins to click. Always push in on the hex screwdriver as it is turned to ensure that it is fully inserted in the setscrew.

CAUTION:
It is important to do the following:

- Ensure that the generator receptacle is clean and free of obstruction.
- Carefully insert the lead connector pin into the generator receptacle without bending the lead connector.
- Visually inspect that the connector pin is clean and completely inserted.
- **Electrical connection to the generator is not established until the setscrew is completely tightened with the hex screwdriver.** Failure to make a good connection can result in HIGH impedance during a System Diagnostics or erratic stimulation at varying intensity due to rapid, unpredictable changes in lead impedance, which is expected to adversely affect device effectiveness and may have serious safety consequences. Additionally, for generators capable of tachycardia detection, heartbeat sensing may be compromised.
- Gently grasp and pull on lead connector boot (the thick section of the lead) to verify the lead is properly secured inside the generator receptacle. Do not pull on the lead body (thin section) or use excessive pull force, because this may cause lead damage.

6.6.6. Test the System

The System Diagnostics, which should be conducted first, is performed with the lead and the generator connected. Thus, if the System Diagnostics is successful, both components are working properly. However, if the System Diagnostics fails, either of the two components could be defective, or there may not be a good electrical connection between the generator and the lead connector pin. If a defective component is suspected, disconnect the lead and perform the optional Generator Diagnostics. Use the resistor assembly supplied with the accessory pack.

NOTE: The Wand should be placed into a sterile laser arm bag or equivalent (Not provided by LivaNova) in order to introduce the Wand into the sterile field.

WARNING: It is important to follow recommended implantation procedures and intra-operative product tests described in the "Implantation Procedure Overview" on page 99. During the intra-operative System Diagnostics infrequent incidents of bradycardia and/or asystole have occurred. If asystole, severe bradycardia (heart rate < 40 bpm), or a clinically significant change in heart rate is encountered during a System Diagnostics or during initiation of stimulation, physicians should be prepared to follow guidelines consistent with Advanced Cardiac Life Support (ACLS).

Additionally, postoperative bradycardia can occur among patients with certain underlying cardiac arrhythmias. If a patient has experienced asystole, severe bradycardia (heart rate < 40 bpm), or a clinically significant change in heart rate during a System Diagnostics test at the time of initial device implantation, the patient should be placed on a cardiac monitor during initiation of stimulation.

The safety of this therapy has not been systematically established for patients that experience bradycardia or asystole during VNS Therapy system implantation.

6.6.6.1. System Diagnostics

System Diagnostics is performed intraoperatively when the lead and the generator are connected. The test checks the connection between the lead, generator, and the nerve. Depending on the generator model and programmed Normal Mode output current, different test pulses (as shown below) may be conducted during the test.

Table 32. System Diagnostics Behavior

Normal Mode Output Current	Model 1000 Model 1000-D	Model 106 Model 105 Model 104 Model 103	Model 102 Model 102R
0 mA	Delivery of programmed output for approximately 4 seconds, followed by one brief pulse at 0.25 mA for less than 130 µsec.*	1 mA, 500 µsec for approximately 14 seconds	1 mA, 500 µsec for approximately 14 seconds
> 0 mA		One brief pulse at 0.25 mA, 130 µsec, followed by delivery of programmed output for the duration of the programmed ON time.	
	NOTE: Once programmed ON, lead impedance measurement readings are automatically performed once every 24 hours.	NOTE: Once programmed ON, lead impedance measurement readings are automatically performed once every 24 hours.	N/A

*Minor differences in the system diagnostics test exist for Model 1000 with serial numbers < 100,000. For more information, see Model 1000 (Serial Numbers <100,000 Only).

To ensure proper system connection and functionality, perform the test and assess the following:

<table>
<tr><th>Model</th><th colspan="2">Assess</th></tr>
<tr><td rowspan="3">Model 1000
Model 1000-D
Model 106
Model 105
Model 104
Model 103</td><td colspan="2">Verify that System Diagnostics is successful (output current and lead impedance are OK).</td></tr>
<tr><td>IF</td><td>THEN</td></tr>
<tr><td>The System Diagnostics fails (output current LOW or lead impedance HIGH or LOW).</td><td>See "Lead Impedance Issues" on page 152.

⚠ CAUTION: Electrical connection between the generator and the lead connector pin may be at fault.</td></tr>
<tr><td rowspan="3">Model 102
Model 102R</td><td colspan="2">Verify that the lead impedance status is OK.</td></tr>
<tr><td>IF</td><td>THEN</td></tr>
<tr><td>Lead impedance status is not OK.</td><td>See "Lead Impedance Issues" on page 152.

⚠ CAUTION: Electrical connection between the generator and the lead connector pin may be at fault.</td></tr>
</table>

6.6.6.2. Generator Diagnostics

The optional Generator Diagnostics is perfomed when troubleshooting during surgery. When System Diagnostics fails (lead impedance HIGH or LOW), use the Generator Diagnostics test with a test resistor to verify that the generator functions properly, independent of the lead. The test resistor is included in the accessory pack.

To connect the test resistor to the generator, perform these steps:

ⓘ NOTE: For the dual-receptacle generator, these directions apply to both receptacles, pins, plugs, and setscrews.

1. Remove the lead connector pin from the generator receptacle. To do so, insert the hex screwdriver through the center of the setscrew plug and loosen the setscrew. Do not back the setscrew out more than necessary to remove the lead. No more than a half turn should be required.
2. Insert the connector pin of the resistor assembly into the generator receptacle. Be careful during the insertion of the test resistor pin into the generator receptacle. If significant resistance is felt or it binds, remove the test resistor, inspect it, and clean it if necessary. Without the use of excessive force, re-insert the test resistor.

   ⓘ NOTE: Fully insert the hex screwdriver into the setscrew and push in on the hex screwdriver whenever the setscrew is tightened or loosened.

3. When the resistor assembly is in place, tighten the setscrew until the hex screwdriver begins to click. Always push in on the hex screwdriver while you turn it to ensure that the hex screwdriver is fully inserted in the setscrew.

Figure 38. Connect the Resistor Assembly

4. Perform Generator Diagnostics and assess the following:

IF	THEN
The Generator Diagnostics is successful (Lead Impedance is **OK**)	The generator is working properly.
The Generator Diagnostics fails (Lead Impedance is **HIGH** or **LOW**)	See "Lead Impedance Issues" on page 152.
If the component is damaged	Contact "Technical Support" on page 223, and disinfect and return the item along with a completed Returned Product Form. To access an electronic copy, see Return Product Form.

NOTE: See the model-specific programming system manual posted at www.livanova.com.

6.6.6.3. Optional Monitoring

Optional physiologic monitoring of VNS Therapy system operation may be done if surgery is performed under local anesthesia. Monitor the patient's voice for signs of hoarseness while the generator output current is gradually increased. After System Diagnostics is performed and successful results are obtained, reset the current to 0 mA.

6.6.6.4. Heartbeat Detection and Tachycardia Detection Configuration

For generators capable of Tachycardia Detection, configure the Heartbeat Detection and Tachycardia Detection functions after the diagnostic testing is complete:

1. Place the generator in the chest pocket. Coil the lead slack and place it to the side of the generator. The generator can be placed with either side facing outward.

2. Use the programming software to turn on Tachycardia Detection and verify Heartbeat Detection.

   NOTE: Steps for configuring Tachycardia Detection and Heartbeat Detection are software specific. For details, see the model specific programming system manual posted at www.livanova.com .

3. Use the following method to select a patient-specific **Heartbeat Detection** (sensitivity) value:
   - Average the two R-wave amplitude measurements obtained from the positional assessment. If this information is not available, go to Step 6.
   - Map the average R-wave amplitude value to the appropriate Heartbeat Detection setting in the Heartbeat Detection Mapping Table and select this value in the programming software.

   NOTE: To determine R-wave amplitude, see "Pre-Surgical Steps" on page 95.

   Table 33. Heartbeat Detection Map

Heartbeat Detection	Average Amplitude (mV) (across different positions)	
	Minimum	Maximum
5	0.40	0.50
4	0.51	0.70
3	0.71	0.85
2	0.86	1.25
1	1.26	–

4. During the Heartbeat Detection verification process, the programming software displays the heart rate detected by the generator for 2 minutes. The process stops automatically after 2 minutes, or you may tap **Stop** to stop the process manually. The Wand must stay over the generator during the entire process.
5. During the Heartbeat Detection verification process, use the ECG monitor to compare the heartbeat reported on the Programmer with that reported by the ECG monitor. If Heartbeat Detection is accurate, go to Step 8, otherwise, go to Step 6.
6. If Heartbeat Detection is inaccurate in Step 5, or if the R-wave amplitude information from "Pre-Surgical Steps" on page 95 is not available, use Heartbeat Detection setting of 1 and repeat Step 4 and Step 5.
7. Monitor and compare the heartbeat reported on the Programmer with that reported by the ECG monitor, and repeat Step 4 and Step 5, as necessary, to test or configure other Heartbeat Detection settings (settings 2, 3, 4, 5) until the device accurately detects heartbeats. If more than one Heartbeat Detection setting results in accurate detection of heartbeats, select the lesser of these detection settings.
8. Select the **AutoStim Threshold** as appropriate (70% – least sensitive, 20% – most sensitive) and apply changes (i.e., program).
9. After configuration, proceed to "Complete the Implant Procedure" on the next page, step 2.

6.6.7. Complete the Implant Procedure

After tests have been completed, finish the implantation procedure:

1. If not already performed, place the generator in the chest pocket. Coil the lead slack that remains and place it to the side of the generator. Either side of the generator can face outward.

   ⚠ CAUTION: Do not place the lead slack under the generator, because this could result in insulation failure and system malfunction.

2. Secure the generator: Place a suture through the suture hole and attach it to fascia (not to muscle).

   ⚠ CAUTION: It is important to suture the generator to fascia to stabilize it and prevent manipulation by the patient, which could damage the lead wires.

   ⚠ CAUTION: Do not place the sutures directly around the body of the lead; this could result in insulation failure and system malfunction, and possible lead breakage.

3. Perform the second System Diagnostics and verify lead impedance status remains “OK.”
4. Interrogate the generator to verify that output current is 0 mA.

   - Normal current: 0 mA
   - Magnet current: 0 mA
   - AutoStim current: 0 mA (For generators capable of AutoStim)

   Contact "Technical Support" on page 223.

   ⚠ CAUTION: **Do not program the VNS Therapy system to an ON or periodic stimulation treatment for at least 14 days after the initial or replacement implantation.** Failure to observe this precaution may result in patient discomfort or adverse events.

5. Irrigation of both incision sites with generous amounts of bacitracin or equivalent solution before closure is recommended.
6. Close the surgical incisions. Use cosmetic closure techniques to minimize the development of scars.
7. Administer antibiotics postoperatively (at the discretion of the physician).

A neck brace can be used by the patient for the first week to help ensure proper lead stabilization.

6.7. Post-Implant Patient Materials

6.7.1. Implant Warranty and Registration Form

Included with the generator is an Implant Warranty and Registration Form that *must* be completed. Space is provided to record both the generator and the lead. If the surgery is for a replacement, include explanted device information. Follow the instructions provided on the form to return a copy to LivaNova, retain a copy for the surgical center, and provide a copy to the patient or caregiver.

LivaNova recommends all local privacy laws be followed when this form is completed. This information is required by some government agencies. Completed forms returned to LivaNova are entered into the implant registry and used as a permanent record of implant recipient information. All applicable privacy laws are followed in the maintenance and security of this information.

To download an electronic copy to return or print, see "Implant and Warranty Registration Form" posted at www.livanova.com.

6.7.2. Patient Magnet Kit

Give the patient a Patient Magnet kit, which contains magnets, accessories, and other patient materials.

6.7.3. Patient Implant Card

The implant card contains information about the patient's VNS Therapy system. Give the cards to the patient and/or caregiver after the implant and tell them to complete it with their device information (if not already included), the patient's name, or other identification information (e.g., patient number) and their prescriber name and phone number. Tell them to carry it with them at all times.

CHAPTER 7

Post-Implant Management

This topic includes the following concepts:

7.1. Guidelines for Epilepsy Patient Follow-Up

7.1.1. After Implantation

During the first few weeks after implantation of new or replacement devices, the patient should be seen to confirm wound healing and proper generator operation. The generator's output current for the programmed stimulation in all modes must be 0 mA for the first 14 days after implantation.

The VNS Therapy system is an adjunctive therapy to current (prior to device implantation) antiepileptic medications. Physicians are encouraged **to keep all antiepileptic medications stable for the first 3 months** of stimulation before a patient's medication is reduced or changed.

7.1.2. Follow-up Visits

7.1.2.1. Initial Titration Visits (Ramp up VNS Therapy)

During initial programming, the patient may be seen more frequently to make adjustments in therapy until a target level (i.e., adequate seizure control with minimal side effects) is reached. Once stimulation is ready to be programmed ON, slowly increase the output current in 0.25 mA increments until the patient feels the stimulation at a comfortable level. Patients who receive replacement generators should also be titrated in the same manner to allow re-accommodation. For more information, see "Dosing Strategies" on page 123.

NOTE: (*Generators with AutoStim only*) — A smaller output current step size of 0.125 mA is available (up to 2 mA) to allow for patient tolerability to device stimulation.

7.1.2.2. Long-Term Follow Up

The physician determines the subsequent follow-up schedule and the nature of each examination based on patient response to and tolerance of the implant. In all other respects, follow up is performed in accordance with the standard medical practice for patients with epilepsy.

If intolerable adverse events are reported, try to reduce stimulation parameters to eliminate or reduce the severity. For parameter adjustment recommendations, see "Tolerability Strategies" on page 124. Additionally, instruct patients or caregivers on magnet application to turn the generator off (output current 0 mA) if an adverse event becomes intolerable.

7.1.2.3. Typical Follow-Up Visit Activities

At each patient visit, use the appropriate version of the VNS Therapy programming software to interrogate the generator. Perform stimulation adjustments dependent upon patient response or tolerability.

VNS Therapy system treatment should not be uncomfortable, nor should it cause bothersome side effects. Observe patients after the last stimulation adjustment to ensure they are comfortable with all available

programmed stimulation modes. Since each patient may respond differently to the stimulation, the observation period may be at least 30 minutes or as long as necessary as determined by the physician.

Ensure a Systems Diagnostic test is performed at each visit to confirm proper VNS Therapy system function. Additionally, if necessary, perform tests of the magnet output while the patient is still in the physician's office to ensure tolerability of the Magnet Mode output.

For generators with AutoStim Mode, evaluate heartbeat detection performance at each visit.

After reprogramming and/or diagnostic tests, record and file the data. These data can be used for comparison with a patient's diary or own records to evaluate the VNS Therapy system, to confirm proper system function, and to assess the need for reprogramming. At the end of the session, perform a final interrogation to confirm parameters are set to the intended dose before the patient leaves the office.

7.2. Individualization of Treatment

7.2.1. Therapy Parameters Used in Clinical Trials

The average output current used during the clinical studies after 3 months of stimulation was about 1 mA[1].

Other standard Normal Mode treatment settings were 30 Hz, 500 µsec pulse width, 30 seconds ON time, and 5 minutes OFF time. There are no data to verify that these are optimal parameters.

⚠ CAUTION: **Generators with AutoStim only** —It is recommended that the output current for the AutoStim Mode not exceed the greater of output current for the Normal Mode or Magnet Mode, especially for patients who experience discomfort or adverse stimulation effects (e.g., during sleep).

⚠ WARNING: **Model 106 Serial Numbers < 80000 only—** Magnet Mode output current should be set at least 0.125 mA higher than AutoStim output current, to prevent rare instances where a device safety feature disables stimulation due to repeated magnet applications.

The table below lists the range of stimulation parameters after 3 months of active treatment used in the randomized, blinded, active control trials.

Table 34. High Stimulation Parameters

Stimulation Parameters	Normal Mode	Magnet Mode
Output current (mA)	0 – 3.5 mA	0 – 3.5 mA
Frequency (Hz)	30 Hz	30 Hz
Pulse width (µsec)	500 µsec	500 µsec

[1](Heck C., Helmers SL, DeGiorgio CM. "Vagus nerve stimulation therapy, epilepsy, and device parameters: scientific basis and recommendations for use". Neurology 2002; 59 (6, Suppl 4): S31-7)

Table 34. High Stimulation Parameters (continued)

Stimulation Parameters	Normal Mode	Magnet Mode
ON time (seconds)	30 sec	30 sec
OFF time (minutes)	5 min	N/A

There is no proven correlation at present between high output current (mAmps) and device effectiveness, nor is there a standard treatment level that needs to be achieved during treatment ramping. However, computational models of vagus nerve stimulation suggest an approximate target for nerve activation[1].

7.2.2. Dosing Strategies

In general, VNS Therapy should be set to a comfortable level for the patient and increased as tolerated to help achieve efficacy. Although LivaNova recommends output current adjustment as necessary, there are no controlled data at this time to indicate that higher current levels are associated with better efficacy. Patients whose seizures are well controlled at follow up should not have their settings changed unless they experience uncomfortable side effects.

Patients should be started on stimulation at a low current setting (0.25 mA), and the current should be increased gradually to allow accommodation to the stimulation. For patient comfort, the output current should be increased in 0.25 mA increments until a comfortable tolerance level is reached. Physicians should appreciate that some patients will accommodate to stimulation levels over time and should therefore allow further increases (in 0.25 mA steps) in output current, if needed.

NOTE: The Guided titration (Guided Programming) feature in select software versions will guide you through the titration process. For details, see the model-specific programming system manual posted at www.livanova.com.

The magnet output should be programmed at each visit, if necessary, to a level that is perceptible to the patient. This is typically set 0.25 mA higher than the Normal Mode output current. Some patients have reported that it is easier to verify daily that stimulation is being delivered if the magnet output current is set to one step above normal stimulation settings. This slightly higher output current is intended to allow patients who have accommodated to normal stimulation to recognize or perceive the magnet stimulation, which confirms device function.

For generator models with AutoStim, the AutoStim output current should be set no greater than the Magnet Mode output current. You may choose to set AutoStim output current between the Normal Mode and Magnet Mode output currents, or equal to Normal Mode for comfort or tolerability.

[1](Helmers SL, Begnaud J, Cowley A, et al. "Application of a computational model of vagus nerve stimulation". Acta Neurol Scand. 2012; 126 (5): 336-43)

WARNING: **Model 106 Serial Numbers < 80000 only—**Magnet Mode output current should be set at least 0.125 mA higher than AutoStim output current, to prevent rare instances where a device safety feature disables stimulation due to repeated magnet applications.

The table below lists the suggested initial stimulation parameters to begin titration of VNS Therapy.

Table 35. Suggested Initial Stimulation Parameters (≥ 2 Weeks After Implant)

Normal Mode	Output Current	0.25 mA
	Signal Frequency†	20 – 30 Hz
	Pulse Width†	250 – 500 µsec
	Duty Cycle: 10%	
	Signal ON Time	30 sec
	Signal OFF Time	5 min
Magnet Mode	Output Current	0.5 mA
	Signal ON Time	60 sec
	Pulse Width	250 – 500 µsec
AutoStim Mode*	Output Current	0.25 – 0.375 mA
	Signal ON Time	60 sec
	Pulse Width	250 – 500 µsec

* Not available in all generator models.
† Some patients may find 20 Hz/ 250 µsec more tolerable. For this reason, some physicians prefer to start at the lower settings, and increase as tolerable.
Other physicians may prefer to start at the higher settings, and adjust downward if needed for tolerability[1].

7.2.3. Tolerability Strategies

After each output current increase, evaluate the patient for tolerability. If an increase in output current is not tolerable, other stimulation parameters may be adjusted, as shown below, to help with patient tolerability.

Prior to each parameter adjustment, it is recommended to revert the output current to the last level that was tolerated by the patient.

Make the parameter adjustment and try the increase in output current again.

If the patient was already started at the lower recommended settings for pulse width and frequency, reductions in output current and further reductions in pulse width may be the only course of action. However, if the pulse width is reduced to 130 µsec, the output current should be increased to minimize the

[1](Heck C., Helmers SL, DeGiorgio CM. "Vagus nerve stimulation therapy, epilepsy, and device parameters: scientific basis and recommendations for use". Neurology 2002; 59 (6, Suppl 4): S31-7)

impact to the overall amount of therapy delivered. Literature has shown that a higher output current is needed to activate the vagus nerve when pulse widths below 250 µsec are used.[1]

Table 36. Parameter Adjustments for Tolerability

Parameter	Adjustment
Pulse Width	Reduce from 500 µsec to 250 µsec
Signal Frequency	Reduce from 30 Hz to 20 Hz*
Output Current	Decrease by 0.125 mA† or 0.25 mA

* 25 Hz is also available
† Only available in certain generator models
Heck C, Helmers SL, DeGiorgio CM. "Vagus nerve stimulation therapy, epilepsy, and device parameters: Scientific basis and recommendations for use". Neurology 2002; 59 (6, Suppl 4):S31-7.

The table below provides an example of how to titrate when you adjust for patient comfort. Each example includes what the starting signal frequency and/or pulse width might be.

Table 37. Example — Tolerability Adjustments During Titration

Programming Steps	Parameter	Adjustment	Purpose
1	Output Current	Increase by 0.25 mA	Titration attempt
If the patient experiences discomfort:			
2	Output Current	Decrease by 0.25 mA	Comfort adjustment
3	Pulse Width or Signal Frequency	Reduce from 500 µsec to 250 µsec	
		Reduce from 30 Hz to 20 Hz	
If a parameter reduction is tolerable, continue titration:			
4	Output Current	Increase by 0.25 mA	Titration attempt

If the output currents are reduced to address side effects, but the target level (i.e., adequate seizure control with minimal side effects) has not been reached, future attempts at increasing output current are recommended.

[1](Koo B, Ham SD, Sood S, Tarver B. "Human vagus nerve electrophysiology: A guide to vagus nerve stimulation parameters". J Clin Neurophysiol 2001;18 (5): 429-33; Helmers SL, Begnaud J, Cowley A, et al. "Application of a computational model of vagus nerve stimulation". Acta Neurol Scand.2012; 126 (5):336-43.)

7.2.4. Example Dosing Approach

This section describes a 2-phase dosing approach[1] .

The goal of Phase 1 (0.5-3 months after implant) is to increase the output current to a target range. The goal of Phase 2 (3-18 months after implant) is to increase the duty cycle. If the patient achieves desired outcomes at any point, further adjustments may be stopped.

7.2.4.1. Phase 1 (Output Current)

NOTE: The Guided Programming feature in select versions of the programming software can help guide you through the initial titration process. For details, see the model-specific programming system manual posted at www.livanova.com.

Two weeks after implantation surgery, apply the initial recommended settings as described in "Dosing Strategies" on page 123. You may choose to start the pulse width and frequency at 500 µsec and 30 Hz respectively and adjust down as needed for tolerability. Or you may start at the lower range of the recommended settings, 250 µsec and 20 Hz.

With a duty cycle of 10%, increase the output current upward in 0.25 mA steps over the next several weeks. The target for output current is 1.5–2.25 mA depending on pulse width (PW) selection[2]:

- 1.5 mA if PW 500 µsec
- 1.75 mA if PW 250 µsec
- 2.25 mA if PW 130 µsec

Multiple step (0.25 mA) increases can be made in output current during a single visit if tolerated by the patient. Frequent visits during this titration phase may allow for faster progress toward the target output current. The table below shows how all three stimulation modes can be adjusted.

Table 38. Output Current Adjustments

Mode (mA)	Step 1	Step 2	Steps 3, 4, 5 ...	Target*
Normal	0.25	0.50	+0.25	1.5 – 2.25
AutoStim†	0.375	0.625	+0.25	1.625 – 2.25†
Magnet	0.50	0.75	+0.25	1.75 – 2.5

* Target output current depends on pulse width selection. See combinations above.
† AutoStim Mode is not available for all generator models. output currents for AutoStim Mode may be set between Normal Mode and Magnet Mode selections (as shown), or equal to the Normal Mode for comfort or tolerability.

[1](Heck C, Helmers SL, DeGiorgio CM. "Vagus nerve stimulation therapy, epilepsy, and device parameters: Scientific basis and recommendations for use". Neurology 2002; 59 (6, Suppl 4):S31-7)
[2](Helmers SL, Begnaud J, Cowley A, et al. "Application of a computational model of vagus nerve stimulation". Acta Neurol Scand. 2012; 126 (5):336-43)

7.2.4.2. Phase 2 (Duty Cycle)

Once the output current has reached the target, duty cycle may be adjusted upward to assess better patient response. Allow adequate time between duty cycle adjustments for patient evaluation. Adjustments to duty cycle should be less frequent (approximately 3-6 months). The table below shows the recommended duty cycle increases.

Figure 39. Duty Cycle Table of Adjustments

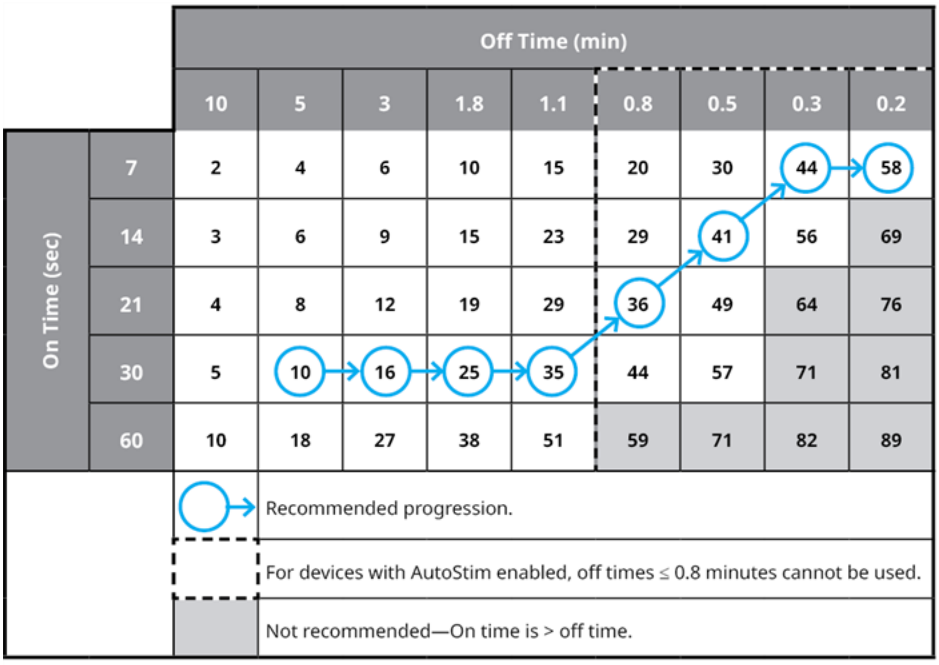
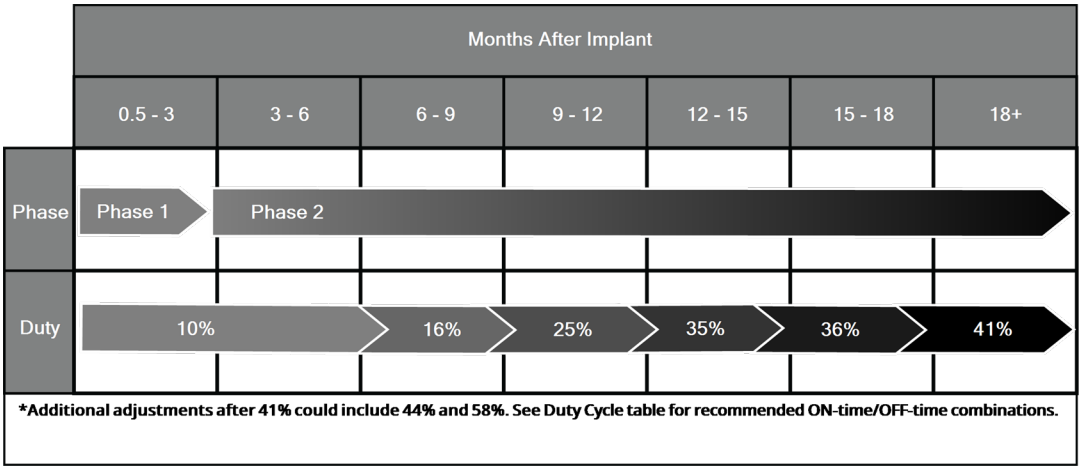


Figure 40. Phase 1 and 2 Adjustments Over Time



7.2.5. Optimize Generators Capable of AutoStim

7.2.5.1. Optimize the Heartbeat Detection Setting

The AutoStim feature relies on accurate Heartbeat Detection in order to perform as intended. The device performs Heartbeat Detection by detecting the R-wave of the ECG morphology, which is known to vary based on the position of the patient. Therefore, a pre-operative assessment of R-wave amplitudes at different body positions is recommended in order to verify minimum detection requirements and to optimize Heartbeat Detection.

NOTE: For pre-operative assessment instructions, see Pre-surgical Evaluation Tool posted at www.livanova.com.

Of the measurements recorded, use the average R-wave amplitude to choose an appropriate Heartbeat Detection setting based on the ranges listed below.

Table 39. Heartbeat Detection Map

Heartbeat Detection	Average Amplitude (mV) (across different positions)	
	Minimum	Maximum
5	0.40	0.50
4	0.51	0.70
3	0.71	0.85
2	0.86	1.25
1	1.26	–

If previous R-wave measurements are not available, either of the following options can be performed as an alternative:

- Repeat the measurements as instructed in Pre-Surgical Steps for AutoStim to determine the average R-wave amplitude.
- Test each of the 5 Heartbeat Detection settings using the Verify Heartbeat Detection feature at each of the 2 body positions and choose the setting that accurately detects heartbeats in both positions.

  NOTE: For details, see the model-specific programming system manual posted at www.livanova.com.

At subsequent follow-up office visits, the physician should verify that the generator continues to accurately detect the heart rate, and adjust the Heartbeat Detection setting, if needed.

7.2.5.2. Optimize AutoStim Threshold Setting

The clinician can adjust the sensitivity of the underlying detection algorithm. Six AutoStim Threshold settings are available, 20%–70% (in 10% increments), each of which correspond to the threshold that the heart rate must surpass in order to elicit a detection (only if detection is enabled) or a detection followed by the triggering of AutoStim (if detection is enabled and AutoStim output current is > 0 mA).

NOTE: When Detection is “ON”, the programming software prevents selection of Normal Mode OFF time less than 1.1 minutes to allow the device sufficient time to detect heart rate changes during each “OFF” cycle.

The objective to optimizing the AutoStim Threshold setting for an individual patient is to reduce the number of detections due to normal, autonomic heart rate changes and maintain a sensitivity that will detect heart rate changes associated with many seizures.

Clinicians may use a variety of tools to establish a reasonable baseline (e.g., heart rate monitors, Holter monitors, etc.). To assess normal baseline heart rates, the clinician can measure heart rate while the patient lies down, sits, or stands (HR_{BL}). After a baseline is established, the clinician can assess a rise in heart rate (HR_{ACT}) during activity by monitoring the heart rate during normal day-to-day activities. The following equation calculates the percent rise from baseline to active ($\%HR_{NORM\ INCR}$).

$$(HR_{ACT} - HR_{BL})/HR_{BL} \times 100 = \%HR_{NORM\ INCR}$$

To determine the heart rate rise during a seizure, the clinician may utilize the electrocardiogram (ECG) collected during the patient's epilepsy monitoring unit (EMU) stay.

NOTE: For an illustration of steps 1 and 2, see " Calculation of Baseline Heart Rate and Heart Rate During a Seizure" on the next page.

1. In the electroencephalography (EEG) recording, go to the beginning of a seizure. Scan up to 5 minutes before the electrographic or clinical onset of the seizure and pick a 10-second period of time to establish a baseline heart rate ($HR_{EEG\ BL}$). Within that 10-second window, count the number of R-R intervals and multiply by 6.

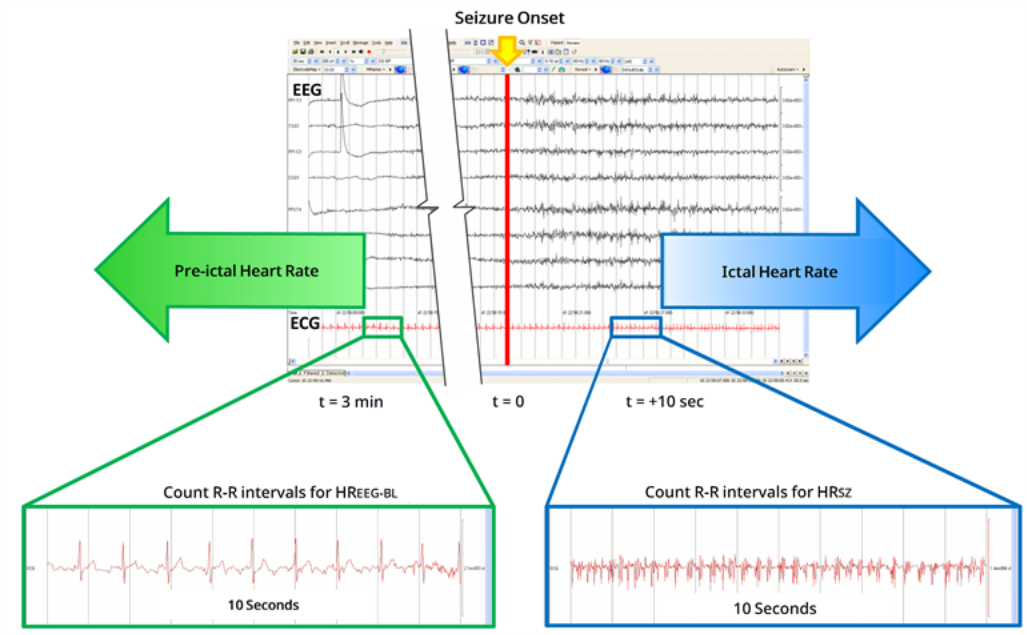
   $$HR_{EEG\ BL} = (\#\ of\ R\text{-}R\ intervals) \times 6$$

   Alternatively, a different section of ECG recording may be used to calculate the pre-ictal heart rate:

   - Obtain the simple average heart rate from at least two non-seizure epochs that occur at least 12 hours after or 1 hour prior to a seizure, with the patient in the same state as the start of the seizure.
   - Obtain the simple average heart rate from at least two clinical measurements of the patient's heart rate while seated in the clinic, measured at least 5 minutes apart. These should occur at least 12 hours after or 1 hour prior to a seizure.
2. In the same recording, identify the start of the electrographic or clinical onset of the seizure. Scan the seizure and choose a 10-second period of time of maximum heart rate during the seizure (HR_{SZ}). Count the number of R-R intervals and multiply by 6.

   $$HR_{SZ} = (\#\ of\ R\text{-}R\ intervals) \times 6$$

Figure 41. Calculation of Baseline Heart Rate and Heart Rate During a Seizure



For this example (see figure above), the baseline heart rate was assessed by scanning the ECG and finding a 10-second window of time approximately 3 minutes prior to seizure onset. Heart rate during the seizure was assessed by finding a 10-second window starting approximately 10 seconds after seizure onset.

3. Calculate the percent increase (%$HR_{SZ\ INCR}$) from baseline:

$$(HR_{SZ} - HR_{EEG\ BL})/HR_{EEG\ BL} \times 100 = \%HR_{SZ\ INCR}$$

If $\%HR_{SZ\ INCR} > \%HR_{NORM\ INCR}$ then choose an AutoStim Threshold setting that represents a threshold between the two values. For example, if $\%HR_{SZ\ INCR}$ is 51% and $\%HR_{NORM\ INCR}$ is 34%, then an AutoStim Threshold setting of 40% or 50% should be chosen. An AutoStim Threshold setting of 50% should be chosen if a lower potential false positive rate is desired or an AutoStim Threshold setting of 40% should be chosen if a higher sensitivity is desired.

If a patient's normal day-to-day heart rate increases are similar to or greater than their increases in heart rate during a seizure, then choose an AutoStim Threshold setting that represents a threshold lower than the $\%HR_{SZ\ INCR}$. For example, if $\%HR_{SZ\ INCR}$is 62% and $\%HR_{NORM\ INCR}$ is 68%, then an AutoStim Threshold setting of 60% should be chosen. In this scenario the patient may expect to receive additional stimulations. If these stimulations are bothersome, place the magnet over the generator for at least 5 seconds to inhibit stimulations.

7.3. Patient Counseling Information

Advise patients to perform magnet stimulation daily to test their generator's operation and verify that stimulation occurs. If stimulation does not occur, their physician should be contacted.

It should be noted that the magnet stimulation timing is not synchronized with the timing clock used for determining ON time and has a tolerance of ± 15% or ± 7 seconds. Therefore, if the Magnet Mode ON time is programmed to 7 seconds and the magnet is passed over the generator at the end of the clock cycle, magnet stimulation may not be perceived by the patient. If the patient does not perceive the magnet stimulation, he or she should be instructed to pass the magnet over the generator a second time.

In the unlikely event of uncomfortable adverse events, continuous stimulation, or other malfunction, instruct the patient or caregiver to hold or tape the magnet directly over the implanted generator to prevent additional stimulation. If patients or caregivers find this procedure necessary, they should immediately notify the patient's physician.

CHAPTER 8

Revision, Replacement, and Removal Procedure

This topic includes the following concepts:

8.1. Introduction

Revision, replacement, or removal of the VNS Therapy system or any component of the system may be needed for several reasons:

- Replacement of the generator may be required due to generator NEOS or if EOS has been reached and the generator cannot communicate or provide therapy.
- Revision or replacement of the lead may be necessary if a broken or damaged lead is suspected, based on diagnostic tests or x-ray evaluation.
- Removal of the system may be required in cases of infection or for certain medical procedures.

NOTE: For precautions related to the implantation procedure, see "Precautions—Related to Implantation" on page 27.

NOTE: Return explanted, or opened and unused component(s) of the VNS Therapy system to LivaNova. A Return Product Kit is available from "Technical Support" on page 223. To access an electronic copy, see Return Product Form.

These instructions are intended to be general guidelines. If you have questions about the procedures, contact "Technical Support" on page 223.

8.2. Components and Surgical Materials

8.2.1. Generator Replacement or Revision

Table 40. Components Needed for Generator Replacement or Revision

Components Needed for Surgery	Single-Receptacle Generator	Dual-Receptacle Generator
Dual-receptacle Generator	N/A	1 primary 1 backup
Single-receptacle Generator	1 primary 1 backup	2 backups (in case lead must also be replaced)
Single-pin Lead	2 backups (in case lead must also be replaced)	2 backups (in case lead must also be replaced)
Accessory Pack	1 accessory pack (test resistors, hex screwdriver and tie-downs)	1 accessory pack (test resistors, hex screwdriver and tie-downs)
Programming System	1 programming system	1 programming system
Tunneler	1 tunneler (if lead is replaced)	1 tunneler (if lead is replaced)
Sterile Laser Arm Bag or equivalent*	Required	Required
Soft vessel loops or silicone sheet*	Used for manipulation of the vagus nerve (suggested but optional)	Used for manipulation of the vagus nerve (suggested but optional)
Commercial ECG monitor*†	Required (Able to print out the ECG waveform / amplitudes on the lead 1 channel)	Required (Able to print out the ECG waveform / amplitudes on the lead 1 channel)
Standard, 10 mm Ag/AgCl skin electrodes*†	Required	Required

* Not provided by LivaNova.
† Used to identify acceptable implant locations for generators with AutoStim.

8.2.2. Lead Replacement or Revision

Table 41. Components Needed for Lead Replacement or Revision

Components Needed for Surgery	Lead Replacement or Revision
Dual-receptacle generator	Do not use

Table 41. Components Needed for Lead Replacement or Revision (continued)

Components Needed for Surgery	Lead Replacement or Revision
Single-receptacle generator	2 backups (in case the generator must also be replaced)
Single-pin lead	1 primary 1 backup
Accessory Pack	1 accessory pack (test resistors, hex screwdriver and tie-downs)
Programming System	1 programming system
Tunneler	1 tunneler
Sterile Laser Arm Bag or equivalent*	Required
Soft vessel loops or silicone sheet*	Suggested but optional

* Not provided by LivaNova.

NOTE: For lead size availability, see "Physical Characteristics" on page 64.

8.3. How to Open the Sterile Pack

Before any sterile pack is opened, examine it carefully for evidence of damage or compromised sterility. If the outer or inner sterile barrier has been opened or damaged, LivaNova cannot guarantee sterility of the contents, and it should not be used. An opened or damaged product should be returned to LivaNova.

CAUTION: Do not open the sales pack if it has been exposed to extreme temperatures or if there is evidence of external damage or damage to the package seal. Instead, return it unopened to LivaNova.

CAUTION: Do not implant or use a sterile device if the device has been dropped. Dropped devices may have damaged internal components.

8.3.1. Generator and Lead

To open the sterile pack, complete the following steps:

1. Grasp the tab and peel back the outer cover.
2. Use sterile technique to lift out the sterile inner tray.
3. Grasp the inner tray's tab and carefully peel off the cover to expose the contents without dropping them.

8.3.2. Tunneler

To open the sterile pack, complete the following steps:

1. Grasp the tab and peel back the outer cover.
2. Use sterile technique to lift out the sterile inner tray.
3. Grasp the inner tray's tab and carefully peel off the cover to expose the contents without dropping them.
4. Remove all four pieces in the package (shaft, bullet tip, large-diameter sleeve, small-diameter sleeve).

8.3.3. Accessory Pack

To open the sterile pack, complete the following steps:

1. Grasp the tab and peel back the outer cover.
2. Use sterile technique to lift out the sterile inner tray.
3. Grasp the inner tray's tab and carefully peel off the cover to expose the contents without dropping them.
4. To remove the hex screwdriver, a resistor assembly, or tie-downs, push down on one end of the item and grasp the opposite (raised) end.

8.4. Revision—Pre-Operative Steps

For all revision surgeries, the patient should consent pre-operatively to receiving a new generator and new lead in case either is damaged during the revision surgery.

For a list of components and surgical materials, see "Components and Surgical Materials — New Implant" on page 92.

8.4.1. Before Surgery

8.4.1.1. Generator

1. Review an x-ray of the generator to determine the route of the lead to avoid inadvertent damage to the lead during generator removal.
2. Consult the physician (prescriber) before the surgery to determine parameter settings following placement of a new generator.

8.4.1.2. Lead

1. Review an x-ray of the lead to confirm the existence of a lead discontinuity (i.e., lead break or pin disconnected), if possible.
2. Consult the physician (prescriber) before the surgery to determine parameter settings in case the generator is also replaced.

8.4.2. Before Patient Enters OR

8.4.2.1. Generator

Interrogate and perform a System Diagnostics on the current generator to confirm generator replacement is required and to determine whether the function of the current lead is normal. For detailed information about System Diagnostics see "Test the System" on page 113.

IF	THEN
Lead Impedance = **OK**	Replace only the generator. See "Generator Replacement—Intra-Operative Steps" on the next page.
Lead Impedance = **HIGH** or **LOW**	The lead requires removal or replacement. See "Lead Replacement—Intra-Operative Steps" on page 139.
The x-ray review shows a gross discontinuity in the lead (i.e., lead break or pin disconnected)	The lead requires removal or replacement. See "Lead Replacement—Intra-Operative Steps" on page 139.

8.4.2.2. Lead

Interrogate and perform a System Diagnostics test on the existing generator to confirm lead replacement is required and to determine whether the function of the existing generator is normal. For detailed information about System Diagnostics see "Test the System" on page 113.

IF	THEN
Lead Impedance = **OK** There is no gross discontinuity in the lead from the x-ray review A short-circuit condition is not suspected	The implanted lead is functioning properly. Reassess the need for surgery or if replacement of the generator is desired, see "Generator Replacement—Intra-Operative Steps" on the next page.
Lead Impedance = **HIGH** or **LOW** The x-ray review shows a gross discontinuity in the lead [lead break or pin disconnected]	The lead requires removal or replacement. If replacement of the generator is desired, see "Generator Replacement—Intra-Operative Steps" on the next page

8.4.3. In the OR Before Generator Replacement

1. Interrogate the replacement generator outside the sterile field in the OR to ensure clear communication.
2. If the replacement generator is capable of tachycardia detection (i.e., Generators with AutoStim), verify that the current generator implant location satisfies the requirements outlined in "Pre-Surgical Steps" on page 95. If the current implant location does not satisfy the minimum R-wave amplitude requirements, use this same procedure to identify a suitable location close to the original implant site

to place the new generator.

NOTE: If the replacement generator is capable of tachycardia detection, the current generator pocket location may need to be revised.

NOTE: It is preferable to place the generator along the axillary border, at or above anterior rib 4, so the patient can have the maximum flexibility for MRI postoperatively.

3. Program the patient data into the new generator.

8.4.4. Replacement

8.4.4.1. Generator

To continue with generator replacement instructions, see "Generator Replacement—Intra-Operative Steps" below.

8.4.4.2. Lead

To continue with lead replacement instructions, see "Lead Replacement—Intra-Operative Steps" on the next page.

8.5. Generator Replacement—Intra-Operative Steps

CAUTION: Do not use electrosurgical equipment after the new generator has been introduced to the sterile field. Exposure to this equipment may damage the generator.

NOTE: For the dual-receptacle generator, these directions apply to both receptacles, pins, plugs, and setscrews.

1. With the lead pin still connected, remove the existing generator from the pocket.
2. Open the new generator sales pack.
3. Use the hex screwdriver to disconnect the existing generator from the implanted lead. Remove the lead connector pin from the generator receptacle. Insert the hex screwdriver through the center of the setscrew plug and loosen the setscrew. Do not back the setscrew out more than necessary to remove the lead. No more than half a turn should be required.

CAUTION: When you use the hex screwdriver, grasp it by the handle only. Do not grasp any other portion of the hex screwdriver during use, as this may affect its proper function. If the metal shaft is touched while the hex screwdriver is engaged with the set screw, an electrostatic discharge into the device circuitry can be conducted, which can damage the generator.

NOTE: Extraneous pocket space left behind from the replacement of a larger generator with a smaller generator may increase the likelihood of certain adverse events (e.g., seroma, device manipulation, and device migration).

NOTE: Replacement of a smaller generator with a larger generator may require enlargement of the generator pocket during surgery. Physicians should assess the potential impact to post-surgical recovery time and likelihood of temporary patient discomfort due to surgical alteration of the generator pocket.

NOTE: It is preferable to place the generator along the axillary border, at or above anterior rib 4, so the patient can have the maximum flexibility for MRI postoperatively.

4. Connect the replacement generator to the lead.
5. To continue with generator replacement instructions, see "Connect the Lead to the Generator" on page 110.

8.6. Lead Replacement—Intra-Operative Steps

NOTE: For the dual-receptacle generator, these directions apply to both receptacles, pins, plugs, and setscrews.

NOTE: For complete troubleshooting steps, see "Lead Impedance Issues" on page 152.

8.6.1. System Diagnostics Reports “HIGH” Lead Impedance

If “HIGH” lead impedance is reported, perform the following steps:

1. With the lead pin still connected, remove the existing generator from the pocket.
2. Open the accessory pack and remove the hex screwdriver and test resistor.
3. Remove the lead connector pin from the generator receptacle. Insert the hex screwdriver through the center of the setscrew plug and loosen the setscrew. Do not back the setscrew out more than necessary to remove the lead. No more than a half turn should be required.
4. If foreign material (e.g., blood) is observed in the generator receptacle, flush the receptacle with saline to remove the foreign material. Drain the excess fluid from the receptacle. Do not place any object (other than the connector pin) into the receptacle. Use saline to clean the lead connector pin, then wipe dry.
5. Follow proper lead insertion techniques to re-insert the existing lead connector pin into the existing generator.

CAUTION: Visually inspect that the connector pin is clean and completely inserted.

NOTE: For proper lead insertion techniques, see "Connect the Lead to the Generator" on page 110.

6. Introduce the programming system into the sterile field with a sterile laser arm bag (or equivalent) and perform an interrogation followed by System Diagnostics.
7. Record System Diagnostics results.

IF	THEN	
Lead Impedance = **OK**	The previous **HIGH** lead impedance is resolved and the system appears to function properly. Assess replacement of the generator.	
	IF	**THEN**
	Replacement of the generator *is not desired*	Verify that all relevant steps outlined in "Test the System" on page 113 have been completed. Finish the procedure. See "Complete the Implant Procedure" on page 118.
	Replacement of the generator *is desired*	Open an new compatible generator sales pack. Follow the steps in "Connect the Lead to the Generator" on page 110 to connect the replacement generator to the lead, then complete the remainder of the implantation procedure. Ensure appropriate patient data has been programmed into the new generator.
Results continue to report **HIGH** lead impedance	Perform Generator Diagnostics to verify that the generator functions properly, independent of the lead. Follow the steps in "Generator Diagnostics" below.	

8.6.2. System Diagnostics Reports “LOW” Lead Impedance

IF	THEN
System Diagnostics reports **LOW** lead impedance	Perform Generator Diagnostics to verify that the generator functions properly, independent of the lead. Follow the steps in "Generator Diagnostics" below.

8.6.3. Generator Diagnostics

1. Remove the lead connector pin from the generator receptacle. To do so, insert the hex screwdriver through the center of the setscrew plug and loosen the setscrew. Do not back the setscrew out more than necessary to remove the lead. No more than a half turn should be required.
2. Insert the connector pin of the resistor assembly into the generator receptacle. Be careful during the insertion of the test resistor pin into the generator receptacle. If significant resistance is felt or it binds, remove the test resistor, inspect it, and clean it if necessary. Without the use of excessive force, re-insert the test resistor.
3. When the resistor assembly is in place, tighten the setscrew until the hex screwdriver begins to click. Always push in on the hex screwdriver while you turn it to ensure that the hex screwdriver is fully inserted in the setscrew.

Figure 42. Resistor Assembly Connection for Single and Dual Receptacle Generators

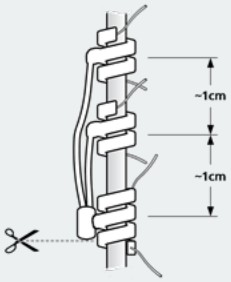
4. Perform Generator Diagnostics and assess the following:

IF	THEN
Generator Diagnostics results indicate **HIGH** or **LOW** lead Impedance	See "Lead Impedance Issues" on page 152.
Generator Diagnostics results indicate **OK** lead Impedance	The implanted lead should be replaced and generator replacement assessed.

8.6.4. Remove Helices and Lead

⚠ CAUTION: Lead replacement or removal is a medical judgment that must be carefully weighed against the known and unknown risks of surgery. At present there are no known long-term hazards or risks associated with leaving the lead implanted, beyond those mentioned in this physician's manual.

1. Open the neck incision and locate the vagus nerve / helices interface.
2. Assess the degree of fibrotic encapsulation to determine if the entire lead can be removed safely.

IF	THEN
Complete removal of the existing helices can be accomplished.	The new helices may be placed in the same location.
Complete removal of the helices from the nerve *is not possible* 	Transect as much of the lead as possible. If ≤ 2 cm of the lead remains, a full body MRI using the body coil to transmit RF is allowable. If it is not possible to leave ≤ 2 cm, then MRI can still be performed for brain or extremity imaging with the appropriate type of T/R coil. For additional details, see the MRI Guidance posted at www.livanova.com.

3. The replacement helices can be placed above or below the existing helices if they must remain.

8.6.5. Complete the Procedure

To continue with lead replacement instructions, see "Place the Electrodes" on page 103. Pay particular attention to all warnings and precautions that pertain to the cardiac branches.

NOTE: The physician (prescriber) will program the stimulation parameters post-operatively after the recommended 2-week recovery period to allow the nerve to heal.

8.7. System Removal

CAUTION: Explanted generators and leads are medical waste and should be handled in accordance with local laws. They should be returned to LivaNova for examination and proper disposal, along with a completed Return Product Form. Before device components are returned, disinfect them with Betadine®, Cidex® soak, or other similar disinfectant, and double seal them in a pouch or other container properly labeled with a biohazard warning. For directions, see "Return Product Form " on page 223.

CAUTION: The generator contains a sealed chemical battery, and an explosion could result if subjected to incineration or cremation temperatures.

If removal is medically necessary, LivaNova recommends removing as much of the VNS Therapy system as can be safely accomplished:

- Assess the degree of fibrotic in-growth in and around the helices.
- Remove the entire system, if possible.
- If fibrotic encapsulation hinders safe removal of the entire system, transect as much of the lead wire as possible. See "Remove Helices and Lead" on the previous page.
- Removal of the generator alone does not alter the hazards associated with certain MRI procedures.

  NOTE: For details, see MRI Guidance posted at www.livanova.com.
- Diathermy procedures are contraindicated for patients with any portion of the VNS Therapy system that remains in the body. For details, see "Contraindications" on page 18.

A Returned Product Form is used for the return of any VNS Therapy system component. To access an electronic copy, see "Return Product Form " on page 223.

CHAPTER 9

General Troubleshooting

This section provides solution steps to resolve error conditions with the programming system components. For other programming system issues not included in this section, contact "Technical Support" on page 223.

NOTE: LivaNova can remotely connect to your programming system for troubleshooting. Discuss the option with Technical Support if this is needed.

This topic includes the following concepts:

9.1. Patient Reports

9.1.1. Patient Cannot Feel Stimulation at Follow-Up

9.1.1.1. Possible Causes

- Patient has become accustomed to the programmed setting
- Generator battery at end of service (EOS)
- High lead impedance
- Defective generator
- Disabled generator
- Short-circuit condition within the lead

9.1.1.2. Solution Steps

Applicable Models:	Model 1000	Model 1000-D	Model 106	Model 105	Model 104	Model 103

Table 42. Patient Cannot Feel Stimulation at Follow-Up

STEP 1	Interrogate the generator.		
	Is therapy disabled in the generator?		
	IF	THEN	
	No	Continue to **STEP 2.**	
	Yes	Is therapy disabled because you performed an intentional generator reset with the Wand?	
		IF	THEN
		Yes	Re-enable the patient's therapy at the desired parameter settings.
		No	Record the cause and contact "Technical Support" on page 223.
STEP 2	Perform a System Diagnostics.		
STEP 3	Record the results.		
	IF	THEN	
	Output Current **OK** Scheduled Programming **OK**	The generator is able to deliver programmed output current and the patient may have grown accustomed to stimulation, as do many patients.	
	Output Current **OK** Lead Impedance **LOW** (≤ 600 Ω)	There is a possible short-circuit condition within the lead. See "Lead Impedance Issues" on page 152.	
	Output Currentt **LOW** Lead Impedance **HIGH** (≥ 5300 Ω)	See "Lead Impedance Issues" on page 152.	
	Output Currentt **LOW** (≤600 Ω) Lead Impedance **OK**	The generator cannot deliver the programmed output. Consider a lower output current with an increased pulse width. Contact "Technical Support" on page 223.	

Applicable Models: Model 102 Model 102R

<table>
<tr><td>STEP 1</td><td colspan="2">Pass the magnet over the generator. Ask the patient if they feel the magnet activation, or experience voice alteration or other common side effect to indicate the presence of stimulation.

NOTE: Use proper magnet activation technique. See "Magnet Activation Technique" on page 82.

NOTE: For details on adverse events, see "Potential Adverse Events" on page 38.</td></tr>
<tr><td>STEP 2</td><td colspan="2">Interrogate the generator.</td></tr>
<tr><td rowspan="4">STEP 3</td><td colspan="2">Perform a System Diagnostics and record the results.</td></tr>
<tr><td>IF</td><td>THEN</td></tr>
<tr><td>Model 250 V11.0 and below—The DC-DC Converter Code is 0 or there has been a significant decrease in DC-DC Converter Code value (e.g., 3 to 1) in respect to prior System Diagnostics
Model 3000 V1.0 and above—The impedance is ≤ 1700 Ω or if there has been a sudden change in impedance range (e.g., 4100–5200 Ω to 1800–2800 Ω) in respect to prior System Diagnostics</td><td>A short-circuit condition may be present within the lead and the patient may not receive the intended therapy.</td></tr>
<tr><td>Model 250 V11.0 and below—The DC-DC Converter Code is not 0, there has been no significant decrease in DC-DC Converter Code value (e.g., 3 to 1) in respect to prior tests, and the System Diagnostics test indicates the lead impedance is OK
Model 3000 V1.0 and above—The System Diagnostics test indicates the lead impedance is OK</td><td>The system is functioning properly and the patient could have become accustomed to the settings, as do many patients.</td></tr>
<tr><td>System Diagnostics indicates the lead impedance is HIGH</td><td>For troubleshooting, see"Lead Impedance Issues" on page 152.</td></tr>
<tr><td colspan="2">⚠ CAUTION: For the system, the software automatically programs the generator to 1 mA, 500 µsec, and 20 Hz. Patients whose generator output current is normally less than these values may experience increased sensation, cough, flushed face, or other effects.</td></tr>
</table>

STEP 4	Perform a Normal Mode Diagnostics test and record the results.	
	IF	THEN
	The Normal Mode Diagnostics test indicates the output current is **LIMIT.**	The generator cannot deliver programmed output. Consider a reduction in the output current or frequency, and a wider pulse width.
	The Normal Mode Diagnostics test indicates the output current is **OK.**	The generator can deliver the programmed output current. NOTE: To obtain accurate information from the device diagnostics, the generator must be programmed to a **minimum** of 0.75 mA, 15 Hz, and **at least** 30 seconds ON time.
	The Normal Mode Diagnostics test indicates **HIGH** lead impedance.	For troubleshooting, see"Lead Impedance Issues" on page 152.

If further assistance is needed, contact "Technical Support" on page 223.

9.1.2. Patient Cannot Feel Magnet Activation at Follow-Up

9.1.2.1. Possible Causes

- Patient has become accustomed to the programmed setting
- Incorrect magnet activation technique
- Magnet output current programmed to 0 mA
- Generator battery at end of service (EOS)
- Generator implanted too deep in the chest
- Defective generator
- Disabled generator
- High lead impedance
- Short-circuit condition within the lead

9.1.2.2. Solution Steps

Applicable Models:	Model 1000	Model 1000-D	Model 106	Model 105	Model 104	Model 103

Table 43. Patient Cannot Feel Magnet Activation at Follow-Up

STEP 1	Interrogate the generator.		
	Is therapy disabled in the generator?		
	IF	THEN	
	Yes	Is therapy disabled because you performed an intentional generator reset with the Wand?	
		IF	THEN
		Yes	Re-enable the patient's therapy at the desired parameter settings.
		No	Record the cause. Contact "Technical Support" on page 223.
	No	Is the Magnet current ≥ Normal output current and Magnet ON time > 7?	
		IF	THEN
		Yes	Continue to **STEP 2**.
		No	Magnet settings may be too low for patients to perceive. Adjust magnet setting.
STEP 2	IF	THEN	
	Indication that the generator did NOT sense a magnet activation	Pass the magnet over the generator again and repeat the test. If the message appears again, contact "Technical Support" on page 223.	
	Output Current **OK** Lead Impedance **OK**	Magnet Mode stimulation is functioning properly and the patient may have become accustomed to the settings. If perceived stimulation is desired, consider a higher magnet current. Contact "Technical Support" on page 223.	
	Output Current **LOW** (≤600 Ω) Lead Impedance **OK**	Generator cannot deliver the programmed magnet output due to increased impedance. Consider a lower magnet output current and higher magnet pulse width. Contact "Technical Support" on page 223.	
	Output Current **LOW** (≤600 Ω) Lead Impedance **HIGH** (≥ 5300 Ω)	See "Lead Impedance Issues" on page 152.	

Applicable Models: Model 102 Model 102R

STEP 1	Interrogate the generator.
STEP 2	Confirm that the magnet output current is ≥ 0.25 mA and magnet ON time is > 7 seconds.
STEP 3	Record the number of magnet activations listed under Device History or Events screen of the programming software.
STEP 4	Pass the magnet over the generator and watch for a clinical response to the stimulation. NOTE: Use proper magnet activation technique. See "Magnet Activation Technique" on page 82. NOTE: Follow the listed instructions and pass the magnet over the generator just before the test starts. To obtain accurate information from the device diagnostics, program the generator to a **minimum** of 0.75 mA (magnet output current), 15 Hz (Normal Mode frequency), and 30 seconds (magnet ON time).
STEP 5	Wait 3 to 4 minutes and re-interrogate the device.
STEP 6	Record the number of magnet activations listed under Device History or Events screen of the programming software. The number of activations should have increased by 1.
STEP 7	If the number of magnet activations increased but the patient does not feel magnet induced stimulation, then increase the magnet output current until the magnet-induced stimulation is felt.

If the number of magnet activations did not increase, then perform a Magnet Mode Diagnostics test and record all results.

IF The Magnet Mode Diagnostics test indicates:	THEN
OK results	The magnet is functioning properly and the patient could have become accustomed to the settings, as do many patients.
Device status **STANDBY** and output current ******** or gives a message that the **magnet activation was not detected**	Perform steps 1 through 6 with an alternate LivaNova magnet.
HIGH lead impedance	For troubleshooting, see "Lead Impedance Issues" on page 152.

If further assistance is needed, contact "Technical Support" on page 223.

9.1.3. Patient Cannot Feel AutoStim Activation at Follow-Up

Applicable Models:	Model 1000	Model 1000-D	Model 106

9.1.3.1. Possible Causes

- AutoStim Threshold is too high (e.g., 70% threshold versus 50%)
- Patient has become accustomed to the programmed setting
- AutoStim output current is programmed to 0 mA
- Generator battery at end of service (EOS)
- Defective generator
- Disabled generator
- Defective lead

9.1.3.2. Solution Steps

Table 44. Patient Cannot Feel AutoStim Activation at Follow-Up

<table>
<tr><td>STEP 1</td><td colspan="3">Interrogate the generator.</td></tr>
<tr><td></td><td colspan="3">Is therapy disabled in the generator?</td></tr>
<tr><td></td><td>IF</td><td colspan="2">THEN</td></tr>
<tr><td></td><td>No</td><td colspan="2">Continue to STEP 2.</td></tr>
<tr><td></td><td>Yes</td><td colspan="2">Is the cause an intentional Wand reset?</td></tr>
<tr><td></td><td></td><td>IF</td><td>THEN</td></tr>
<tr><td></td><td></td><td>Yes</td><td>Re-enable the patient's therapy at the desired parameter settings.</td></tr>
<tr><td></td><td></td><td>No</td><td>Record the cause. Contact "Technical Support" on page 223.</td></tr>
<tr><td>STEP 2</td><td>Confirm the following:</td><td></td><td></td></tr>
<tr><td></td><td colspan="3">• Detection is enabled
• AutoStim output current is set to > 0 mA and ≥ normal output current
• Heartbeat detection is accurate</td></tr>
<tr><td>STEP 3</td><td colspan="3">Perform an AutoStimdiagnostics (AutoStimTest) and record the results.</td></tr>
<tr><td></td><td colspan="3">Was current delivered?</td></tr>
<tr><td></td><td>IF</td><td colspan="2">THEN</td></tr>
<tr><td></td><td>Yes</td><td colspan="2">Continue to STEP 4.</td></tr>
<tr><td></td><td>No</td><td colspan="2">Contact "Technical Support" on page 223.</td></tr>
</table>

Table 44. Patient Cannot Feel AutoStim Activation at Follow-Up (continued)

STEP 4	Evaluate available AutoStim data to identify any changes.	
	What are the average number of AutoStims per day?	
	IF	THEN
	Available AutoStim data shows no activations and patient has had seizures during the period.	Adjust the AutoStim threshold setting toward 20%. Repeat this process at subsequent patient visits until the patient perceives stimulation or the device confirms that events are detected. NOTE: A decreased detection threshold increases the likelihood of a heart rate increase detection associated with seizures but may increase the overall number of AutoStims delivered and impact battery longevity.
	Available AutoStim data shows regular activations, the generator is able to deliver AutoStim.	If perceived stimulation is desired, consider a higher AutoStim current. Re-evaluate at the next patient visit.

NOTE: A decrease in the detection threshold increases the likelihood of the detection of heart rate rises associated with seizures but may increase the overall number of AutoStims delivered and impact battery longevity. For details, see "Generators with AutoStim" on page 79.

9.2. Lead Impedance Issues

9.2.1. High Lead Impedance in the OR

9.2.1.1. Possible Causes

- Improper connection between the lead and the generator
- Incorrect placement of lead on the nerve
- The nerve has become dry
- Defective generator
- Defective lead

9.2.1.2. Solution Steps

Table 45. High Lead Impedance in the OR

STEP 1	Reinsert the lead pin into the generator receptacle.	
	• Back out setscrew, remove lead pin, and leave the hex screwdriver engaged in setscrew. • Verify that the setscrew is not visible in the generator receptacle. • Insert lead pin and tighten setscrew until the hex screwdriver clicks. • Confirm the lead pin is past the back end of the connector block. • For single-receptacle generators, verify the end of the connector ring is inside of the generator receptacle. • Irrigate dry nerve site and remove pooled fluid, if necessary. • Verify proper lead electrode placement on the nerve.	
STEP 2	Retry System Diagnostics.	
	What are the lead impedance results?	
	IF	THEN
	OK	Proceed with the implant.
	HIGH	Continue with **STEP 3**.
STEP 3	Troubleshoot the generator.	
	• Back out setscrew and remove the lead pin. • Insert the test resistor into the generator and tighten the setscrew until the hex screwdriver clicks. • Troubleshoot the Programmer. • Perform Generator Diagnostics.	
STEP 4	Retry System Diagnostics.	
	What are the lead impedance results?	
	IF	THEN
	OK	Continue with **STEP 5**.
	HIGH	Contact "Technical Support" on page 223.
STEP 5	Reinsert the lead into the generator.	
	• Back out the setscrew and remove the test resistor. • Verify that the setscrew is not visible in the generator receptacle. • Engage the hex screwdriver in the setscrew. • Insert connector pin and tighten the setscrew until the hex screwdriver clicks. • Visually inspect the generator receptacle and verify that the lead pin is past the back end of the connector block.	

Table 45. High Lead Impedance in the OR (continued)

STEP 6	Retry System Diagnostics.	
	What are the lead impedance results?	
	IF	THEN
	OK	Proceed with the implant.
	HIGH	Contact "Technical Support" on page 223.

9.2.2. Low Lead Impedance in the OR

9.2.2.1. Possible Causes

- Incorrect placement of lead on the nerve
- Excessive irrigation of the nerve
- Defective generator
- Defective lead
- Short-circuit condition within the lead (during generator replacement surgery)

9.2.2.2. Solution Steps

Table 46. Low Lead Impedance in the OR

Initial Implant Complete Steps 1 through 6.		
Generator Replacement Complete Steps 3 through 6.		
STEP 1	Check the lead.	
	• Verify lead electrodes are correctly placed on the nerve. • Remove pooled fluid if nerve site is saturated.	
STEP 2	Retry System Diagnostics.	
	What are the lead impedance results?	
	IF	THEN
	OK	Proceed with the implant.
	LOW	Continue with **STEP 3**.
STEP 3	Troubleshoot the generator.	
	• Back out setscrew and remove the lead pin. • Insert the test resistor into the generator and tighten the setscrew until the hex screwdriver clicks. • Troubleshoot the Programmer. • Perform a Generator Diagnostics.	
STEP 4	Retry Generator Diagnostics.	
	What are the lead impedance results?	
	IF	THEN
	OK	Continue with the implant.
	LOW	Continue with **STEP 5**.
STEP 5	Reinsert the lead into the generator.	
	• Back out the setscrew and remove the lead pin. • Verify that the setscrew is not visible in the generator receptacle. • Engage the hex screwdriver in the setscrew. • Insert lead pin and tighten the setscrew until the hex screwdriver clicks. • Visually inspect the generator receptacle and verify that the lead pin is past the back end of the connector block.	

Table 46. Low Lead Impedance in the OR (continued)

STEP 6	Retry System Diagnostics.	
	What are the lead impedance results?	
	IF	THEN
	OK	Proceed with the implant.
	LOW	Contact "Technical Support" on page 223.

9.2.3. High / Low Lead Impedance or Low Output Current at Follow-Up

Applicable Models:	Model 1000	Model 1000-D	Model 106	Model 105	Model 104	Model 103

9.2.3.1. Solution Steps

Table 47. High / Low Lead Impedance or Low Output Current at Follow-Up

Perform System Diagnostics and Record Results		
Results	Possible Cause	Action
• Lead Impedance: **OK** • Output Current: **OK**	• The generator is delivering stimulation as intended	Proceed with intended use.
• Lead Impedance: **HIGH** • Output Current: **OK** or **LOW**	• Lead discontinuity • Short-circuit condition within the lead • Fibrosis between the nerve and the electrode • Electrode detachment from the nerve • Defective generator	Contact "Technical Support" on page 223.
• Lead Impedance: **LOW** • Output Current: **OK**	• Short-circuit condition within the lead • Defective generator	
• Lead Impedance: **OK** • Output Current: **LOW**	• Increased impedance in the system	

9.2.4. High Lead Impedance at Follow-Up

Applicable Models: Model 102 Model 102R

9.2.4.1. Solution Steps

Table 48. High Lead Impedance at Follow-Up

STEP 1	Perform System Diagnostics and Normal Mode Diagnostics.		
STEP 2	Record and Evaluate Results.		
	What are the System Diagnostics results?		
	Results	Possible Cause	Action
	NEOS	• The generator battery is near end of service (NEOS).	Replace the generator as soon as possible.
	System Diagnostics: • Lead Impedance: HIGH • Output Status: LIMIT Normal Mode: • Output Status: LIMIT	• Lead discontinuity • Lead disconnected from the generator • Fibrosis between the nerve and electrode • Electrode detachment from the nerve • Defective generator	Contact "Technical Support" on page 223.
	System Diagnostics: • Lead Impedance: HIGH • Output Status: OK Normal Mode: • Output Status: LIMIT	• Lead discontinuity • Lead disconnected from the generator • Fibrosis between the nerve and electrode • Electrode detachment from the nerve • Defective generator	Contact "Technical Support" on page 223.
	System Diagnostics: • Lead Impedance: OK • Output Status: OK Normal Mode: • Output Status: LIMIT	• The generator cannot deliver programmed output. Reduce the output current or frequency and widen the pulse width.	Contact "Technical Support" on page 223.
	System Diagnostics: • Lead Impedance: OK • Output Status: OK Normal Mode: • Output Status: OK	• The generator is performing as intended.	

9.3. Battery Issues

9.3.1. Low Battery or End of Service Indications in the OR

9.3.1.1. Possible Causes

Prior to Surgery

- Generator has been recently exposed to low storage temperatures
- Defective generator

During Surgery

- Electrosurgical equipment used near the generator
- Generator exposed to electrostatic discharge (ESD)

9.3.1.2. Solution Steps

Table 49. Low Battery or End of Service Indications in the OR

Perform System Diagnostics and Record results.	
IF	**THEN**
IFI = **NO**	The generator battery is OK. Follow standard guidance for other System Diagnostics parameters and proceed with the implant.
Software indications: • Generator Battery NEOS • Generator Battery EOS • The Intensified Followup Indicator (IFI) is set. • Generator disabled	**Number of Attempts:** **1** – Wait approximately 30 minutes with the generator at room temperature. **2** – Contact "Technical Support" on page 223.

9.3.2. New Generator Disabled Due to EOS at First Follow-Up

Applicable Models:	Model 1000	Model 1000-D	Model 106	Model 105	Model 104	Model 103

The batteries can temporarily drain and become disabled if exposed to certain conditions.

9.3.2.1. Possible Causes

- Electrosurgical equipment used near the generator
- Generator exposed to electrostatic discharge (ESD)

9.3.2.2. Solution Steps

Table 50. New Generator Disabled Due to EOS at First Follow-Up

STEP 1	**Enable Stimulation and Check System**	
	• **Enable Therapy**. • Perform a System Diagnostics test. NOTE: Therapy must be enabled to retrieve full System Diagnostics results (e.g., lead impedance, battery status, and output current).	
STEP 2	**Battery Status**	
	What is the battery status?	
	IF	**THEN**
	IFI = No	Proceed with the intended use.
	IFI = Yes	Monitor the patient for low battery indicators. NOTE: the battery life will be shortened.
	NEOS = Yes or **EOS = Yes**	Replace the generator immediately.
	All other errors	Contact "Technical Support" on page 223.

9.3.3. Sudden Decrease in Battery Power

If the generator battery power suddenly decreases, the following are possible causes:

- First visit after a surgery: The decrease may have been caused by exposure to certain conditions (e.g., electrocautery) during VNS or other surgery. If the condition occurred, but was not detected in the OR,

it is possible you may detect the decrease at the follow-up visit. The device will still function normally but will have decreased battery life. Monitor the patient closely for any low battery indicators.

- There has been a significant change in the lead impedance or an increase in programmed stimulation parameters. Evaluate battery power that remains between consecutive patient visits before stimulation parameters are adjusted. Review lead impedance for any significant changes.

If any device issue is suspected, contact "Technical Support" on page 223.

9.4. Detection Issues

Applicable Models:	Model 1000	Model 1000-D	Model 106

9.4.1. Heartbeat Detection Inaccurate (Over / Under) in the OR or at Follow-Up

The heartbeat detection setting may need to be adjusted to accurately detect heartbeats. The Wand must be held over the generator during the entire Verify Heartbeat Detection process.

9.4.1.1. Solution Steps

Table 51. Heartbeat Detection Inaccurate (Over / Under) in the OR or at Follow-Up (Generators Capable of AutoStim)

STEP 1	Turn on the Wand.	
STEP 2	Confirm that the Programmer is not plugged in to wall outlet.	
STEP 3	Confirm detection is enabled.	
STEP 4	Confirm that the Wand is over the generator.	
STEP 5	Check the bpm.	
	What is the bpm?	
	IF	THEN
	???	Ensure Wand is directly over the generator and try a different Heartbeat Detection setting as necessary. If you have persistent issues, contact "Technical Support" on page 223.
	Low	Adjust the Heartbeat Detection setting up (toward 5).
	High	Adjust the Heartbeat Detection setting downward (toward 1) and confirm accuracy in different body positions (e.g., off-the-shelf heart rate monitor.

Table 51. Heartbeat Detection Inaccurate (Over / Under) in the OR or at Follow-Up (Generators Capable of AutoStim) (continued)

STEP 6	Check for accuracy.	
	Is the Heartbeat Detection accurate?	
	IF	THEN
	Yes	Heartbeat detection is complete.
	No, but there are more settings to try.	Select a new heartbeat detection value and try again.
	No and all settings have been tried without success.	Contact "Technical Support" on page 223.

9.4.2. Tachycardia Detection Issue - Inaccurate AutoStim at Follow-Up

Sometimes generator detection or AutoStim threshold settings may miss detection of heart rate changes that may be associated with a seizure.

9.4.2.1. Possible Causes

- Duty cycle – Because the generator can only detect events during OFF time, the OFF time affects accuracy. Shorter OFF time means less chance for the generator to detect events. Longer OFF time, on the other hand, means more chance for the generator to detect events.
- Heart rate changes – Exercise, physical activity, and normal sleep can increase the heart rate and cause the generator to falsely declare an event.

9.4.2.2. Solution Steps

Table 52. Tachycardia Detection Issue - Inaccurate AutoStim at Follow-Up

STEP 1	Confirm Heartbeat Detection settings	
	See "Heartbeat Detection Inaccurate (Over / Under) in the OR or at Follow-Up" on page 163.	
STEP 2	Number of AutoStims	
	IF	THEN
	Too few	Adjust the AutoStim threshold setting toward 20%.
	Too many	Adjust the AutoStim threshold setting toward 70%.
STEP 3	Monitor accuracy over the course of therapy.	
	Is the detection still inaccurate after several adjustments?	
	IF	THEN
	Yes	Contact "Technical Support" on page 223.
	No	Continue with programmed setting.

9.5. Generator (Device) Reset

The system allows the generator microprocessor to be reset in the event of a malfunction. A reset is necessary only in the rare case of microprocessor memory malfunction, which might be caused by conditions described in "Indications, Warnings and Precautions " on page 17 . A microprocessor reset may be appropriate when the generator and the programming system are unable to communicate.

NOTE: For solution steps related to communication issues, see the model specific programming system manual posted at www.livanova.com.

If you have eliminated possible environmental hazards and completed all possible troubleshooting steps, a generator reset may be necessary. Contact "Technical Support" on page 223 for assistance with a generator reset.

Model 1000 Model 1000-D Model 106 Model 105 Model 104 Model 103	CAUTION: *Generator (device) reset*: When the generator is reset, optional features (e.g., Day-Night Programming) and stimulation output are disabled (0 mA); however, all settings and device history are preserved. After a successful reset, the generator stimulation output may be re-enabled to resume operation at the previously programmed settings and optional features reactivated.
Model 102 Model 102R	CAUTION: *Generator (device) reset*: When the generator is reset, all device history information is lost, and the reset parameters (0 mA, 10 Hz; 500 µsec; ON time, 30 sec; OFF time, 60 min) are internally programmed. A generator reset turns the device off (output current = 0 mA). After a successful reset, the generator stimulation output may be re-enabled to resume operation at the previously programmed settings and optional features reactivated.

CHAPTER 10

Battery Longevity Tables

This topic includes the following concepts:

10.1. Model 1000 / Model 1000-D Battery Longevity and Programmed Setting Choices

10.1.1. AutoStim Feature Disabled

AutoStim Feature Disabled Model 1000 Model 1000-D											
Parameters at 3 kΩ			Normal Mode Duty Cycle								
			10% (30s ON / 5 min OFF)			35% (30s ON / 1.1 min OFF)			51% (60s ON / 1.1 min OFF)		
			BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS
mA	Hz	µS	Years	Years	Years	Years	Years	Years	Years	Years	Years
0.5	20	250	11.9	1.2	1.2	6.1	0.6	0.6	4.6	0.5	0.5
0.5	20	500	11.8	1.2	1.2	6.0	0.6	0.6	4.5	0.5	0.5
0.5	30	250	10.2	1.0	1.0	4.7	0.5	0.5	3.5	0.4	0.4
0.5	30	500	10.1	1.0	1.0	4.6	0.5	0.5	3.4	0.3	0.3
1	20	250	11.7	1.2	1.2	5.9	0.6	0.6	4.5	0.5	0.4
1	20	500	11.6	1.2	1.1	5.8	0.6	0.5	4.4	0.4	0.4
1	30	250	10.0	1.0	1.0	4.5	0.5	0.5	3.3	0.3	0.3
1	30	500	9.9	1.0	1.0	4.4	0.4	0.4	3.2	0.3	0.3
1.5	20	250	11.4	1.1	1.1	5.7	0.6	0.5	4.2	0.4	0.4
1.5	20	500	9.4	0.9	0.8	4.1	0.4	0.3	3.0	0.3	0.2
1.5	30	250	9.8	1.0	0.9	4.4	0.4	0.4	3.2	0.3	0.3
1.5	30	500	7.7	0.7	0.7	3.1	0.3	0.2	2.2	0.2	0.2
2	20	250	9.7	0.9	0.8	4.3	0.4	0.3	3.2	0.3	0.2
2	20	500	7.2	0.7	0.6	2.8	0.3	0.2	2.0	0.2	0.2
2	30	250	8.2	0.8	0.7	3.3	0.3	0.3	2.4	0.2	0.2
2	30	500	5.6	0.5	0.5	2.0	0.2	0.2	1.4	0.1	0.1
2.5	20	250	7.9	0.7	0.7	3.2	0.3	0.2	2.3	0.2	0.2
2.5	20	500	5.5	0.5	0.4	1.9	0.2	0.1	1.4	0.1	0.1
2.5	30	250	6.5	0.6	0.5	2.4	0.2	0.2	1.7	0.2	0.1
2.5	30	500	4.2	0.4	0.3	1.4	0.1	0.1	1.0	0.1	0.1
3	20	250	6.4	0.6	0.5	2.4	0.2	0.2	1.7	0.2	0.1
3	20	500	4.2	0.4	0.3	1.4	0.1	0.1	1.0	0.1	0.1
3	30	250	5.1	0.5	0.4	1.8	0.2	0.1	1.2	0.1	0.1

AutoStim Feature Disabled Model 1000 Model 1000-D											
Parameters at 3 kΩ			Normal Mode Duty Cycle								
			10% (30s ON / 5 min OFF)			35% (30s ON / 1.1 min OFF)			51% (60s ON / 1.1 min OFF)		
			BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS
mA	Hz	µS	Years	Years	Years	Years	Years	Years	Years	Years	Years
3	30	500	3.1	0.3	0.2	1.0	0.1	0.1	0.7	0.1	0.1
3.5	20	250	5.2	0.5	0.4	1.8	0.2	0.1	1.3	0.1	0.1
3.5	20	500	3.2	0.3	0.2	1.0	0.1	0.1	0.7	0.1	0.1
3.5	30	250	4.0	0.4	0.3	1.3	0.1	0.1	0.9	0.1	0.1
3.5	30	500	2.3	0.2	0.2	0.7	0.1	0.1	0.5	0.0	0.0

10.1.2. AutoStim Feature Enabled

10.1.2.1. One AutoStim / Hour and AutoStim ON Time 60 Seconds

AutoStim Feature Enabled (1 AutoStim / Hour; AutoStim ON Time 60 Seconds) Model 1000 Model 1000-D								
Parameters at 3 kΩ			Normal Mode Duty Cycle					
			10% (30s ON / 5 min OFF)			35% (30s ON / 1.1 min OFF)		
			BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS
mA	Hz	µS	Years	Years	Years	Years	Years	Years
0.5	20	250	7.3	0.7	0.7	4.9	0.5	0.5
0.5	20	500	7.2	0.7	0.7	4.8	0.5	0.5
0.5	30	250	6.5	0.7	0.7	3.9	0.4	0.4
0.5	30	500	6.5	0.7	0.7	3.9	0.4	0.4
1	20	250	7.2	0.7	0.7	4.8	0.5	0.5
1	20	500	7.1	0.7	0.7	4.7	0.5	0.4
1	30	250	6.4	0.7	0.7	3.8	0.4	0.4
1	30	500	6.4	0.6	0.6	3.7	0.4	0.4
1.5	20	250	7.1	0.7	0.7	4.6	0.5	0.4
1.5	20	500	6.1	0.6	0.6	3.5	0.3	0.3
1.5	30	250	6.3	0.6	0.6	3.7	0.4	0.3
1.5	30	500	5.3	0.5	0.5	2.7	0.3	0.2
2	20	250	6.3	0.6	0.6	3.7	0.3	0.3
2	20	500	5.0	0.5	0.4	2.5	0.2	0.2
2	30	250	5.5	0.5	0.5	2.9	0.3	0.2
2	30	500	4.1	0.4	0.3	1.8	0.2	0.1
2.5	20	250	5.4	0.5	0.5	2.8	0.3	0.2
2.5	20	500	4.0	0.4	0.3	1.8	0.2	0.1
2.5	30	250	4.6	0.4	0.4	2.2	0.2	0.2
2.5	30	500	3.2	0.3	0.3	1.3	0.1	0.1
3	20	250	4.6	0.4	0.4	2.1	0.2	0.2
3	20	500	3.2	0.3	0.3	1.3	0.1	0.1
3	30	250	3.8	0.4	0.3	1.6	0.1	0.1
3	30	500	2.5	0.2	0.2	0.9	0.1	0.1
3.5	20	250	3.8	0.4	0.3	1.7	0.1	0.1
3.5	20	500	2.5	0.2	0.2	1.0	0.1	0.1
3.5	30	250	3.1	0.3	0.3	1.2	0.1	0.1
3.5	30	500	1.9	0.2	0.1	0.7	0.1	0.0

10.1.2.2. One AutoStim / Hour and AutoStim ON Time 30 Seconds

AutoStim Feature Enabled (1 AutoStim / Hour; AutoStim ON Time 30 Seconds) Model 1000 Model 1000-D								
Parameters at 3 kΩ			Normal Mode Duty Cycle					
			10% (30 ON / 5 min OFF)			35% (30s ON / 1.1 min OFF)		
			BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS
mA	Hz	µS	Years	Years	Years	Years	Years	Years
0.5	20	250	7.4	0.8	0.8	4.9	0.5	0.5
0.5	20	500	7.3	0.7	0.8	4.9	0.5	0.5
0.5	30	250	6.7	0.7	0.7	4.0	0.4	0.4
0.5	30	500	6.6	0.7	0.7	3.9	0.4	0.4
1	20	250	7.3	0.7	0.7	4.8	0.5	0.5
1	20	500	7.3	0.7	0.7	4.8	0.5	0.5
1	30	250	6.6	0.7	0.7	3.9	0.4	0.4
1	30	500	6.5	0.7	0.6	3.8	0.4	0.4
1.5	20	250	7.2	0.7	0.7	4.7	0.5	0.4
1.5	20	500	6.3	0.6	0.6	3.5	0.3	0.3
1.5	30	250	6.5	0.7	0.6	3.7	0.4	0.3
1.5	30	500	5.5	0.5	0.5	2.7	0.3	0.2
2	20	250	6.5	0.6	0.6	3.7	0.3	0.3
2	20	500	5.2	0.5	0.5	2.5	0.2	0.2
2	30	250	5.7	0.6	0.5	2.9	0.3	0.2
2	30	500	4.3	0.4	0.4	1.9	0.2	0.1
2.5	20	250	5.6	0.5	0.5	2.8	0.3	0.2
2.5	20	500	4.2	0.4	0.4	1.8	0.2	0.1
2.5	30	250	4.8	0.5	0.4	2.2	0.2	0.2
2.5	30	500	3.4	0.3	0.3	1.3	0.1	0.1
3	20	250	4.8	0.4	0.4	2.2	0.2	0.2
3	20	500	3.4	0.3	0.3	1.3	0.1	0.1
3	30	250	4.0	0.4	0.3	1.7	0.2	0.1
3	30	500	2.6	0.2	0.2	0.9	0.1	0.1
3.5	20	250	4.0	0.4	0.3	1.7	0.2	0.1
3.5	20	500	2.7	0.2	0.2	1.0	0.1	0.1
3.5	30	250	3.2	0.3	0.3	1.3	0.1	0.1
3.5	30	500	2.0	0.2	0.2	0.7	0.1	0.1

10.1.2.3. Seven AutoStims / Hour and AutoStim ON Time 60 Seconds

AutoStim Feature Enabled (7 AutoStims / Hour; AutoStim ON Time 60 Seconds) Model 1000 Model 1000-D								
Parameters at 3 kΩ			Normal Mode Duty Cycle					
			10% (30s ON / 5 min OFF)			35% (30s ON / 1.1 min OFF)		
			BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS
mA	Hz	µS	Years	Years	Years	Years	Years	Years
0.5	20	250	6.3	0.6	0.7	4.6	0.5	0.5
0.5	20	500	6.3	0.6	0.6	4.5	0.5	0.5
0.5	30	250	5.5	0.6	0.6	3.6	0.4	0.4
0.5	30	500	5.4	0.5	0.6	3.5	0.4	0.4
1	20	250	6.3	0.6	0.6	4.5	0.5	0.5
1	20	500	6.2	0.6	0.6	4.4	0.4	0.4
1	30	250	5.4	0.5	0.5	3.5	0.4	0.4
1	30	500	5.3	0.5	0.5	3.4	0.3	0.3
1.5	20	250	6.1	0.6	0.6	4.3	0.4	0.4
1.5	20	500	5.0	0.5	0.4	3.2	0.3	0.3
1.5	30	250	5.2	0.5	0.5	3.4	0.3	0.3
1.5	30	500	4.1	0.4	0.4	2.4	0.2	0.2
2	20	250	5.2	0.5	0.4	3.4	0.3	0.3
2	20	500	3.8	0.4	0.3	2.2	0.2	0.2
2	30	250	4.4	0.4	0.4	2.6	0.2	0.2
2	30	500	3.0	0.3	0.2	1.6	0.1	0.1
2.5	20	250	4.2	0.4	0.4	2.5	0.2	0.2
2.5	20	500	2.9	0.3	0.2	1.6	0.1	0.1
2.5	30	250	3.5	0.3	0.3	1.9	0.2	0.2
2.5	30	500	2.2	0.2	0.2	1.1	0.1	0.1
3	20	250	3.4	0.3	0.3	1.9	0.2	0.1
3	20	500	2.2	0.2	0.2	1.2	0.1	0.1
3	30	250	2.7	0.3	0.2	1.5	0.1	0.1
3	30	500	1.7	0.1	0.1	0.8	0.1	0.1
3.5	20	250	2.8	0.3	0.2	1.5	0.1	0.1
3.5	20	500	1.7	0.2	0.1	0.8	0.1	0.1
3.5	30	250	2.1	0.2	0.2	1.1	0.1	0.1
3.5	30	500	1.2	0.1	0.1	0.6	0.1	0.0

*Longevity values with Prone Detection ON vary by no more than 4%.

10.1.2.4. Seven AutoStims / Hour and AutoStim ON Time 30 Seconds

AutoStim Feature Enabled (7 AutoStims / Hour; AutoStim ON Time 30 Seconds) Model 1000 Model 1000-D								
Parameters at 3 kΩ			Normal Mode Duty Cycle					
			10% (30s ON / 5 min OFF)			35% (30s ON / 1.1 min OFF)		
			BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS
mA	Hz	µS	Years	Years	Years	Years	Years	Years
0.5	20	250	7.0	0.7	0.7	4.8	0.5	0.5
0.5	20	500	7.0	0.7	0.7	4.7	0.5	0.5
0.5	30	250	6.2	0.6	0.6	3.9	0.4	0.4
0.5	30	500	6.2	0.6	0.6	3.8	0.4	0.4
1	20	250	6.9	0.7	0.7	4.7	0.5	0.5
1	20	500	6.9	0.7	0.7	4.6	0.5	0.4
1	30	250	6.1	0.6	0.6	3.7	0.4	0.4
1	30	500	6.1	0.6	0.6	3.7	0.4	0.3
1.5	20	250	6.8	0.7	0.7	4.5	0.5	0.4
1.5	20	500	5.8	0.6	0.5	3.4	0.3	0.3
1.5	30	250	6.0	0.6	0.6	3.6	0.4	0.3
1.5	30	500	5.0	0.5	0.4	2.6	0.2	0.2
2	20	250	6.0	0.6	0.5	3.6	0.3	0.3
2	20	500	4.7	0.4	0.4	2.4	0.2	0.2
2	30	250	5.2	0.5	0.5	2.8	0.3	0.2
2	30	500	3.8	0.4	0.3	1.8	0.2	0.1
2.5	20	250	5.1	0.5	0.4	2.7	0.3	0.2
2.5	20	500	3.7	0.3	0.3	1.7	0.2	0.1
2.5	30	250	4.3	0.4	0.4	2.1	0.2	0.2
2.5	30	500	2.9	0.3	0.2	1.3	0.1	0.1
3	20	250	4.2	0.4	0.4	2.1	0.2	0.2
3	20	500	2.9	0.3	0.2	1.3	0.1	0.1
3	30	250	3.5	0.3	0.3	1.6	0.1	0.1
3	30	500	2.2	0.2	0.2	0.9	0.1	0.1
3.5	20	250	3.5	0.3	0.3	1.6	0.1	0.1
3.5	20	500	2.3	0.2	0.2	0.9	0.1	0.1
3.5	30	250	2.8	0.3	0.2	1.2	0.1	0.1
3.5	30	500	1.7	0.2	0.1	0.7	0.1	0.0

*Longevity values with Prone Detection ON vary by no more than 5%.

10.1.2.5. Fifteen AutoStims / Hour and AutoStim ON Time 60 Seconds

AutoStim Feature Enabled (15 AutoStims / Hour; AutoStim ON Time 60 Seconds) Model 1000 Model 1000-D								
Parameters at 3 kΩ			Normal Mode Duty Cycle					
			10% (30s ON / 5 min OFF)			35% (30s ON / 1.1 min OFF)		
			BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS
mA	Hz	µS	Years	Years	Years	Years	Years	Years
0.5	20	250	5.4	0.6	0.6	4.2	0.4	0.4
0.5	20	500	5.4	0.5	0.6	4.1	0.4	0.4
0.5	30	250	4.5	0.5	0.5	3.3	0.3	0.3
0.5	30	500	4.4	0.4	0.5	3.2	0.3	0.3
1	20	250	5.3	0.5	0.5	4.1	0.4	0.4
1	20	500	5.3	0.5	0.5	4.0	0.4	0.4
1	30	250	4.4	0.4	0.4	3.2	0.3	0.3
1	30	500	4.3	0.4	0.4	3.1	0.3	0.3
1.5	20	250	5.2	0.5	0.5	3.9	0.4	0.4
1.5	20	500	4.0	0.4	0.3	2.9	0.3	0.2
1.5	30	250	4.3	0.4	0.4	3.1	0.3	0.3
1.5	30	500	3.2	0.3	0.3	2.2	0.2	0.2
2	20	250	4.2	0.4	0.4	3.0	0.3	0.2
2	20	500	2.9	0.3	0.2	2.0	0.2	0.2
2	30	250	3.4	0.3	0.3	2.3	0.2	0.2
2	30	500	2.2	0.2	0.2	1.4	0.1	0.1
2.5	20	250	3.3	0.3	0.3	2.2	0.2	0.2
2.5	20	500	2.1	0.2	0.2	1.4	0.1	0.1
2.5	30	250	2.6	0.2	0.2	1.7	0.2	0.1
2.5	30	500	1.6	0.1	0.1	1.0	0.1	0.1
3	20	250	2.6	0.2	0.2	1.7	0.2	0.1
3	20	500	1.6	0.1	0.1	1.0	0.1	0.1
3	30	250	2.0	0.2	0.2	1.3	0.1	0.1
3	30	500	1.1	0.1	0.1	0.7	0.1	0.1
3.5	20	250	2.0	0.2	0.2	1.3	0.1	0.1
3.5	20	500	1.2	0.1	0.1	0.7	0.1	0.1
3.5	30	250	1.5	0.1	0.1	0.9	0.1	0.1
3.5	30	500	0.8	0.1	0.1	0.5	0.0	0.0

10.1.2.6. Fifteen AutoStims / Hour and AutoStim ON Time 30 Seconds

AutoStim Feature Enabled (15 AutoStims / Hour; AutoStim ON Time 30 Seconds) Model 1000 Model 1000-D								
Parameters at 3 kΩ			Normal Mode Duty Cycle					
			10% (30s ON / 5 min OFF)			35% (30s ON / 1.1 min OFF)		
			BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS
mA	Hz	µS	Years	Years	Years	Years	Years	Years
0.5	20	250	6.6	0.7	0.7	4.6	0.5	0.5
0.5	20	500	6.5	0.7	0.7	4.6	0.5	0.5
0.5	30	250	5.7	0.6	0.6	3.7	0.4	0.4
0.5	30	500	5.7	0.6	0.6	3.6	0.4	0.4
1	20	250	6.5	0.7	0.7	4.6	0.5	0.5
1	20	500	6.5	0.6	0.6	4.5	0.4	0.4
1	30	250	5.6	0.6	0.6	3.6	0.4	0.4
1	30	500	5.5	0.6	0.5	3.5	0.4	0.3
1.5	20	250	6.4	0.6	0.6	4.4	0.4	0.4
1.5	20	500	5.3	0.5	0.5	3.3	0.3	0.3
1.5	30	250	5.5	0.6	0.5	3.5	0.4	0.3
1.5	30	500	4.4	0.4	0.4	2.5	0.2	0.2
2	20	250	5.5	0.5	0.5	3.4	0.3	0.3
2	20	500	4.1	0.4	0.3	2.3	0.2	0.2
2	30	250	4.7	0.4	0.4	2.7	0.3	0.2
2	30	500	3.3	0.3	0.3	1.7	0.2	0.1
2.5	20	250	4.5	0.4	0.4	2.6	0.2	0.2
2.5	20	500	3.2	0.3	0.3	1.6	0.1	0.1
2.5	30	250	3.7	0.4	0.3	2.0	0.2	0.2
2.5	30	500	2.4	0.2	0.2	1.2	0.1	0.1
3	20	250	3.7	0.3	0.3	2.0	0.2	0.2
3	20	500	2.5	0.2	0.2	1.2	0.1	0.1
3	30	250	3.0	0.3	0.2	1.5	0.1	0.1
3	30	500	1.8	0.2	0.1	0.8	0.1	0.1
3.5	20	250	3.0	0.3	0.2	1.5	0.1	0.1
3.5	20	500	1.9	0.2	0.1	0.9	0.1	0.1
3.5	30	250	2.4	0.2	0.2	1.1	0.1	0.1
3.5	30	500	1.4	0.1	0.1	0.6	0.1	0.0

10.2. Model 106 Battery Longevity and Programmed Setting Choices

10.2.1. AutoStim Feature Disabled

AutoStim Feature Disabled Model 106											
Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
0.5	10	130	>10	>10	>10	3.0	2.5	2.2	2.2	1.8	1.6
0.5	10	250	>10	>10	>10	2.9	2.3	2.0	2.2	1.7	1.5
0.5	10	500	>10	>10	>10	2.7	1.9	1.6	2.0	1.4	1.2
0.5	10	750	>10	>10	>10	2.6	1.7	1.3	1.9	1.2	1.0
0.5	10	1000	>10	>10	>10	2.4	1.5	1.1	1.8	1.1	0.8
0.5	15	130	>10	>10	>10	2.9	2.2	1.9	2.1	1.6	1.4
0.5	15	250	>10	>10	>10	2.8	2.0	1.7	2.1	1.5	1.2
0.5	15	500	>10	>10	>10	2.5	1.6	1.3	1.9	1.2	0.9
0.5	15	750	>10	>10	>10	2.3	1.4	1.0	1.7	1.0	0.8
0.5	15	1000	>10	>10	>10	2.1	1.2	0.9	1.6	0.9	0.6
0.5	20	130	>10	>10	>10	2.8	2.0	1.7	2.1	1.5	1.2
0.5	20	250	>10	>10	>10	2.7	1.8	1.5	2.0	1.3	1.1
0.5	20	500	>10	>10	>10	2.4	1.4	1.1	1.7	1.0	0.8
0.5	20	750	>10	>10	>10	2.1	1.1	0.9	1.6	0.8	0.6
0.5	20	1000	>10	>10	9.3	1.9	1.0	0.7	1.4	0.7	0.5
0.5	25	130	>10	>10	>10	2.7	1.8	1.5	2.0	1.4	1.1
0.5	25	250	>10	>10	>10	2.5	1.6	1.3	1.9	1.2	1.0
0.5	25	500	>10	>10	>10	2.2	1.2	0.9	1.6	0.9	0.7
0.5	25	750	>10	>10	9.6	1.9	1.0	0.7	1.4	0.7	0.5
0.5	25	1000	>10	>10	7.8	1.7	0.8	0.6	1.3	0.6	0.4
0.5	30	130	>10	>10	>10	2.6	1.7	1.3	1.9	1.3	1.0
0.5	30	250	>10	>10	>10	2.4	1.5	1.2	1.8	1.1	0.9
0.5	30	500	>10	>10	>10	2.1	1.1	0.8	1.5	0.8	0.6
0.5	30	750	>10	>10	8.3	1.8	0.9	0.6	1.3	0.6	0.5
0.5	30	1000	>10	9.5	6.7	1.6	0.7	0.5	1.2	0.5	0.4
1	10	130	>10	>10	>10	2.7	1.8	1.5	1.9	1.2	1.0

AutoStim Feature Disabled Model 106											
Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1	10	250	>10	>10	>10	2.5	1.6	1.2	1.7	1.0	0.8
1	10	500	>10	>10	>10	2.2	1.2	0.9	1.5	0.8	0.6
1	10	750	>10	>10	>10	2.0	1.0	0.7	1.3	0.6	0.4
1	10	1000	>10	>10	9.7	1.8	0.8	0.6	1.1	0.5	0.4
1	15	130	>10	>10	>10	2.6	1.7	1.4	1.8	1.2	0.9
1	15	250	>10	>10	>10	2.4	1.4	1.1	1.6	0.9	0.7
1	15	500	>10	>10	>10	2.0	1.1	0.8	1.3	0.7	0.5
1	15	750	>10	>10	8.7	1.7	0.8	0.6	1.1	0.5	0.4
1	15	1000	>10	9.8	7.0	1.5	0.7	0.5	1.0	0.4	0.3
1	20	130	>10	>10	>10	2.5	1.6	1.3	1.8	1.1	0.9
1	20	250	>10	>10	>10	2.3	1.3	1.0	1.6	0.8	0.6
1	20	500	>10	>10	9.3	1.8	0.9	0.7	1.2	0.6	0.4
1	20	750	>10	9.7	6.9	1.5	0.7	0.5	1.0	0.4	0.3
1	20	1000	>10	7.8	5.5	1.3	0.5	0.4	0.8	0.3	0.2
1	25	130	>10	>10	>10	2.4	1.5	1.2	1.7	1.0	0.8
1	25	250	>10	>10	>10	2.1	1.2	0.9	1.5	0.8	0.6
1	25	500	>10	>10	7.8	1.7	0.8	0.6	1.1	0.5	0.3
1	25	750	>10	8.2	5.7	1.4	0.6	0.4	0.9	0.4	0.2
1	25	1000	>10	6.5	4.5	1.2	0.5	0.3	0.7	0.3	0.2
1	30	130	>10	>10	>10	2.4	1.4	1.1	1.7	1.0	0.7
1	30	250	>10	>10	>10	2.0	1.0	0.8	1.4	0.7	0.5
1	30	500	>10	9.5	6.7	1.5	0.7	0.5	1.0	0.4	0.3
1	30	750	>10	7.0	4.9	1.2	0.5	0.3	0.8	0.3	0.2
1	30	1000	>10	5.6	3.8	1.0	0.4	0.3	0.7	0.2	0.2
1.5	10	130	>10	>10	>10	2.3	1.3	1.0	1.6	0.9	0.7
1.5	10	250	>10	>10	>10	2.0	1.0	0.8	1.4	0.7	0.5
1.5	10	500	>10	>10	7.9	1.6	0.7	0.5	1.1	0.5	0.3
1.5	10	750	>10	8.1	5.7	1.2	0.5	0.4	0.8	0.3	0.2
1.5	10	1000	>10	6.4	4.4	1.0	0.4	0.3	0.7	0.3	0.2
1.5	15	130	>10	>10	>10	2.2	1.2	0.9	1.5	0.8	0.6
1.5	15	250	>10	>10	9.7	1.8	0.9	0.6	1.3	0.6	0.4
1.5	15	500	>10	8.5	6.0	1.3	0.5	0.4	0.9	0.4	0.3
1.5	15	750	>10	6.1	4.2	1.0	0.4	0.3	0.7	0.3	0.2

AutoStim Feature Disabled Model 106											
Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1.5	15	1000	>10	4.7	3.2	0.8	0.3	0.2	0.6	0.2	0.1
1.5	20	130	>10	>10	>10	2.0	1.1	0.8	1.5	0.7	0.6
1.5	20	250	>10	>10	8.5	1.7	0.8	0.5	1.1	0.5	0.4
1.5	20	500	>10	7.2	5.0	1.2	0.5	0.3	0.8	0.3	0.2
1.5	20	750	>10	5.0	3.4	0.9	0.3	0.2	0.6	0.2	0.1
1.5	20	1000	>10	3.8	2.6	0.7	0.2	0.2	0.5	0.2	0.1
1.5	25	130	>10	>10	>10	1.9	1.0	0.7	1.4	0.7	0.5
1.5	25	250	>10	>10	7.5	1.5	0.7	0.5	1.1	0.5	0.3
1.5	25	500	>10	6.3	4.4	1.0	0.4	0.3	0.7	0.3	0.2
1.5	25	750	>10	4.3	2.9	0.8	0.3	0.2	0.5	0.2	0.1
1.5	25	1000	9.2	3.3	2.2	0.6	0.2	0.1	0.4	0.1	0.1
1.5	30	130	>10	>10	9.8	1.8	0.9	0.7	1.3	0.6	0.4
1.5	30	250	>10	9.5	6.8	1.4	0.6	0.4	1.0	0.4	0.3
1.5	30	500	>10	5.5	3.8	0.9	0.4	0.2	0.6	0.2	0.2
1.5	30	750	>10	3.8	2.6	0.7	0.2	0.2	0.5	0.2	0.1
1.5	30	1000	8.2	2.8	1.9	0.5	0.2	0.1	0.4	0.1	0.1
2	10	130	>10	>10	>10	2.0	1.0	0.8	1.4	0.7	0.5
2	10	250	>10	>10	8.2	1.6	0.7	0.5	1.1	0.5	0.3
2	10	500	>10	7.2	5.0	1.2	0.5	0.3	0.8	0.3	0.2
2	10	750	>10	5.2	3.6	0.9	0.3	0.2	0.6	0.2	0.1
2	10	1000	>10	4.0	2.8	0.7	0.3	0.2	0.5	0.2	0.1
2	15	130	>10	>10	9.5	1.8	0.9	0.6	1.3	0.6	0.4
2	15	250	>10	8.9	6.3	1.4	0.6	0.4	0.9	0.4	0.3
2	15	500	>10	5.3	3.7	0.9	0.3	0.2	0.6	0.2	0.2
2	15	750	>10	3.8	2.6	0.7	0.2	0.2	0.5	0.2	0.1
2	15	1000	8.3	2.9	2.0	0.5	0.2	0.1	0.4	0.1	0.1
2	20	130	>10	>10	8.1	1.6	0.8	0.5	1.1	0.5	0.4
2	20	250	>10	7.3	5.1	1.2	0.5	0.3	0.8	0.3	0.2
2	20	500	>10	4.2	2.9	0.8	0.3	0.2	0.5	0.2	0.1
2	20	750	8.4	2.9	2.0	0.6	0.2	0.1	0.4	0.1	0.1
2	20	1000	6.6	2.2	1.5	0.4	0.1	0.1	0.3	0.1	0.1
2	25	130	>10	>10	7.2	1.5	0.7	0.5	1.1	0.5	0.3
2	25	250	>10	6.4	4.4	1.1	0.4	0.3	0.7	0.3	0.2

AutoStim Feature Disabled Model 106											
Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
2	25	500	>10	3.6	2.4	0.7	0.2	0.2	0.5	0.2	0.1
2	25	750	7.2	2.5	1.7	0.5	0.2	0.1	0.3	0.1	0.1
2	25	1000	5.6	1.9	1.2	0.4	0.1	0.1	0.2	0.1	0.1
2	30	130	>10	9.0	6.4	1.4	0.6	0.4	1.0	0.4	0.3
2	30	250	>10	5.6	3.9	1.0	0.4	0.3	0.7	0.2	0.2
2	30	500	8.9	3.1	2.1	0.6	0.2	0.1	0.4	0.1	0.1
2	30	750	6.4	2.1	1.4	0.4	0.1	0.1	0.3	0.1	0.1
2	30	1000	4.9	1.6	1.1	0.3	0.1	0.1	0.2	0.1	0.0
2.5	10	130	>10	>10	9.9	1.8	0.9	0.7	1.3	0.6	0.4
2.5	10	250	>10	9.3	6.6	1.4	0.6	0.4	1.0	0.4	0.3
2.5	10	500	>10	5.8	4.0	1.0	0.4	0.3	0.6	0.2	0.2
2.5	10	750	>10	4.1	2.8	0.7	0.3	0.2	0.5	0.2	0.1
2.5	10	1000	9.1	3.2	2.2	0.6	0.2	0.1	0.4	0.1	0.1
2.5	15	130	>10	>10	8.0	1.6	0.7	0.5	1.1	0.5	0.3
2.5	15	250	>10	7.2	5.0	1.2	0.5	0.3	0.8	0.3	0.2
2.5	15	500	>10	4.2	2.9	0.8	0.3	0.2	0.5	0.2	0.1
2.5	15	750	8.5	2.9	2.0	0.5	0.2	0.1	0.4	0.1	0.1
2.5	15	1000	6.7	2.3	1.5	0.4	0.1	0.1	0.3	0.1	0.1
2.5	20	130	>10	9.3	6.6	1.4	0.6	0.4	1.0	0.4	0.3
2.5	20	250	>10	5.8	4.0	1.0	0.4	0.3	0.7	0.3	0.2
2.5	20	500	9.3	3.3	2.2	0.6	0.2	0.1	0.4	0.1	0.1
2.5	20	750	6.8	2.3	1.5	0.4	0.1	0.1	0.3	0.1	0.1
2.5	20	1000	5.3	1.7	1.2	0.3	0.1	0.1	0.2	0.1	0.0
2.5	25	130	>10	8.1	5.7	1.3	0.5	0.4	0.9	0.4	0.3
2.5	25	250	>10	4.9	3.4	0.9	0.3	0.2	0.6	0.2	0.1
2.5	25	500	7.9	2.7	1.8	0.5	0.2	0.1	0.4	0.1	0.1
2.5	25	750	5.7	1.9	1.3	0.4	0.1	0.1	0.3	0.1	0.1
2.5	25	1000	4.4	1.4	1.0	0.3	0.1	0.1	0.2	0.1	0.0
2.5	30	130	>10	7.2	5.1	1.2	0.5	0.3	0.8	0.3	0.2
2.5	30	250	>10	4.3	2.9	0.8	0.3	0.2	0.5	0.2	0.1
2.5	30	500	7.0	2.4	1.6	0.5	0.2	0.1	0.3	0.1	0.1
2.5	30	750	4.9	1.6	1.1	0.3	0.1	0.1	0.2	0.1	0.0
2.5	30	1000	3.8	1.2	0.8	0.2	0.1	0.1	0.2	0.1	0.0

AutoStim Feature Disabled Model 106											
Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
3	10	130	>10	>10	8.4	1.7	0.8	0.6	1.1	0.5	0.4
3	10	250	>10	7.5	5.3	1.2	0.5	0.3	0.8	0.3	0.2
3	10	500	>10	4.4	3.0	0.8	0.3	0.2	0.5	0.2	0.1
3	10	750	8.6	3.0	2.0	0.6	0.2	0.1	0.4	0.1	0.1
3	10	1000	6.8	2.3	1.5	0.4	0.1	0.1	0.3	0.1	0.1
3	15	130	>10	9.3	6.6	1.4	0.6	0.4	1.0	0.4	0.3
3	15	250	>10	5.7	3.9	1.0	0.4	0.3	0.7	0.2	0.2
3	15	500	9.0	3.2	2.1	0.6	0.2	0.1	0.4	0.1	0.1
3	15	750	6.4	2.2	1.5	0.4	0.1	0.1	0.3	0.1	0.1
3	15	1000	5.0	1.6	1.1	0.3	0.1	0.1	0.2	0.1	0.0
3	20	130	>10	7.7	5.4	1.2	0.5	0.4	0.8	0.3	0.2
3	20	250	>10	4.6	3.1	0.8	0.3	0.2	0.5	0.2	0.1
3	20	500	7.3	2.5	1.7	0.5	0.2	0.1	0.3	0.1	0.1
3	20	750	5.1	1.7	1.1	0.3	0.1	0.1	0.2	0.1	0.0
3	20	1000	3.9	1.3	0.8	0.3	0.1	0.1	0.2	0.1	0.0
3	25	130	>10	6.6	4.6	1.1	0.4	0.3	0.8	0.3	0.2
3	25	250	>10	3.9	2.6	0.7	0.2	0.2	0.5	0.2	0.1
3	25	500	6.1	2.1	1.4	0.4	0.1	0.1	0.3	0.1	0.1
3	25	750	4.3	1.4	0.9	0.3	0.1	0.1	0.2	0.1	0.0
3	25	1000	3.3	1.0	0.7	0.2	0.1	0.0	0.1	0.0	0.0
3	30	130	>10	5.8	4.0	1.0	0.4	0.3	0.7	0.3	0.2
3	30	250	9.3	3.3	2.2	0.6	0.2	0.1	0.4	0.1	0.1
3	30	500	5.3	1.7	1.2	0.3	0.1	0.1	0.2	0.1	0.0
3	30	750	3.7	1.2	0.8	0.2	0.1	0.0	0.2	0.0	0.0
3	30	1000	2.8	0.9	0.6	0.2	0.1	0.0	0.1	0.0	0.0
3.5	10	130	>10	7.2	5.1	1.3	0.5	0.4	0.9	0.4	0.3
3.5	10	250	>10	4.7	3.2	0.9	0.3	0.2	0.6	0.2	0.2
3.5	10	500	7.3	2.5	1.7	0.5	0.2	0.1	0.4	0.1	0.1
3.5	10	750	5.3	1.7	1.2	0.4	0.1	0.1	0.2	0.1	0.1
3.5	10	1000	4.5	1.4	1.0	0.3	0.1	0.1	0.2	0.1	0.0
3.5	15	130	>10	6.1	4.2	1.1	0.4	0.3	0.8	0.3	0.2
3.5	15	250	>10	3.7	2.5	0.7	0.3	0.2	0.5	0.2	0.1
3.5	15	500	5.9	2.0	1.3	0.4	0.1	0.1	0.3	0.1	0.1

AutoStim Feature Disabled Model 106											
Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
3.5	15	750	4.2	1.4	0.9	0.3	0.1	0.1	0.2	0.1	0.0
3.5	15	1000	3.4	1.1	0.7	0.2	0.1	0.0	0.2	0.0	0.0
3.5	20	130	>10	5.2	3.6	1.0	0.4	0.2	0.7	0.3	0.2
3.5	20	250	8.9	3.1	2.1	0.6	0.2	0.1	0.4	0.1	0.1
3.5	20	500	5.0	1.6	1.1	0.3	0.1	0.1	0.2	0.1	0.0
3.5	20	750	3.5	1.1	0.7	0.2	0.1	0.0	0.2	0.0	0.0
3.5	20	1000	2.8	0.9	0.6	0.2	0.1	0.0	0.1	0.0	0.0
3.5	25	130	>10	4.6	3.1	0.9	0.3	0.2	0.6	0.2	0.1
3.5	25	250	7.7	2.7	1.8	0.5	0.2	0.1	0.3	0.1	0.1
3.5	25	500	4.3	1.4	0.9	0.3	0.1	0.1	0.2	0.1	0.0
3.5	25	750	2.9	0.9	0.6	0.2	0.1	0.0	0.1	0.0	0.0
3.5	25	1000	2.4	0.7	0.5	0.2	0.0	0.0	0.1	0.0	0.0
3.5	30	130	>10	4.1	2.8	0.8	0.3	0.2	0.5	0.2	0.1
3.5	30	250	6.8	2.3	1.6	0.5	0.2	0.1	0.3	0.1	0.1
3.5	30	500	3.7	1.2	0.8	0.2	0.1	0.1	0.2	0.1	0.0
3.5	30	750	2.6	0.8	0.5	0.2	0.1	0.0	0.1	0.0	0.0
3.5	30	1000	2.0	0.6	0.4	0.1	0.0	0.0	0.1	0.0	0.0

10.2.2. AutoStim Feature Enabled

10.2.2.1. One AutoStim / Hour and AutoStim ON Time 60 Seconds

AutoStim Feature Enabled (1 AutoStim / Hour; AutoStim ON Time 60 Seconds) Model 106								
Parameters at 3 kΩ			Normal ModeDuty Cycle					
			10% (30s ON / 5 min OFF)			35% (30s ON / 1.1 min OFF)		
			BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS
mA	Hz	µS	Years	Years	Years	Years	Years	Years
0.5	20	250	10.2	0.8	0.6	10.6	0.8	0.6
0.5	20	500	9.8	0.7	0.5	9.4	0.7	0.5
0.5	30	250	9.9	0.7	0.5	9.7	0.7	0.5
0.5	30	500	9.3	0.7	0.5	8.2	0.6	0.5
1	20	250	9.8	0.7	0.5	9.4	0.7	0.5
1	20	500	9.1	0.7	0.5	7.6	0.5	0.4
1	30	250	9.3	0.7	0.5	8.2	0.6	0.4
1	30	500	8.4	0.6	0.4	6.3	0.5	0.3
1.5	20	250	8.9	0.6	0.5	7.2	0.5	0.3
1.5	20	500	7.7	0.5	0.4	5.2	0.3	0.2
1.5	30	250	8.4	0.6	0.4	6.3	0.4	0.3
1.5	30	500	7.0	0.5	0.3	4.2	0.3	0.2
2	20	250	7.7	0.6	0.4	5.2	0.4	0.2
2	20	500	6.2	0.4	0.3	3.4	0.2	0.2
2	30	250	7.0	0.5	0.3	4.3	0.3	0.2
2	30	500	5.3	0.4	0.3	2.6	0.2	0.1
2.5	20	250	7.1	0.5	0.4	4.4	0.3	0.2
2.5	20	500	5.4	0.4	0.3	2.7	0.2	0.1
2.5	30	250	6.2	0.4	0.3	3.4	0.2	0.2
2.5	30	500	4.5	0.3	0.2	2.0	0.1	0.1
3	20	250	6.4	0.4	0.3	3.6	0.2	0.2
3	20	500	4.6	0.3	0.2	2.1	0.1	0.1
3	30	250	5.4	0.4	0.3	2.7	0.2	0.1
3	30	500	3.7	0.2	0.2	1.6	0.1	0.1
3.5	20	250	5.3	0.4	0.3	2.6	0.2	0.1
3.5	20	500	3.5	0.2	0.2	1.5	0.1	0.1
3.5	30	250	4.4	0.3	0.2	2.0	0.1	0.1
3.5	30	500	2.8	0.2	0.1	1.1	0.1	0.0

10.2.2.2. One AutoStim / Hour and AutoStim ON Time 30 Seconds

AutoStim Feature Enabled (1 AutoStim / Hour; AutoStim ON Time 30 Seconds) Model 106								
Parameters at 3 kΩ			Normal ModeDuty Cycle					
			10% (30s ON / 5 min OFF)			35% (30s ON / 1.1 min OFF)		
			BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS
mA	Hz	µS	Years	Years	Years	Years	Years	Years
0.5	20	250	10.2	0.8	0.6	10.6	0.8	0.6
0.5	20	500	9.8	0.7	0.5	9.4	0.7	0.5
0.5	30	250	9.9	0.7	0.5	9.7	0.7	0.5
0.5	30	500	9.4	0.7	0.5	8.2	0.6	0.5
1	20	250	9.8	0.7	0.5	9.4	0.7	0.5
1	20	500	9.1	0.7	0.5	7.6	0.5	0.4
1	30	250	9.4	0.7	0.5	8.2	0.6	0.4
1	30	500	8.5	0.6	0.4	6.3	0.5	0.3
1.5	20	250	9.0	0.6	0.5	7.3	0.5	0.3
1.5	20	500	7.8	0.6	0.4	5.2	0.3	0.2
1.5	30	250	8.5	0.6	0.4	6.3	0.4	0.3
1.5	30	500	7.1	0.5	0.3	4.3	0.3	0.2
2	20	250	7.8	0.6	0.4	5.2	0.4	0.2
2	20	500	6.3	0.4	0.3	3.4	0.2	0.2
2	30	250	7.2	0.5	0.4	4.3	0.3	0.2
2	30	500	5.5	0.4	0.3	2.7	0.2	0.1
2.5	20	250	7.3	0.5	0.4	4.4	0.3	0.2
2.5	20	500	5.6	0.4	0.3	2.8	0.2	0.1
2.5	30	250	6.4	0.4	0.3	3.5	0.2	0.2
2.5	30	500	4.6	0.3	0.2	2.1	0.1	0.1
3	20	250	6.6	0.5	0.3	3.7	0.2	0.2
3	20	500	4.8	0.3	0.2	2.2	0.1	0.1
3	30	250	5.6	0.4	0.3	2.8	0.2	0.1
3	30	500	3.8	0.3	0.2	1.6	0.1	0.1
3.5	20	250	5.4	0.4	0.3	2.6	0.2	0.1
3.5	20	500	3.7	0.3	0.2	1.5	0.1	0.1
3.5	30	250	4.6	0.3	0.2	2.0	0.1	0.1
3.5	30	500	2.9	0.2	0.1	1.1	0.1	0.0

10.2.2.3. Seven AutoStims / Hour and AutoStim ON Time 60 Seconds

AutoStim Feature Enabled (7 AutoStims / Hour; AutoStim ON Time 60 Seconds) Model 106								
Parameters at 3 kΩ			Normal ModeDuty Cycle					
			10% (30s ON / 5 min OFF)			35% (30s ON/1.1 min OFF)		
			BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS
mA	Hz	µS	Years	Years	Years	Years	Years	Years
0.5	20	250	10.3	0.8	0.6	10.8	0.8	0.6
0.5	20	500	9.7	0.7	0.5	9.3	0.7	0.5
0.5	30	250	9.8	0.7	0.5	9.6	0.7	0.5
0.5	30	500	9.0	0.7	0.5	8.0	0.6	0.4
1	20	250	9.7	0.7	0.5	9.3	0.7	0.5
1	20	500	8.6	0.6	0.4	7.3	0.5	0.3
1	30	250	9.0	0.7	0.5	8.0	0.6	0.4
1	30	500	7.6	0.6	0.4	5.9	0.4	0.3
1.5	20	250	8.3	0.6	0.4	6.9	0.5	0.3
1.5	20	500	6.7	0.5	0.3	4.8	0.3	0.2
1.5	30	250	7.6	0.5	0.4	5.9	0.4	0.3
1.5	30	500	5.8	0.4	0.3	3.9	0.3	0.2
2	20	250	6.7	0.5	0.3	4.8	0.3	0.2
2	20	500	5.0	0.3	0.2	3.1	0.2	0.1
2	30	250	5.9	0.4	0.3	3.9	0.3	0.2
2	30	500	4.1	0.3	0.2	2.4	0.2	0.1
2.5	20	250	6.0	0.4	0.3	4.0	0.3	0.2
2.5	20	500	4.2	0.3	0.2	2.5	0.2	0.1
2.5	30	250	5.0	0.3	0.2	3.1	0.2	0.1
2.5	30	500	3.3	0.2	0.2	1.8	0.1	0.1
3	20	250	5.2	0.4	0.2	3.3	0.2	0.1
3	20	500	3.4	0.2	0.2	1.9	0.1	0.1
3	30	250	4.2	0.3	0.2	2.5	0.2	0.1
3	30	500	2.6	0.2	0.1	1.4	0.1	0.1
3.5	20	250	4.0	0.3	0.2	2.3	0.2	0.1
3.5	20	500	2.5	0.2	0.1	1.3	0.1	0.1
3.5	30	250	3.3	0.2	0.1	1.8	0.1	0.1
3.5	30	500	1.9	0.1	0.1	1.0	0.1	0.0

10.2.2.4. Seven AutoStims / Hour and AutoStim ON Time 30 Seconds

AutoStim Feature Enabled (7 AutoStims / Hour; AutoStim ON Time 30 Seconds) Model 106								
Parameters at 3 kΩ			Normal ModeDuty Cycle					
			10% (30s ON / 5 min OFF)			35% (30s ON/1.1 min OFF)		
			BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS
mA	Hz	µS	Years	Years	Years	Years	Years	Years
0.5	20	250	10.2	0.8	0.6	10.7	0.8	0.6
0.5	20	500	9.8	0.7	0.5	9.4	0.7	0.5
0.5	30	250	9.9	0.7	0.5	9.7	0.7	0.5
0.5	30	500	9.2	0.7	0.5	8.1	0.6	0.5
1	20	250	9.8	0.7	0.5	9.4	0.7	0.5
1	20	500	8.9	0.7	0.5	7.5	0.5	0.4
1	30	250	9.3	0.7	0.5	8.2	0.6	0.4
1	30	500	8.2	0.6	0.4	6.2	0.4	0.3
1.5	20	250	8.8	0.6	0.4	7.1	0.5	0.3
1.5	20	500	7.4	0.5	0.4	5.1	0.3	0.2
1.5	30	250	8.2	0.6	0.4	6.2	0.4	0.3
1.5	30	500	6.6	0.5	0.3	4.1	0.3	0.2
2	20	250	7.5	0.5	0.4	5.1	0.3	0.2
2	20	500	5.8	0.4	0.3	3.3	0.2	0.1
2	30	250	6.7	0.5	0.3	4.2	0.3	0.2
2	30	500	4.9	0.3	0.2	2.6	0.2	0.1
2.5	20	250	6.8	0.5	0.3	4.3	0.3	0.2
2.5	20	500	5.1	0.3	0.2	2.7	0.2	0.1
2.5	30	250	5.9	0.4	0.3	3.4	0.2	0.2
2.5	30	500	4.1	0.3	0.2	2.0	0.1	0.1
3	20	250	6.1	0.4	0.3	3.5	0.2	0.2
3	20	500	4.3	0.3	0.2	2.1	0.1	0.1
3	30	250	5.1	0.3	0.2	2.7	0.2	0.1
3	30	500	3.3	0.2	0.2	1.5	0.1	0.1
3.5	20	250	4.9	0.3	0.2	2.5	0.2	0.1
3.5	20	500	3.2	0.2	0.2	1.4	0.1	0.1
3.5	30	250	4.1	0.3	0.2	2.0	0.1	0.1
3.5	30	500	2.5	0.2	0.1	1.1	0.1	0.0

10.2.2.5. Fifteen AutoStims / Hour and AutoStim ON Time 60 Seconds

AutoStim Feature Enabled (15 AutoStims / Hour; AutoStim ON Time 60 Seconds) Model 106								
Parameters at 3 kΩ			Normal ModeDuty Cycle					
			10% (30s ON / 5 min OFF)			35% (30s ON / 1.1 min OFF)		
			BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS
mA	Hz	µS	Years	Years	Years	Years	Years	Years
0.5	20	250	10.5	0.8	0.6	10.9	0.8	0.6
0.5	20	500	9.5	0.7	0.5	9.2	0.7	0.5
0.5	30	250	9.7	0.7	0.5	9.6	0.7	0.5
0.5	30	500	8.5	0.6	0.5	7.7	0.6	0.4
1	20	250	9.5	0.7	0.5	9.2	0.7	0.4
1	20	500	8.0	0.6	0.4	7.0	0.5	0.3
1	30	250	8.5	0.6	0.4	7.7	0.6	0.4
1	30	500	6.8	0.5	0.3	5.5	0.4	0.3
1.5	20	250	7.7	0.5	0.4	6.6	0.4	0.3
1.5	20	500	5.7	0.4	0.3	4.4	0.3	0.2
1.5	30	250	6.8	0.5	0.3	5.5	0.4	0.2
1.5	30	500	4.8	0.3	0.2	3.5	0.2	0.2
2	20	250	5.8	0.4	0.3	4.4	0.3	0.2
2	20	500	3.9	0.3	0.2	2.8	0.2	0.1
2	30	250	4.8	0.3	0.2	3.5	0.2	0.2
2	30	500	3.1	0.2	0.1	2.1	0.1	0.1
2.5	20	250	5.0	0.3	0.2	3.7	0.2	0.2
2.5	20	500	3.2	0.2	0.1	2.2	0.1	0.1
2.5	30	250	4.0	0.3	0.2	2.8	0.2	0.1
2.5	30	500	2.5	0.2	0.1	1.6	0.1	0.1
3	20	250	4.2	0.3	0.2	3.0	0.2	0.1
3	20	500	2.6	0.2	0.1	1.7	0.1	0.1
3	30	250	3.2	0.2	0.1	2.2	0.1	0.1
3	30	500	1.9	0.1	0.1	1.2	0.1	0.1
3.5	20	250	3.1	0.2	0.1	2.1	0.1	0.1
3.5	20	500	1.8	0.1	0.1	1.1	0.1	0.1
3.5	30	250	2.4	0.2	0.1	1.6	0.1	0.1
3.5	30	500	1.3	0.1	0.1	0.8	0.1	0.0

10.2.2.6. Fifteen AutoStims / Hour and AutoStim ON Time 30 Seconds

AutoStim Feature Enabled (15 AutoStims / Hour; AutoStim ON Time 30 Seconds) Model 106								
Parameters at 3 kΩ			Normal ModeDuty Cycle					
			10% (30s ON / 5 min OFF)			35% (30s ON / 1.1 min OFF)		
			BOL to IFI	IFI to NEOS	NEOS to EOS	BOL to IFI	IFI to NEOS	NEOS to EOS
mA	Hz	µS	Years	Years	Years	Years	Years	Years
0.5	20	250	10.3	0.8	0.6	10.7	0.8	0.6
0.5	20	500	9.7	0.7	0.5	9.3	0.7	0.5
0.5	30	250	9.8	0.7	0.5	9.7	0.7	0.5
0.5	30	500	9.1	0.7	0.5	8.0	0.6	0.4
1	20	250	9.7	0.7	0.5	9.3	0.7	0.5
1	20	500	8.7	0.6	0.4	7.4	0.5	0.4
1	30	250	9.1	0.7	0.5	8.1	0.6	0.4
1	30	500	7.8	0.6	0.4	6.0	0.4	0.3
1.5	20	250	8.5	0.6	0.4	7.0	0.5	0.3
1.5	20	500	7.0	0.5	0.3	4.9	0.3	0.2
1.5	30	250	7.8	0.5	0.4	6.0	0.4	0.3
1.5	30	500	6.1	0.4	0.3	4.0	0.3	0.2
2	20	250	7.0	0.5	0.3	4.9	0.3	0.2
2	20	500	5.3	0.4	0.3	3.2	0.2	0.1
2	30	250	6.2	0.4	0.3	4.0	0.3	0.2
2	30	500	4.4	0.3	0.2	2.4	0.2	0.1
2.5	20	250	6.3	0.4	0.3	4.1	0.3	0.2
2.5	20	500	4.5	0.3	0.2	2.5	0.2	0.1
2.5	30	250	5.3	0.4	0.3	3.2	0.2	0.1
2.5	30	500	3.6	0.2	0.2	1.9	0.1	0.1
3	20	250	5.5	0.4	0.3	3.4	0.2	0.1
3	20	500	3.7	0.2	0.2	2.0	0.1	0.1
3	30	250	4.5	0.3	0.2	2.5	0.2	0.1
3	30	500	2.8	0.2	0.1	1.4	0.1	0.1
3.5	20	250	4.3	0.3	0.2	2.4	0.2	0.1
3.5	20	500	2.7	0.2	0.1	1.3	0.1	0.1
3.5	30	250	3.5	0.2	0.2	1.9	0.1	0.1
3.5	30	500	2.1	0.1	0.1	1.0	0.1	0.0

10.3. Model 105 Battery Longevity and Programmed Setting Choices

Battery Longevity and Programmed Setting Choices Model 105												
Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
0.5	10	130	>10	>10	>10	2.5	1.6	1.3	1.9	1.2	0.9
0.5	15	130	>10	>10	>10	2.5	1.5	1.2	1.8	1.1	0.9
0.5	20	130	>10	>10	>10	2.4	1.4	1.1	1.7	1.0	0.8
0.5	25	130	>10	>10	>10	2.2	1.3	1.0	1.7	1.0	0.7
0.5	30	130	>10	>10	>10	2.2	1.2	0.9	1.6	0.9	0.7
0.5	10	250	>10	>10	>10	2.5	1.6	1.3	1.9	1.2	1.0
0.5	15	250	>10	>10	>10	2.4	1.4	1.1	1.8	1.1	0.8
0.5	20	250	>10	>10	>10	2.3	1.3	1.0	1.7	1.0	0.7
0.5	25	250	>10	>10	>10	2.2	1.2	0.9	1.6	0.9	0.7
0.5	30	250	>10	>10	>10	2.1	1.1	0.8	1.5	0.8	0.6
0.5	10	500	>10	>10	>10	2.4	1.4	1.1	1.7	1.0	0.8
0.5	15	500	>10	>10	>10	2.2	1.2	0.9	1.6	0.9	0.7
0.5	20	500	>10	>10	>10	2.0	1.1	0.8	1.5	0.8	0.6
0.5	25	500	>10	>10	9.0	1.9	0.9	0.7	1.4	0.7	0.5
0.5	30	500	>10	>10	8.6	1.8	0.9	0.6	1.3	0.7	0.5
0.5	10	750	>10	>10	>10	2.2	1.3	1.0	1.7	0.9	0.7
0.5	15	750	>10	>10	>10	2.0	1.1	0.8	1.5	0.8	0.6
0.5	20	750	>10	>10	8.9	1.9	0.9	0.7	1.4	0.7	0.5
0.5	25	750	>10	>10	7.7	1.7	0.8	0.6	1.3	0.6	0.4
0.5	30	750	>10	9.6	6.8	1.6	0.7	0.5	1.2	0.5	0.4
0.5	10	1000	>10	>10	>10	2.1	1.2	0.9	1.6	0.9	0.6
0.5	15	1000	>10	>10	8.9	1.9	0.9	0.7	1.4	0.7	0.5
0.5	20	1000	>10	>10	7.3	1.7	0.8	0.6	1.2	0.6	0.4
0.5	25	1000	>10	9.2	6.5	1.5	0.7	0.5	1.1	0.5	0.4
0.5	30	1000	>10	8.0	5.7	1.4	0.6	0.4	1.0	0.4	0.3
1	10	130	>10	>10	>10	2.4	1.4	1.1	1.7	0.9	0.7
1	15	130	>10	>10	>10	2.3	1.4	1.0	1.6	0.9	0.7
1	20	130	>10	>10	>10	2.3	1.3	1.0	1.6	0.9	0.7

Battery Longevity and Programmed Setting Choices Model 105											
Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1	25	130	>10	>10	>10	2.2	1.2	0.9	1.5	0.8	0.6
1	30	130	>10	>10	>10	2.1	1.1	0.8	1.5	0.8	0.6
1	10	250	>10	>10	>10	2.2	1.2	0.9	1.5	0.8	0.6
1	15	250	>10	>10	>10	2.1	1.1	0.8	1.5	0.8	0.6
1	20	250	>10	>10	>10	2.0	1.0	0.7	1.4	0.7	0.5
1	25	250	>10	>10	9.7	1.9	0.9	0.7	1.3	0.6	0.5
1	30	250	>10	>10	8.9	1.8	0.8	0.6	1.2	0.6	0.4
1	10	500	>10	>10	>10	2.0	1.0	0.7	1.3	0.6	0.5
1	15	500	>10	>10	9.6	1.8	0.8	0.6	1.2	0.5	0.4
1	20	500	>10	>10	7.8	1.6	0.7	0.5	1.1	0.5	0.3
1	25	500	>10	9.3	6.6	1.4	0.6	0.4	1.0	0.4	0.3
1	30	500	>10	8.4	5.9	1.3	0.6	0.4	0.9	0.4	0.3
1	10	750	>10	>10	9.7	1.7	0.8	0.6	1.2	0.5	0.4
1	15	750	>10	>10	7.4	1.5	0.7	0.5	1.0	0.4	0.3
1	20	750	>10	8.6	6.0	1.3	0.6	0.4	0.9	0.4	0.3
1	25	750	>10	7.3	5.1	1.2	0.5	0.3	0.8	0.3	0.2
1	30	750	>10	6.4	4.4	1.1	0.4	0.3	0.7	0.3	0.2
1	10	1000	>10	>10	8.0	1.5	0.7	0.5	1.0	0.4	0.3
1	15	1000	>10	8.8	6.2	1.3	0.5	0.4	0.9	0.4	0.2
1	20	1000	>10	7.1	4.9	1.1	0.5	0.3	0.8	0.3	0.2
1	25	1000	>10	6.0	4.1	1.0	0.4	0.3	0.7	0.3	0.2
1	30	1000	>10	5.1	3.5	0.9	0.3	0.2	0.6	0.2	0.2
1.5	10	130	>10	>10	>10	2.0	1.1	0.8	1.5	0.7	0.6
1.5	15	130	>10	>10	>10	1.9	1.0	0.7	1.4	0.7	0.5
1.5	20	130	>10	>10	9.4	1.8	0.9	0.7	1.3	0.6	0.5
1.5	25	130	>10	>10	8.8	1.8	0.8	0.6	1.3	0.6	0.4
1.5	30	130	>10	>10	7.8	1.7	0.8	0.6	1.2	0.6	0.4
1.5	10	250	>10	>10	9.3	1.8	0.9	0.6	1.3	0.6	0.4
1.5	15	250	>10	>10	7.9	1.6	0.7	0.5	1.1	0.5	0.4
1.5	20	250	>10	>10	7.6	1.6	0.7	0.5	1.1	0.5	0.3
1.5	25	250	>10	9.1	6.5	1.4	0.6	0.4	1.0	0.4	0.3
1.5	30	250	>10	8.5	6.0	1.3	0.6	0.4	0.9	0.4	0.3
1.5	10	500	>10	9.4	6.6	1.4	0.6	0.4	1.0	0.4	0.3

Battery Longevity and Programmed Setting Choices Model 105											
Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1.5	15	500	>10	7.4	5.2	1.2	0.5	0.3	0.8	0.3	0.2
1.5	20	500	>10	6.5	4.5	1.1	0.4	0.3	0.7	0.3	0.2
1.5	25	500	>10	5.7	4.0	1.0	0.4	0.3	0.7	0.2	0.2
1.5	30	500	>10	5.1	3.5	0.9	0.3	0.2	0.6	0.2	0.1
1.5	10	750	>10	7.2	5.0	1.2	0.5	0.3	0.8	0.3	0.2
1.5	15	750	>10	5.5	3.8	1.0	0.4	0.2	0.7	0.2	0.2
1.5	20	750	>10	4.7	3.2	0.8	0.3	0.2	0.6	0.2	0.1
1.5	25	750	>10	4.0	2.7	0.7	0.3	0.2	0.5	0.2	0.1
1.5	30	750	10.0	3.6	2.4	0.7	0.2	0.2	0.4	0.2	0.1
1.5	10	1000	>10	5.7	4.0	1.0	0.4	0.3	0.7	0.2	0.2
1.5	15	1000	>10	4.3	2.9	0.8	0.3	0.2	0.5	0.2	0.1
1.5	20	1000	9.9	3.5	2.4	0.7	0.2	0.2	0.4	0.2	0.1
1.5	25	1000	8.7	3.1	2.1	0.6	0.2	0.1	0.4	0.1	0.1
1.5	30	1000	7.8	2.7	1.8	0.5	0.2	0.1	0.3	0.1	0.1
2	10	130	>10	>10	9.4	1.8	0.9	0.6	1.3	0.6	0.4
2	15	130	>10	>10	8.0	1.7	0.8	0.5	1.2	0.5	0.4
2	20	130	>10	9.8	7.0	1.5	0.7	0.5	1.1	0.5	0.3
2	25	130	>10	8.8	6.2	1.4	0.6	0.4	1.0	0.4	0.3
2	30	130	>10	8.1	5.7	1.3	0.6	0.4	0.9	0.4	0.3
2	10	250	>10	9.7	6.9	1.5	0.7	0.5	1.0	0.4	0.3
2	15	250	>10	8.2	5.7	1.3	0.5	0.4	0.9	0.4	0.3
2	20	250	>10	6.8	4.7	1.1	0.5	0.3	0.8	0.3	0.2
2	25	250	>10	5.9	4.1	1.0	0.4	0.3	0.7	0.3	0.2
2	30	250	>10	5.2	3.6	0.9	0.4	0.2	0.6	0.2	0.2
2	10	500	>10	6.5	4.5	1.1	0.4	0.3	0.7	0.3	0.2
2	15	500	>10	5.0	3.4	0.9	0.3	0.2	0.6	0.2	0.1
2	20	500	>10	4.0	2.7	0.7	0.3	0.2	0.5	0.2	0.1
2	25	500	9.6	3.4	2.3	0.7	0.2	0.2	0.4	0.2	0.1
2	30	500	8.7	3.0	2.1	0.6	0.2	0.1	0.4	0.1	0.1
2	10	750	>10	4.8	3.3	0.9	0.3	0.2	0.6	0.2	0.1
2	15	750	>10	3.6	2.4	0.7	0.2	0.2	0.4	0.2	0.1
2	20	750	8.1	2.8	1.9	0.5	0.2	0.1	0.4	0.1	0.1
2	25	750	7.0	2.4	1.6	0.5	0.2	0.1	0.3	0.1	0.1

Battery Longevity and Programmed Setting Choices Model 105											
Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
2	30	750	6.2	2.1	1.4	0.4	0.1	0.1	0.3	0.1	0.1
2	10	1000	>10	3.8	2.6	0.7	0.2	0.2	0.5	0.2	0.1
2	15	1000	8.0	2.8	1.9	0.5	0.2	0.1	0.4	0.1	0.1
2	20	1000	6.5	2.2	1.5	0.4	0.1	0.1	0.3	0.1	0.1
2	25	1000	5.5	1.8	1.2	0.4	0.1	0.1	0.2	0.1	0.1
2	30	1000	4.8	1.6	1.1	0.3	0.1	0.1	0.2	0.1	0.0
2.5	10	130	>10	>10	8.3	1.7	0.8	0.6	1.2	0.5	0.4
2.5	15	130	>10	9.6	6.8	1.5	0.6	0.5	1.0	0.4	0.3
2.5	20	130	>10	8.5	6.0	1.4	0.6	0.4	0.9	0.4	0.3
2.5	25	130	>10	7.4	5.2	1.2	0.5	0.4	0.9	0.3	0.2
2.5	30	130	>10	6.7	4.7	1.1	0.5	0.3	0.8	0.3	0.2
2.5	10	250	>10	8.3	5.9	1.3	0.6	0.4	0.9	0.4	0.3
2.5	15	250	>10	6.5	4.5	1.1	0.4	0.3	0.8	0.3	0.2
2.5	20	250	>10	5.5	3.8	1.0	0.4	0.3	0.7	0.2	0.2
2.5	25	250	>10	4.6	3.2	0.8	0.3	0.2	0.6	0.2	0.1
2.5	30	250	>10	4.1	2.8	0.8	0.3	0.2	0.5	0.2	0.1
2.5	10	500	>10	5.4	3.7	0.9	0.4	0.2	0.6	0.2	0.2
2.5	15	500	>10	4.0	2.7	0.7	0.3	0.2	0.5	0.2	0.1
2.5	20	500	9.0	3.2	2.1	0.6	0.2	0.1	0.4	0.1	0.1
2.5	25	500	7.8	2.7	1.8	0.5	0.2	0.1	0.3	0.1	0.1
2.5	30	500	6.8	2.3	1.5	0.5	0.2	0.1	0.3	0.1	0.1
2.5	10	750	>10	3.9	2.7	0.7	0.3	0.2	0.5	0.2	0.1
2.5	15	750	8.2	2.9	1.9	0.5	0.2	0.1	0.4	0.1	0.1
2.5	20	750	6.6	2.2	1.5	0.4	0.1	0.1	0.3	0.1	0.1
2.5	25	750	5.5	1.8	1.2	0.4	0.1	0.1	0.2	0.1	0.1
2.5	30	750	4.9	1.6	1.1	0.3	0.1	0.1	0.2	0.1	0.0
2.5	10	1000	8.8	3.1	2.1	0.6	0.2	0.1	0.4	0.1	0.1
2.5	15	1000	6.5	2.2	1.5	0.4	0.1	0.1	0.3	0.1	0.1
2.5	20	1000	5.2	1.7	1.1	0.3	0.1	0.1	0.2	0.1	0.0
2.5	25	1000	4.3	1.4	0.9	0.3	0.1	0.1	0.2	0.1	0.0
2.5	30	1000	3.7	1.2	0.8	0.2	0.1	0.1	0.2	0.1	0.0
3	10	130	>10	>10	7.3	1.5	0.7	0.5	1.1	0.5	0.3
3	15	130	>10	8.5	6.0	1.3	0.6	0.4	0.9	0.4	0.3

Battery Longevity and Programmed Setting Choices Model 105											
Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
3	20	130	>10	7.4	5.1	1.2	0.5	0.3	0.8	0.3	0.2
3	25	130	>10	6.2	4.3	1.1	0.4	0.3	0.7	0.3	0.2
3	30	130	>10	5.5	3.8	1.0	0.4	0.3	0.7	0.2	0.2
3	10	250	>10	6.9	4.8	1.2	0.5	0.3	0.8	0.3	0.2
3	15	250	>10	5.3	3.7	0.9	0.4	0.2	0.6	0.2	0.2
3	20	250	>10	4.4	3.0	0.8	0.3	0.2	0.5	0.2	0.1
3	25	250	>10	3.7	2.5	0.7	0.2	0.2	0.5	0.2	0.1
3	30	250	9.2	3.2	2.2	0.6	0.2	0.1	0.4	0.1	0.1
3	10	500	>10	4.1	2.8	0.8	0.3	0.2	0.5	0.2	0.1
3	15	500	8.7	3.1	2.1	0.6	0.2	0.1	0.4	0.1	0.1
3	20	500	7.1	2.4	1.6	0.5	0.2	0.1	0.3	0.1	0.1
3	25	500	6.1	2.0	1.4	0.4	0.1	0.1	0.3	0.1	0.1
3	30	500	5.3	1.7	1.2	0.3	0.1	0.1	0.2	0.1	0.0
3	10	750	8.4	2.9	2.0	0.6	0.2	0.1	0.4	0.1	0.1
3	15	750	6.3	2.1	1.4	0.4	0.1	0.1	0.3	0.1	0.1
3	20	750	5.1	1.7	1.1	0.3	0.1	0.1	0.2	0.1	0.0
3	25	750	4.2	1.4	0.9	0.3	0.1	0.1	0.2	0.1	0.0
3	30	750	3.6	1.2	0.8	0.2	0.1	0.1	0.2	0.0	0.0
3	10	1000	6.6	2.2	1.5	0.4	0.1	0.1	0.3	0.1	0.1
3	15	1000	4.9	1.6	1.1	0.3	0.1	0.1	0.2	0.1	0.0
3	20	1000	3.9	1.3	0.8	0.3	0.1	0.1	0.2	0.1	0.0
3	25	1000	3.2	1.0	0.7	0.2	0.1	0.0	0.1	0.0	0.0
3	30	1000	2.7	0.9	0.6	0.2	0.1	0.0	0.1	0.0	0.0
3.5	10	130	>10	6.7	4.7	1.2	0.5	0.3	0.9	0.4	0.2
3.5	15	130	>10	6.0	4.1	1.1	0.4	0.3	0.8	0.3	0.2
3.5	20	130	>10	5.0	3.4	0.9	0.4	0.2	0.7	0.2	0.2
3.5	25	130	>10	4.6	3.1	0.8	0.3	0.2	0.6	0.2	0.1
3.5	30	130	>10	4.1	2.8	0.8	0.3	0.2	0.5	0.2	0.1
3.5	10	250	>10	4.6	3.1	0.9	0.3	0.2	0.6	0.2	0.1
3.5	15	250	>10	3.6	2.5	0.7	0.2	0.2	0.5	0.2	0.1
3.5	20	250	8.7	3.0	2.1	0.6	0.2	0.1	0.4	0.1	0.1
3.5	25	250	7.5	2.6	1.7	0.5	0.2	0.1	0.3	0.1	0.1
3.5	30	250	6.7	2.3	1.5	0.5	0.2	0.1	0.3	0.1	0.1

Battery Longevity and Programmed Setting Choices Model 105											
Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
3.5	10	500	7.2	2.4	1.6	0.5	0.2	0.1	0.4	0.1	0.1
3.5	15	500	5.9	2.0	1.3	0.4	0.1	0.1	0.3	0.1	0.1
3.5	20	500	5.0	1.6	1.1	0.3	0.1	0.1	0.2	0.1	0.0
3.5	25	500	4.3	1.4	0.9	0.3	0.1	0.1	0.2	0.1	0.0
3.5	30	500	3.7	1.2	0.8	0.2	0.1	0.1	0.2	0.1	0.0
3.5	10	750	5.2	1.7	1.1	0.4	0.1	0.1	0.3	0.1	0.1
3.5	15	750	4.1	1.3	0.9	0.3	0.1	0.1	0.2	0.1	0.0
3.5	20	750	3.4	1.1	0.7	0.2	0.1	0.0	0.2	0.0	0.0
3.5	25	750	3.0	0.9	0.6	0.2	0.1	0.0	0.1	0.0	0.0
3.5	30	750	2.6	0.8	0.5	0.2	0.1	0.0	0.1	0.0	0.0
3.5	10	1000	4.4	1.4	1.0	0.3	0.1	0.1	0.2	0.1	0.0
3.5	15	1000	3.4	1.1	0.7	0.2	0.1	0.0	0.2	0.0	0.0
3.5	20	1000	2.8	0.9	0.6	0.2	0.1	0.0	0.1	0.0	0.0
3.5	25	1000	2.3	0.7	0.5	0.2	0.0	0.0	0.1	0.0	0.0
3.5	30	1000	2.0	0.6	0.4	0.1	0.0	0.0	0.1	0.0	0.0

10.4. Model 103 / Model 104 Battery Longevity and Programmed Setting Choices

Battery Longevity and Programmed Setting Choices Model 103 Model 104											
Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
0.5	10	130	>10	>10	>10	2.8	2.5	2.4	2.2	2.0	1.9
0.5	15	130	>10	>10	>10	2.7	2.2	1.9	2.1	1.7	1.5
0.5	20	130	>10	>10	>10	2.5	1.9	1.7	2.0	1.5	1.3
0.5	25	130	>10	>10	>10	2.4	1.7	1.4	1.9	1.4	1.2
0.5	30	130	>10	>10	9.5	2.3	1.6	1.3	1.8	1.3	1.0
0.5	10	250	>10	>10	>10	2.7	2.3	2.0	2.1	1.8	1.6
0.5	15	250	>10	>10	>10	2.5	1.9	1.6	2.0	1.5	1.3
0.5	20	250	>10	>10	>10	2.4	1.7	1.4	1.9	1.3	1.1
0.5	25	250	>10	>10	8.7	2.3	1.5	1.2	1.8	1.2	0.9
0.5	30	250	>10	9.8	7.6	2.1	1.3	1.0	1.7	1.0	0.8
0.5	10	500	>10	>10	>10	2.5	1.9	1.6	1.9	1.5	1.2
0.5	15	500	>10	>10	8.9	2.3	1.5	1.2	1.8	1.2	0.9
0.5	20	500	>10	9.3	7.2	2.1	1.2	1.0	1.6	1.0	0.8
0.5	25	500	>10	8.1	6.1	1.9	1.1	0.8	1.5	0.9	0.6
0.5	30	500	>10	7.1	5.2	1.8	0.9	0.7	1.4	0.8	0.6
0.5	10	750	>10	>10	9.4	2.3	1.6	1.3	1.8	1.2	1.0
0.5	15	750	>10	9.1	7.0	2.1	1.2	0.9	1.6	1.0	0.7
0.5	20	750	>10	7.5	5.6	1.9	1.0	0.7	1.5	0.8	0.6
0.5	25	750	>10	6.4	4.7	1.7	0.9	0.6	1.3	0.7	0.5
0.5	30	750	>10	5.5	4.0	1.5	0.7	0.5	1.2	0.6	0.4
0.5	10	1000	>10	>10	7.9	2.2	1.4	1.1	1.7	1.1	0.8
0.5	15	1000	>10	7.7	5.8	1.9	1.0	0.8	1.5	0.8	0.6
0.5	20	1000	>10	6.3	4.6	1.7	0.8	0.6	1.3	0.7	0.5
0.5	25	1000	>10	5.3	3.8	1.5	0.7	0.5	1.2	0.6	0.4
0.5	30	1000	>10	4.6	3.2	1.4	0.6	0.4	1.1	0.5	0.3
1	10	130	>10	>10	>10	2.6	2.1	1.9	2.0	1.5	1.3
1	15	130	>10	>10	>10	2.5	1.9	1.6	1.9	1.4	1.1

Battery Longevity and Programmed Setting Choices
Model 103
Model 104

Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1	20	130	>10	>10	>10	2.4	1.6	1.3	1.8	1.2	0.9
1	25	130	>10	>10	9.3	2.2	1.5	1.2	1.7	1.1	0.8
1	30	130	>10	>10	8.2	2.1	1.3	1.0	1.6	1.0	0.8
1	10	250	>10	>10	>10	2.4	1.7	1.4	1.8	1.3	1.0
1	15	250	>10	>10	8.9	2.2	1.4	1.1	1.7	1.1	0.9
1	20	250	>10	9.4	7.2	2.1	1.2	0.9	1.6	0.9	0.7
1	25	250	>10	8.1	6.1	1.9	1.1	0.8	1.5	0.8	0.6
1	30	250	>10	7.1	5.3	1.8	0.9	0.7	1.4	0.7	0.5
1	10	500	>10	>10	7.9	2.1	1.2	1.0	1.5	0.9	0.7
1	15	500	>10	7.8	5.8	1.8	1.0	0.7	1.4	0.7	0.5
1	20	500	>10	6.3	4.6	1.6	0.8	0.6	1.2	0.6	0.4
1	25	500	>10	5.3	3.8	1.5	0.7	0.5	1.1	0.5	0.4
1	30	500	>10	4.6	3.2	1.3	0.6	0.4	1.0	0.4	0.3
1	10	750	>10	8.0	6.0	1.8	1.0	0.7	1.3	0.7	0.5
1	15	750	>10	6.0	4.3	1.5	0.7	0.5	1.1	0.5	0.4
1	20	750	>10	4.7	3.4	1.3	0.6	0.4	1.0	0.4	0.3
1	25	750	9.3	3.9	2.8	1.2	0.5	0.3	0.9	0.4	0.3
1	30	750	8.3	3.4	2.3	1.1	0.4	0.3	0.8	0.3	0.2
1	10	1000	>10	6.6	4.9	1.6	0.8	0.6	1.2	0.5	0.4
1	15	1000	>10	4.8	3.4	1.3	0.6	0.4	1.0	0.4	0.3
1	20	1000	9.0	3.8	2.7	1.1	0.5	0.3	0.8	0.3	0.2
1	25	1000	7.8	3.1	2.2	1.0	0.4	0.3	0.7	0.3	0.2
1	30	1000	6.9	2.7	1.8	0.9	0.3	0.2	0.6	0.2	0.2
1.5	10	130	>10	>10	8.8	2.2	1.4	1.1	1.6	1.0	0.8
1.5	15	130	>10	>10	7.9	2.1	1.3	1.0	1.6	0.9	0.7
1.5	20	130	>10	9.3	7.1	2.0	1.1	0.9	1.5	0.8	0.6
1.5	25	130	>10	8.3	6.3	1.9	1.0	0.8	1.4	0.7	0.5
1.5	30	130	>10	7.6	5.7	1.8	0.9	0.7	1.3	0.6	0.5
1.5	10	250	>10	>10	8.8	2.1	1.3	1.0	1.5	0.8	0.6
1.5	15	250	>10	8.9	6.8	1.9	1.0	0.8	1.3	0.7	0.5
1.5	20	250	>10	7.5	5.6	1.7	0.9	0.6	1.2	0.6	0.4
1.5	25	250	>10	6.4	4.7	1.6	0.8	0.5	1.1	0.5	0.4

Battery Longevity and Programmed Setting Choices
Model 103
Model 104

Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1.5	30	250	>10	5.6	4.0	1.4	0.7	0.5	1.0	0.5	0.3
1.5	10	500	>10	7.3	5.4	1.7	0.8	0.6	1.2	0.6	0.4
1.5	15	500	>10	5.7	4.1	1.4	0.7	0.5	1.0	0.4	0.3
1.5	20	500	>10	4.7	3.3	1.2	0.5	0.4	0.9	0.4	0.2
1.5	25	500	9.2	3.9	2.7	1.1	0.4	0.3	0.8	0.3	0.2
1.5	30	500	8.2	3.3	2.3	1.0	0.4	0.3	0.7	0.3	0.2
1.5	10	750	>10	5.3	3.8	1.4	0.6	0.4	0.9	0.4	0.3
1.5	15	750	9.5	4.1	2.9	1.1	0.5	0.3	0.8	0.3	0.2
1.5	20	750	8.1	3.3	2.3	1.0	0.4	0.3	0.6	0.2	0.2
1.5	25	750	7.0	2.7	1.9	0.8	0.3	0.2	0.6	0.2	0.1
1.5	30	750	6.2	2.3	1.6	0.7	0.3	0.2	0.5	0.2	0.1
1.5	10	1000	9.7	4.2	3.0	1.1	0.5	0.3	0.8	0.3	0.2
1.5	15	1000	7.8	3.1	2.2	0.9	0.4	0.2	0.6	0.2	0.2
1.5	20	1000	6.5	2.5	1.7	0.8	0.3	0.2	0.5	0.2	0.1
1.5	25	1000	5.6	2.1	1.4	0.7	0.2	0.2	0.4	0.2	0.1
1.5	30	1000	4.9	1.8	1.2	0.6	0.2	0.1	0.4	0.1	0.1
2	10	130	>10	8.7	6.6	1.9	1.1	0.8	1.4	0.7	0.5
2	15	130	>10	7.2	5.3	1.7	0.9	0.6	1.2	0.6	0.4
2	20	130	>10	6.2	4.5	1.6	0.8	0.5	1.1	0.5	0.4
2	25	130	>10	5.5	4.0	1.4	0.7	0.5	1.0	0.5	0.3
2	30	130	>10	5.0	3.5	1.3	0.6	0.4	1.0	0.4	0.3
2	10	250	>10	6.4	4.7	1.6	0.8	0.6	1.2	0.5	0.4
2	15	250	>10	5.2	3.8	1.4	0.6	0.4	1.0	0.4	0.3
2	20	250	>10	4.4	3.1	1.2	0.5	0.4	0.9	0.4	0.3
2	25	250	9.1	3.8	2.7	1.1	0.5	0.3	0.8	0.3	0.2
2	30	250	8.3	3.4	2.3	1.0	0.4	0.3	0.7	0.3	0.2
2	10	500	9.5	4.1	2.9	1.2	0.5	0.3	0.8	0.3	0.2
2	15	500	7.8	3.1	2.2	1.0	0.4	0.3	0.7	0.3	0.2
2	20	500	6.7	2.6	1.8	0.8	0.3	0.2	0.6	0.2	0.1
2	25	500	5.9	2.2	1.5	0.7	0.3	0.2	0.5	0.2	0.1
2	30	500	5.2	1.9	1.3	0.6	0.2	0.1	0.4	0.1	0.1
2	10	750	7.5	2.9	2.0	0.9	0.3	0.2	0.6	0.2	0.2

Battery Longevity and Programmed Setting Choices
Model 103
Model 104

Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
2	15	750	5.9	2.2	1.5	0.7	0.3	0.2	0.5	0.2	0.1
2	20	750	5.0	1.8	1.2	0.6	0.2	0.1	0.4	0.1	0.1
2	25	750	4.3	1.5	1.0	0.5	0.2	0.1	0.3	0.1	0.1
2	30	750	3.7	1.3	0.9	0.4	0.1	0.1	0.3	0.1	0.1
2	10	1000	6.1	2.3	1.6	0.7	0.3	0.2	0.5	0.2	0.1
2	15	1000	4.7	1.7	1.1	0.6	0.2	0.1	0.4	0.1	0.1
2	20	1000	3.9	1.3	0.9	0.5	0.2	0.1	0.3	0.1	0.1
2	25	1000	3.3	1.1	0.8	0.4	0.1	0.1	0.3	0.1	0.1
2	30	1000	2.9	1.0	0.6	0.3	0.1	0.1	0.2	0.1	0.0
2.5	10	130	>10	7.2	5.3	1.7	0.9	0.6	1.3	0.6	0.5
2.5	15	130	>10	6.0	4.4	1.5	0.7	0.5	1.1	0.5	0.4
2.5	20	130	>10	5.1	3.7	1.4	0.6	0.4	1.0	0.4	0.3
2.5	25	130	>10	4.5	3.2	1.2	0.5	0.4	0.9	0.4	0.3
2.5	30	130	9.3	4.0	2.8	1.1	0.5	0.3	0.8	0.3	0.2
2.5	10	250	>10	5.4	3.9	1.4	0.6	0.5	1.0	0.4	0.3
2.5	15	250	9.6	4.1	2.9	1.2	0.5	0.3	0.8	0.3	0.2
2.5	20	250	8.4	3.4	2.4	1.0	0.4	0.3	0.7	0.3	0.2
2.5	25	250	7.4	2.9	2.0	0.9	0.3	0.2	0.6	0.2	0.2
2.5	30	250	6.7	2.5	1.7	0.8	0.3	0.2	0.5	0.2	0.1
2.5	10	500	8.0	3.2	2.2	1.0	0.4	0.3	0.7	0.3	0.2
2.5	15	500	6.3	2.4	1.6	0.8	0.3	0.2	0.5	0.2	0.1
2.5	20	500	5.3	1.9	1.3	0.6	0.2	0.2	0.4	0.2	0.1
2.5	25	500	4.6	1.6	1.1	0.5	0.2	0.1	0.4	0.1	0.1
2.5	30	500	4.0	1.4	0.9	0.5	0.2	0.1	0.3	0.1	0.1
2.5	10	750	6.1	2.3	1.6	0.7	0.3	0.2	0.5	0.2	0.1
2.5	15	750	4.7	1.7	1.1	0.6	0.2	0.1	0.4	0.1	0.1
2.5	20	750	3.9	1.3	0.9	0.5	0.2	0.1	0.3	0.1	0.1
2.5	25	750	3.3	1.1	0.7	0.4	0.1	0.1	0.3	0.1	0.1
2.5	30	750	2.8	0.9	0.6	0.3	0.1	0.1	0.2	0.1	0.0
2.5	10	1000	5.0	1.8	1.2	0.6	0.2	0.1	0.4	0.1	0.1
2.5	15	1000	3.7	1.3	0.9	0.4	0.1	0.1	0.3	0.1	0.1
2.5	20	1000	3.0	1.0	0.7	0.4	0.1	0.1	0.2	0.1	0.1

Battery Longevity and Programmed Setting Choices
Model 103
Model 104

Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
2.5	25	1000	2.5	0.8	0.6	0.3	0.1	0.1	0.2	0.1	0.0
2.5	30	1000	2.2	0.7	0.5	0.3	0.1	0.1	0.2	0.1	0.0
3	10	130	>10	6.3	4.6	1.6	0.7	0.5	1.1	0.5	0.4
3	15	130	>10	5.0	3.6	1.3	0.6	0.4	1.0	0.4	0.3
3	20	130	9.6	4.2	2.9	1.2	0.5	0.3	0.8	0.3	0.2
3	25	130	8.6	3.6	2.5	1.0	0.4	0.3	0.7	0.3	0.2
3	30	130	7.8	3.1	2.2	0.9	0.4	0.3	0.7	0.2	0.2
3	10	250	>10	4.4	3.1	1.2	0.5	0.4	0.8	0.3	0.2
3	15	250	8.1	3.3	2.3	1.0	0.4	0.3	0.7	0.3	0.2
3	20	250	6.8	2.6	1.8	0.8	0.3	0.2	0.6	0.2	0.1
3	25	250	5.9	2.2	1.5	0.7	0.3	0.2	0.5	0.2	0.1
3	30	250	5.3	1.9	1.3	0.6	0.2	0.2	0.4	0.1	0.1
3	10	500	6.6	2.5	1.7	0.8	0.3	0.2	0.5	0.2	0.1
3	15	500	5.0	1.8	1.2	0.6	0.2	0.1	0.4	0.1	0.1
3	20	500	4.0	1.4	0.9	0.5	0.2	0.1	0.3	0.1	0.1
3	25	500	3.4	1.2	0.8	0.4	0.1	0.1	0.3	0.1	0.1
3	30	500	3.0	1.0	0.7	0.3	0.1	0.1	0.2	0.1	0.1
3	10	750	4.9	1.7	1.2	0.6	0.2	0.1	0.4	0.1	0.1
3	15	750	3.6	1.2	0.8	0.4	0.1	0.1	0.3	0.1	0.1
3	20	750	2.8	0.9	0.6	0.3	0.1	0.1	0.2	0.1	0.0
3	25	750	2.4	0.8	0.5	0.3	0.1	0.1	0.2	0.1	0.0
3	30	750	2.0	0.7	0.4	0.2	0.1	0.1	0.2	0.1	0.0
3	10	1000	3.8	1.3	0.9	0.4	0.2	0.1	0.3	0.1	0.1
3	15	1000	2.8	0.9	0.6	0.3	0.1	0.1	0.2	0.1	0.0
3	20	1000	2.2	0.7	0.5	0.3	0.1	0.1	0.2	0.1	0.0
3	25	1000	1.8	0.6	0.4	0.2	0.1	0.0	0.1	0.0	0.0
3	30	1000	1.5	0.5	0.3	0.2	0.1	0.0	0.1	0.0	0.0
3.5	10	130	>10	4.7	3.4	1.3	0.6	0.4	0.9	0.4	0.3
3.5	15	130	9.0	3.8	2.6	1.1	0.4	0.3	0.8	0.3	0.2
3.5	20	130	7.7	3.1	2.1	0.9	0.4	0.3	0.6	0.2	0.2
3.5	25	130	6.8	2.6	1.8	0.8	0.3	0.2	0.6	0.2	0.1
3.5	30	130	6.1	2.3	1.6	0.7	0.3	0.2	0.5	0.2	0.1

Battery Longevity and Programmed Setting Choices
Model 103
Model 104

Parameters at 3 kΩ			Time from BOL to IFI (Years)			Time from IFI to NEOS (Years)			Time from NEOS to EOS (Years)		
mA	Hz	µS	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle	10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
3.5	10	250	8.0	3.2	2.2	1.0	0.4	0.3	0.7	0.3	0.2
3.5	15	250	6.4	2.4	1.7	0.8	0.3	0.2	0.5	0.2	0.1
3.5	20	250	5.3	1.9	1.3	0.6	0.2	0.2	0.4	0.2	0.1
3.5	25	250	4.6	1.6	1.1	0.5	0.2	0.1	0.4	0.1	0.1
3.5	30	250	4.0	1.4	0.9	0.5	0.2	0.1	0.3	0.1	0.1
3.5	10	500	4.7	1.7	1.1	0.6	0.2	0.1	0.4	0.1	0.1
3.5	15	500	3.6	1.2	0.8	0.4	0.1	0.1	0.3	0.1	0.1
3.5	20	500	3.0	1.0	0.7	0.3	0.1	0.1	0.2	0.1	0.1
3.5	25	500	2.5	0.8	0.5	0.3	0.1	0.1	0.2	0.1	0.0
3.5	30	500	2.1	0.7	0.5	0.2	0.1	0.1	0.2	0.1	0.0
3.5	10	750	3.2	1.1	0.7	0.4	0.1	0.1	0.3	0.1	0.1
3.5	15	750	2.4	0.8	0.5	0.3	0.1	0.1	0.2	0.1	0.0
3.5	20	750	2.0	0.6	0.4	0.2	0.1	0.0	0.2	0.1	0.0
3.5	25	750	1.7	0.5	0.4	0.2	0.1	0.0	0.1	0.0	0.0
3.5	30	750	1.4	0.5	0.3	0.2	0.1	0.0	0.1	0.0	0.0
3.5	10	1000	2.4	0.8	0.5	0.3	0.1	0.1	0.2	0.1	0.0
3.5	15	1000	1.9	0.6	0.4	0.2	0.1	0.0	0.2	0.0	0.0
3.5	20	1000	1.5	0.5	0.3	0.2	0.1	0.0	0.1	0.0	0.0
3.5	25	1000	1.3	0.4	0.3	0.1	0.0	0.0	0.1	0.0	0.0
3.5	30	1000	1.1	0.3	0.2	0.1	0.0	0.0	0.1	0.0	0.0

10.5. Model 102 / Model 102R Battery Longevity and Programmed Setting Choices

10.5.1. Nominal Estimates – Beginning of Life (BOL) to End of Service (EOS)

Nominal Estimates – Beginning of Life (BOL) to End of Service (EOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Nominal Estimated Battery Life (Years)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1	10	130	2	15.3	11.3	9.5
1	10	130	3	15.1	11.1	9.2
1	10	130	5	14.8	10.5	8.7
1	10	130	7	14.4	9.8	8.0
1	10	500	2	14.2	9.6	7.7
1	10	500	3	13.8	8.9	7.1
1	10	500	5	13.0	7.9	6.1
1	10	500	7	12.4	7.3	5.6
1	10	1000	2	12.8	7.6	5.9
1	10	1000	3	12.2	6.9	5.3
1	10	1000	5	10.9	5.7	4.2
1	10	1000	7	10.3	5.2	3.8
1	20	130	2	14.2	9.5	7.6
1	20	130	3	13.8	9.0	7.2
1	20	130	5	13.4	8.5	6.7
1	20	130	7	12.7	7.6	5.9
1	20	500	2	12.3	7.1	5.4
1	20	500	3	11.7	6.5	4.9
1	20	500	5	10.6	5.5	4.0
1	20	500	7	10.0	4.9	3.6
1	20	1000	2	10.3	5.2	3.8
1	20	1000	3	9.6	4.6	3.3
1	20	1000	5	8.2	3.6	2.6
1	20	1000	7	7.5	3.2	2.3
1	30	130	2	13.1	8.1	6.3
1	30	130	3	12.7	7.6	5.9
1	30	130	5	12.2	7.0	5.3
1	30	130	7	11.4	6.2	4.6
1	30	500	2	10.9	5.7	4.2

Nominal Estimates – Beginning of Life (BOL) to End of Service (EOS)
Model 102
Model 102R

Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Nominal Estimated Battery Life (Years)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1	30	500	3	10.2	5.1	3.7
1	30	500	5	9.0	4.2	3.0
1	30	500	7	8.3	3.7	2.6
1	30	1000	2	8.7	3.9	2.8
1	30	1000	3	7.9	3.5	2.4
1	30	1000	5	6.6	2.7	1.8
1	30	1000	7	5.9	2.3	1.6
1.5	10	130	2	14.7	10.3	8.4
1.5	10	130	3	14.4	9.8	7.9
1.5	10	130	5	13.7	8.8	7.0
1.5	10	130	7	13.8	8.9	7.1
1.5	10	500	2	12.4	7.3	5.6
1.5	10	500	3	12.0	6.7	5.1
1.5	10	500	5	10.9	5.7	4.3
1.5	10	500	7	11.2	6.0	4.5
1.5	10	1000	2	10.3	5.2	3.8
1.5	10	1000	3	9.6	4.6	3.3
1.5	10	1000	5	8.4	3.8	2.7
1.5	10	1000	7	8.9	4.1	2.9
1.5	20	130	2	13.1	8.0	6.2
1.5	20	130	3	12.6	7.5	5.8
1.5	20	130	5	11.8	6.5	4.9
1.5	20	130	7	11.8	6.6	5.0
1.5	20	500	2	10.0	5.0	3.6
1.5	20	500	3	9.4	4.5	3.2
1.5	20	500	5	8.2	3.7	2.6
1.5	20	500	7	8.6	3.9	2.8
1.5	20	1000	2	7.5	3.2	2.2
1.5	20	1000	3	6.8	2.8	2.0
1.5	20	1000	5	5.7	2.2	1.5
1.5	20	1000	7	6.2	2.4	1.7
1.5	30	130	2	11.8	6.5	4.9
1.5	30	130	3	11.3	6.1	4.5

Nominal Estimates – Beginning of Life (BOL) to End of Service (EOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Nominal Estimated Battery Life (Years)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1.5	30	130	5	10.3	5.2	3.8
1.5	30	130	7	10.4	5.3	3.9
1.5	30	500	2	8.4	3.8	2.7
1.5	30	500	3	7.7	3.3	2.4
1.5	30	500	5	6.6	2.7	1.9
1.5	30	500	7	7.0	2.9	2.0
1.5	30	1000	2	5.9	2.3	1.6
1.5	30	1000	3	5.3	2.0	1.4
1.5	30	1000	5	4.3	1.6	1.1
1.5	30	1000	7	4.7	1.8	1.2
2	10	130	2	14.1	9.4	7.5
2	10	130	3	13.5	8.5	6.7
2	10	130	5	13.5	8.5	6.7
2	10	130	7	13.7	8.8	7.0
2	10	500	2	11.2	6.0	4.4
2	10	500	3	10.1	5.0	3.6
2	10	500	5	10.5	5.4	3.9
2	10	500	7	11.1	5.9	4.3
2	10	1000	2	8.4	3.8	2.7
2	10	1000	3	7.4	3.1	2.2
2	10	1000	5	7.9	3.5	2.4
2	10	1000	7	8.6	3.9	2.8
2	20	130	2	12.2	7.0	5.3
2	20	130	3	11.3	6.0	4.5
2	20	130	5	11.4	6.2	4.6
2	20	130	7	11.7	6.5	4.9
2	20	500	2	8.4	3.8	2.7
2	20	500	3	7.3	3.1	2.2
2	20	500	5	7.8	3.4	2.4
2	20	500	7	8.4	3.8	2.7
2	20	1000	2	5.5	2.1	1.5
2	20	1000	3	4.8	1.8	1.2
2	20	1000	5	5.3	2.0	1.4

Nominal Estimates – Beginning of Life (BOL) to End of Service (EOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Nominal Estimated Battery Life (Years)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
2	20	1000	7	5.9	2.3	1.6
2	30	130	2	10.8	5.6	4.1
2	30	130	3	9.7	4.7	3.4
2	30	130	5	9.9	4.9	3.5
2	30	130	7	10.2	5.1	3.8
2	30	500	2	6.8	2.8	1.9
2	30	500	3	5.7	2.2	1.5
2	30	500	5	6.2	2.5	1.7
2	30	500	7	6.8	2.8	1.9
2	30	1000	2	4.0	1.4	1.0
2	30	1000	3	3.6	1.3	0.8
2	30	1000	5	4.0	1.4	1.0
2	30	1000	7	4.6	1.7	1.1
3.5	10	130	2	12.6	7.5	5.7
3.5	10	130	3	12.9	7.8	6.0
3.5	10	130	5	13.3	8.3	6.5
3.5	10	130	7	13.5	8.6	6.8
3.5	10	500	2	8.6	3.9	2.8
3.5	10	500	3	9.2	4.4	3.1
3.5	10	500	5	10.1	5.0	3.7
3.5	10	500	7	10.8	5.6	4.1
3.5	10	1000	2	5.8	2.3	1.6
3.5	10	1000	3	6.5	2.6	1.8
3.5	10	1000	5	7.5	3.2	2.3
3.5	10	1000	7	8.3	3.7	2.6
3.5	20	130	2	10.2	5.1	3.8
3.5	20	130	3	10.6	5.5	4.0
3.5	20	130	5	11.1	5.9	4.4
3.5	20	130	7	11.5	6.3	4.7
3.5	20	500	2	5.9	2.3	1.6
3.5	20	500	3	6.5	2.6	1.8
3.5	20	500	5	7.4	3.1	2.2
3.5	20	500	7	8.1	3.5	2.5

Nominal Estimates – Beginning of Life (BOL) to End of Service (EOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Nominal Estimated Battery Life (Years)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
3.5	20	1000	2	3.6	1.3	0.9
3.5	20	1000	3	4.1	1.5	1.0
3.5	20	1000	5	5.0	1.9	1.3
3.5	20	1000	7	5.6	2.2	1.5
3.5	30	130	2	8.6	3.9	2.8
3.5	30	130	3	9.0	4.2	3.0
3.5	30	130	5	9.6	4.6	3.3
3.5	30	130	7	10.0	4.9	3.6
3.5	30	500	2	4.5	1.7	1.1
3.5	30	500	3	5.0	1.9	1.3
3.5	30	500	5	5.8	2.3	1.6
3.5	30	500	7	6.5	2.6	1.8
3.5	30	1000	2	2.7	0.9	0.6
3.5	30	1000	3	3.0	1.0	0.7
3.5	30	1000	5	3.7	1.3	0.9
3.5	30	1000	7	4.3	1.6	1.1

10.5.2. Worst Case Estimates – Beginning of Life (BOL) to Near End of Service (NEOS)

Worst Case Estimates – Beginning of Life (BOL) to Near End of Service (NEOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Worst Case Estimated Battery Life (Years)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1	10	130	2	9.3	7.1	6.0
1	10	130	3	9.3	7.2	6.1
1	10	130	5	8.8	6.2	5.1
1	10	130	7	8.8	6.2	5.0
1	10	500	2	9.1	6.8	5.7
1	10	500	3	8.9	6.4	5.2
1	10	500	5	8.2	5.3	4.2
1	10	500	7	8.0	5.0	3.9
1	10	1000	2	8.3	5.4	4.3
1	10	1000	3	8.0	5.1	4.0
1	10	1000	5	7.2	4.1	3.1
1	10	1000	7	6.8	3.7	2.8
1	20	130	2	9.1	6.7	5.6
1	20	130	3	8.9	6.4	5.3
1	20	130	5	8.6	5.9	4.8
1	20	130	7	8.2	5.3	4.2
1	20	500	2	8.2	5.2	4.2
1	20	500	3	7.8	4.8	3.7
1	20	500	5	6.9	3.8	2.8
1	20	500	7	6.7	3.6	2.7
1	20	1000	2	6.9	3.7	2.8
1	20	1000	3	6.6	3.5	2.6
1	20	1000	5	5.7	2.8	2.0
1	20	1000	7	5.2	2.4	1.7
1	30	130	2	8.6	5.9	4.7
1	30	130	3	8.4	5.6	4.4
1	30	130	5	8.0	5.0	3.9
1	30	130	7	7.5	4.5	3.4
1	30	500	2	7.4	4.3	3.3

Worst Case Estimates – Beginning of Life (BOL) to Near End of Service (NEOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Worst Case Estimated Battery Life (Years)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1	30	500	3	7.0	3.9	2.9
1	30	500	5	6.1	3.0	2.2
1	30	500	7	5.7	2.8	2.0
1	30	1000	2	5.8	2.8	2.0
1	30	1000	3	5.6	2.7	1.9
1	30	1000	5	4.7	2.1	1.5
1	30	1000	7	4.1	1.7	1.2
1.5	10	130	2	9.2	6.9	5.9
1.5	10	130	3	8.9	6.5	5.4
1.5	10	130	5	8.3	5.4	4.3
1.5	10	130	7	8.3	5.5	4.4
1.5	10	500	2	7.9	4.9	3.8
1.5	10	500	3	7.8	4.8	3.7
1.5	10	500	5	7.1	4.0	3.0
1.5	10	500	7	7.2	4.1	3.1
1.5	10	1000	2	7.0	3.9	2.9
1.5	10	1000	3	6.6	3.5	2.6
1.5	10	1000	5	5.8	2.8	2.0
1.5	10	1000	7	6.0	3.0	2.2
1.5	20	130	2	8.5	5.7	4.6
1.5	20	130	3	8.2	5.3	4.2
1.5	20	130	5	7.6	4.5	3.5
1.5	20	130	7	7.6	4.6	3.5
1.5	20	500	2	6.9	3.8	2.8
1.5	20	500	3	6.5	3.4	2.5
1.5	20	500	5	5.7	2.7	2.0
1.5	20	500	7	5.9	2.9	2.1
1.5	20	1000	2	5.3	2.5	1.8
1.5	20	1000	3	4.9	2.2	1.5
1.5	20	1000	5	4.2	1.7	1.2
1.5	20	1000	7	4.5	1.9	1.3
1.5	30	130	2	7.8	4.8	3.8
1.5	30	130	3	7.5	4.5	3.4

Worst Case Estimates – Beginning of Life (BOL) to Near End of Service (NEOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Worst Case Estimated Battery Life (Years)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1.5	30	130	5	6.9	3.7	2.8
1.5	30	130	7	6.9	3.8	2.8
1.5	30	500	2	5.9	2.9	2.1
1.5	30	500	3	5.5	2.6	1.9
1.5	30	500	5	4.8	2.1	1.5
1.5	30	500	7	5.0	2.2	1.6
1.5	30	1000	2	4.3	1.8	1.3
1.5	30	1000	3	3.9	1.6	1.1
1.5	30	1000	5	3.3	1.2	0.8
1.5	30	1000	7	3.5	1.4	1.0
2	10	130	2	8.8	6.3	5.2
2	10	130	3	8.0	5.0	4.0
2	10	130	5	8.2	5.3	4.2
2	10	130	7	8.3	5.5	4.4
2	10	500	2	7.4	4.3	3.3
2	10	500	3	6.6	3.5	2.6
2	10	500	5	6.9	3.7	2.8
2	10	500	7	7.2	4.0	3.1
2	10	1000	2	5.6	2.6	1.9
2	10	1000	3	5.1	2.3	1.7
2	10	1000	5	5.5	2.6	1.9
2	10	1000	7	5.9	2.9	2.1
2	20	130	2	8.0	5.0	3.9
2	20	130	3	7.3	4.2	3.2
2	20	130	5	7.4	4.3	3.3
2	20	130	7	7.6	4.5	3.4
2	20	500	2	5.8	2.8	2.0
2	20	500	3	5.2	2.3	1.7
2	20	500	5	5.4	2.5	1.8
2	20	500	7	5.8	2.8	2.0
2	20	1000	2	3.7	1.4	1.0
2	20	1000	3	3.6	1.4	1.0
2	20	1000	5	3.9	1.6	1.1

Worst Case Estimates – Beginning of Life (BOL) to Near End of Service (NEOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Worst Case Estimated Battery Life (Years)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
2	20	1000	7	4.3	1.8	1.3
2	30	130	2	7.3	4.1	3.1
2	30	130	3	6.5	3.4	2.5
2	30	130	5	6.7	3.5	2.6
2	30	130	7	6.8	3.7	2.8
2	30	500	2	4.7	2.1	1.5
2	30	500	3	4.2	1.7	1.2
2	30	500	5	4.5	1.9	1.3
2	30	500	7	4.9	2.1	1.5
2	30	1000	2	2.9	1.0	0.7
2	30	1000	3	2.7	1.0	0.7
2	30	1000	5	3.1	1.1	0.8
2	30	1000	7	3.4	1.3	0.9
3.5	10	130	2	7.9	4.9	3.8
3.5	10	130	3	8.0	5.1	4.0
3.5	10	130	5	8.2	5.3	4.2
3.5	10	130	7	8.3	5.5	4.4
3.5	10	500	2	5.9	2.9	2.1
3.5	10	500	3	6.2	3.1	2.3
3.5	10	500	5	6.7	3.6	2.7
3.5	10	500	7	7.0	3.9	2.9
3.5	10	1000	2	4.2	1.8	1.2
3.5	10	1000	3	4.6	2.0	1.4
3.5	10	1000	5	5.2	2.4	1.7
3.5	10	1000	7	5.7	2.7	2.0
3.5	20	130	2	6.8	3.7	2.7
3.5	20	130	3	7.0	3.9	2.9
3.5	20	130	5	7.3	4.2	3.2
3.5	20	130	7	7.4	4.4	3.3
3.5	20	500	2	4.3	1.8	1.3
3.5	20	500	3	4.7	2.0	1.4
3.5	20	500	5	5.2	2.4	1.7
3.5	20	500	7	5.6	2.7	1.9

Worst Case Estimates – Beginning of Life (BOL) to Near End of Service (NEOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Worst Case Estimated Battery Life (Years)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
3.5	20	1000	2	2.8	1.0	0.7
3.5	20	1000	3	3.1	1.2	0.8
3.5	20	1000	5	3.7	1.5	1.0
3.5	20	1000	7	4.1	1.7	1.2
3.5	30	130	2	6.0	2.9	2.1
3.5	30	130	3	6.2	3.1	2.3
3.5	30	130	5	6.5	3.4	2.5
3.5	30	130	7	6.7	3.6	2.7
3.5	30	500	2	3.4	1.3	0.9
3.5	30	500	3	3.7	1.5	1.0
3.5	30	500	5	4.3	1.8	1.2
3.5	30	500	7	4.7	2.0	1.4
3.5	30	1000	2	2.1	0.7	0.5
3.5	30	1000	3	2.4	0.8	0.6
3.5	30	1000	5	2.9	1.1	0.7
3.5	30	1000	7	3.2	1.2	0.8

10.5.3. Nominal Time Estimates – Near End of Service (NEOS) to End of Service (EOS)

Nominal Time Estimates – Near End of Service (NEOS) to End of Service (EOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Nominal Time from NEOS to EOS (Months)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1	10	130	2	9.4	6.7	5.5
1	10	130	3	9.3	6.5	5.3
1	10	130	5	9.1	6.2	5.0
1	10	130	7	8.8	5.8	4.6
1	10	500	2	8.7	5.6	4.4
1	10	500	3	8.4	5.2	4.1
1	10	500	5	7.9	4.6	3.5
1	10	500	7	7.5	4.2	3.2
1	10	1000	2	7.7	4.4	3.4
1	10	1000	3	7.3	4.0	3.1
1	10	1000	5	6.5	3.3	2.5
1	10	1000	7	6.2	3.0	2.2
1	20	130	2	8.6	5.5	4.4
1	20	130	3	8.4	5.3	4.1
1	20	130	5	8.2	4.9	3.8
1	20	130	7	7.7	4.4	3.4
1	20	500	2	7.4	4.1	3.1
1	20	500	3	7.0	3.8	2.8
1	20	500	5	6.3	3.2	2.3
1	20	500	7	5.9	2.9	2.1
1	20	1000	2	6.2	3.0	2.2
1	20	1000	3	5.7	2.7	2.0
1	20	1000	5	4.8	2.1	1.5
1	20	1000	7	4.4	1.9	1.4
1	30	130	2	8.0	4.7	3.6
1	30	130	3	7.7	4.4	3.4
1	30	130	5	7.4	4.1	3.1
1	30	130	7	6.9	3.6	2.7
1	30	500	2	6.5	3.3	2.4

Nominal Time Estimates – Near End of Service (NEOS) to End of Service (EOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Nominal Time from NEOS to EOS (Months)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1	30	500	3	6.1	3.0	2.2
1	30	500	5	5.3	2.4	1.8
1	30	500	7	4.9	2.2	1.6
1	30	1000	2	5.1	2.3	1.7
1	30	1000	3	4.7	2.0	1.5
1	30	1000	5	3.9	1.6	1.1
1	30	1000	7	3.3	1.3	0.9
1.5	10	130	2	9.0	6.0	4.9
1.5	10	130	3	8.8	5.7	4.6
1.5	10	130	5	8.4	5.2	4.0
1.5	10	130	7	8.4	5.2	4.1
1.5	10	500	2	7.5	4.2	3.2
1.5	10	500	3	7.2	3.9	3.0
1.5	10	500	5	6.6	3.3	2.5
1.5	10	500	7	6.7	3.5	2.6
1.5	10	1000	2	6.1	3.0	2.2
1.5	10	1000	3	5.7	2.7	2.0
1.5	10	1000	5	5.0	2.2	1.6
1.5	10	1000	7	5.3	2.4	1.7
1.5	20	130	2	7.9	4.7	3.6
1.5	20	130	3	7.6	4.4	3.3
1.5	20	130	5	7.1	3.8	2.8
1.5	20	130	7	7.1	3.8	2.9
1.5	20	500	2	6.0	2.9	2.1
1.5	20	500	3	5.6	2.6	1.9
1.5	20	500	5	4.9	2.2	1.6
1.5	20	500	7	5.1	2.3	1.7
1.5	20	1000	2	4.4	1.9	1.4
1.5	20	1000	3	4.0	1.7	1.2
1.5	20	1000	5	3.1	1.3	0.9
1.5	20	1000	7	3.6	1.5	1.1
1.5	30	130	2	7.1	3.8	2.9
1.5	30	130	3	6.8	3.5	2.6

Nominal Time Estimates – Near End of Service (NEOS) to End of Service (EOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Nominal Time from NEOS to EOS (Months)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1.5	30	130	5	6.1	3.0	2.2
1.5	30	130	7	6.2	3.1	2.3
1.5	30	500	2	5.0	2.2	1.6
1.5	30	500	3	4.6	2.0	1.4
1.5	30	500	5	3.9	1.6	1.2
1.5	30	500	7	4.1	1.7	1.2
1.5	30	1000	2	3.2	1.3	0.9
1.5	30	1000	3	2.9	1.1	0.8
1.5	30	1000	5	2.4	0.9	0.7
1.5	30	1000	7	2.6	1.0	0.7
2	10	130	2	8.6	5.5	4.3
2	10	130	3	8.2	5.0	3.9
2	10	130	5	8.2	5.0	3.9
2	10	130	7	8.3	5.1	4.0
2	10	500	2	6.7	3.5	2.6
2	10	500	3	6.0	2.9	2.1
2	10	500	5	6.3	3.1	2.3
2	10	500	7	6.6	3.4	2.5
2	10	1000	2	5.0	2.2	1.6
2	10	1000	3	4.3	1.8	1.3
2	10	1000	5	4.7	2.0	1.5
2	10	1000	7	5.1	2.3	1.7
2	20	130	2	7.4	4.1	3.1
2	20	130	3	6.8	3.5	2.6
2	20	130	5	6.9	3.6	2.7
2	20	130	7	7.0	3.8	2.8
2	20	500	2	5.0	2.2	1.6
2	20	500	3	4.3	1.8	1.3
2	20	500	5	4.6	2.0	1.4
2	20	500	7	5.0	2.2	1.6
2	20	1000	2	3.0	1.2	0.9
2	20	1000	3	2.6	1.0	0.7
2	20	1000	5	2.9	1.2	0.8

Nominal Time Estimates – Near End of Service (NEOS) to End of Service (EOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Nominal Time from NEOS to EOS (Months)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
2	20	1000	7	3.3	1.3	0.9
2	30	130	2	6.4	3.2	2.4
2	30	130	3	5.8	2.8	2.0
2	30	130	5	5.9	2.8	2.1
2	30	130	7	6.1	3.0	2.2
2	30	500	2	4.0	1.7	1.2
2	30	500	3	3.2	1.3	0.9
2	30	500	5	3.6	1.5	1.1
2	30	500	7	4.0	1.7	1.2
2	30	1000	2	2.2	0.9	0.6
2	30	1000	3	2.0	0.8	0.6
2	30	1000	5	2.2	0.9	0.6
2	30	1000	7	2.5	1.0	0.7
3.5	10	130	2	7.6	4.3	3.3
3.5	10	130	3	7.8	4.5	3.5
3.5	10	130	5	8.1	4.8	3.7
3.5	10	130	7	8.2	5.0	3.9
3.5	10	500	2	5.1	2.3	1.7
3.5	10	500	3	5.5	2.5	1.8
3.5	10	500	5	6.0	2.9	2.1
3.5	10	500	7	6.4	3.2	2.4
3.5	10	1000	2	3.2	1.3	0.9
3.5	10	1000	3	3.8	1.6	1.1
3.5	10	1000	5	4.4	1.9	1.4
3.5	10	1000	7	4.9	2.2	1.6
3.5	20	130	2	6.1	3.0	2.2
3.5	20	130	3	6.3	3.2	2.3
3.5	20	130	5	6.7	3.4	2.6
3.5	20	130	7	6.9	3.6	2.7
3.5	20	500	2	3.3	1.3	0.9
3.5	20	500	3	3.8	1.6	1.1
3.5	20	500	5	4.3	1.9	1.3
3.5	20	500	7	4.8	2.1	1.5

Nominal Time Estimates – Near End of Service (NEOS) to End of Service (EOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Nominal Time from NEOS to EOS (Months)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
3.5	20	1000	2	2.0	0.8	0.6
3.5	20	1000	3	2.3	0.9	0.6
3.5	20	1000	5	2.7	1.1	0.8
3.5	20	1000	7	3.1	1.2	0.9
3.5	30	130	2	5.1	2.3	1.7
3.5	30	130	3	5.4	2.5	1.8
3.5	30	130	5	5.7	2.7	2.0
3.5	30	130	7	6.0	2.9	2.1
3.5	30	500	2	2.5	1.0	0.7
3.5	30	500	3	2.8	1.1	0.8
3.5	30	500	5	3.2	1.3	0.9
3.5	30	500	7	3.8	1.6	1.1
3.5	30	1000	2	1.5	0.6	0.4
3.5	30	1000	3	1.7	0.7	0.5
3.5	30	1000	5	2.1	0.8	0.6
3.5	30	1000	7	2.4	0.9	0.7

10.5.4. Worst Case Time Estimates – Near End of Service (NEOS) to End of Service (EOS)

Worst Case Time Estimates – Near End of Service (NEOS) to End of Service (EOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Worst Case Time from NEOS to EOS (Months)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1	10	130	2	7.7	5.6	4.7
1	10	130	3	7.8	5.7	4.8
1	10	130	5	7.2	4.9	4.0
1	10	130	7	7.2	4.9	3.9
1	10	500	2	7.6	5.4	4.4
1	10	500	3	7.3	5.0	4.1
1	10	500	5	6.7	4.2	3.3
1	10	500	7	6.5	3.9	3.0
1	10	1000	2	6.8	4.2	3.3
1	10	1000	3	6.6	4.0	3.1
1	10	1000	5	5.9	3.2	2.4
1	10	1000	7	5.5	2.9	2.2
1	20	130	2	7.5	5.3	4.4
1	20	130	3	7.4	5.1	4.1
1	20	130	5	7.1	4.7	3.7
1	20	130	7	6.7	4.1	3.2
1	20	500	2	6.7	4.1	3.2
1	20	500	3	6.4	3.8	2.9
1	20	500	5	5.6	3.0	2.2
1	20	500	7	5.4	2.8	2.1
1	20	1000	2	5.6	2.9	2.2
1	20	1000	3	5.3	2.8	2.1
1	20	1000	5	4.6	2.2	1.6
1	20	1000	7	4.1	1.9	1.4
1	30	130	2	7.1	4.6	3.7
1	30	130	3	6.9	4.4	3.5
1	30	130	5	6.5	3.9	3.0
1	30	130	7	6.1	3.5	2.7
1	30	500	2	6.0	3.4	2.6

Worst Case Time Estimates – Near End of Service (NEOS) to End of Service (EOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Worst Case Time from NEOS to EOS (Months)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1	30	500	3	5.7	3.0	2.3
1	30	500	5	4.9	2.4	1.8
1	30	500	7	4.6	2.2	1.6
1	30	1000	2	4.6	2.2	1.6
1	30	1000	3	4.5	2.1	1.6
1	30	1000	5	3.8	1.7	1.2
1	30	1000	7	3.1	1.3	0.9
1.5	10	130	2	7.6	5.5	4.6
1.5	10	130	3	7.4	5.1	4.2
1.5	10	130	5	6.8	4.3	3.4
1.5	10	130	7	6.8	4.3	3.4
1.5	10	500	2	6.4	3.8	3.0
1.5	10	500	3	6.4	3.8	2.9
1.5	10	500	5	5.7	3.1	2.3
1.5	10	500	7	5.9	3.3	2.5
1.5	10	1000	2	5.6	3.0	2.3
1.5	10	1000	3	5.3	2.7	2.0
1.5	10	1000	5	4.6	2.2	1.6
1.5	10	1000	7	4.8	2.4	1.7
1.5	20	130	2	7.0	4.5	3.6
1.5	20	130	3	6.7	4.2	3.3
1.5	20	130	5	6.2	3.5	2.7
1.5	20	130	7	6.2	3.6	2.7
1.5	20	500	2	5.6	3.0	2.2
1.5	20	500	3	5.2	2.7	2.0
1.5	20	500	5	4.6	2.2	1.6
1.5	20	500	7	4.7	2.3	1.7
1.5	20	1000	2	4.3	2.0	1.4
1.5	20	1000	3	3.9	1.7	1.3
1.5	20	1000	5	3.1	1.3	0.9
1.5	20	1000	7	3.5	1.5	1.1
1.5	30	130	2	6.4	3.8	2.9
1.5	30	130	3	6.1	3.5	2.7

Worst Case Time Estimates – Near End of Service (NEOS) to End of Service (EOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Worst Case Time from NEOS to EOS (Months)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
1.5	30	130	5	5.5	2.9	2.2
1.5	30	130	7	5.6	3.0	2.2
1.5	30	500	2	4.8	2.3	1.7
1.5	30	500	3	4.4	2.1	1.5
1.5	30	500	5	3.8	1.7	1.2
1.5	30	500	7	4.0	1.8	1.3
1.5	30	1000	2	3.3	1.4	1.0
1.5	30	1000	3	2.9	1.2	0.9
1.5	30	1000	5	2.4	1.0	0.7
1.5	30	1000	7	2.6	1.1	0.8
2	10	130	2	7.3	4.9	4.0
2	10	130	3	6.5	4.0	3.1
2	10	130	5	6.7	4.2	3.3
2	10	130	7	6.8	4.3	3.4
2	10	500	2	6.0	3.4	2.6
2	10	500	3	5.4	2.8	2.1
2	10	500	5	5.5	2.9	2.2
2	10	500	7	5.8	3.2	2.4
2	10	1000	2	4.5	2.1	1.5
2	10	1000	3	4.1	1.9	1.3
2	10	1000	5	4.4	2.1	1.5
2	10	1000	7	4.7	2.3	1.7
2	20	130	2	6.5	3.9	3.1
2	20	130	3	5.9	3.3	2.5
2	20	130	5	6.0	3.4	2.6
2	20	130	7	6.1	3.5	2.7
2	20	500	2	4.7	2.2	1.6
2	20	500	3	4.1	1.9	1.4
2	20	500	5	4.3	2.0	1.5
2	20	500	7	4.6	2.2	1.6
2	20	1000	2	2.7	1.1	0.8
2	20	1000	3	2.7	1.1	0.8
2	20	1000	5	2.9	1.2	0.9

Worst Case Time Estimates – Near End of Service (NEOS) to End of Service (EOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Worst Case Time from NEOS to EOS (Months)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
2	20	1000	7	3.2	1.4	1.0
2	30	130	2	5.9	3.3	2.5
2	30	130	3	5.3	2.7	2.0
2	30	130	5	5.4	2.8	2.1
2	30	130	7	5.5	2.9	2.2
2	30	500	2	3.8	1.7	1.2
2	30	500	3	3.1	1.3	0.9
2	30	500	5	3.6	1.5	1.1
2	30	500	7	3.9	1.7	1.2
2	30	1000	2	2.1	0.8	0.6
2	30	1000	3	2.0	0.8	0.6
2	30	1000	5	2.3	0.9	0.7
2	30	1000	7	2.6	1.0	0.7
3.5	10	130	2	6.4	3.8	3.0
3.5	10	130	3	6.6	4.0	3.1
3.5	10	130	5	6.7	4.2	3.3
3.5	10	130	7	6.8	4.3	3.4
3.5	10	500	2	4.7	2.3	1.7
3.5	10	500	3	5.0	2.5	1.8
3.5	10	500	5	5.4	2.8	2.1
3.5	10	500	7	5.7	3.1	2.3
3.5	10	1000	2	3.2	1.3	1.0
3.5	10	1000	3	3.7	1.6	1.2
3.5	10	1000	5	4.2	1.9	1.4
3.5	10	1000	7	4.6	2.2	1.6
3.5	20	130	2	5.5	2.9	2.2
3.5	20	130	3	5.7	3.0	2.3
3.5	20	130	5	5.9	3.3	2.5
3.5	20	130	7	6.1	3.4	2.6
3.5	20	500	2	3.2	1.4	1.0
3.5	20	500	3	3.7	1.6	1.2
3.5	20	500	5	4.2	1.9	1.4
3.5	20	500	7	4.5	2.1	1.5

Worst Case Time Estimates – Near End of Service (NEOS) to End of Service (EOS) Model 102 Model 102R						
Output Current (mA)	Frequency (Hz)	Pulse Width (µsec)	DC-DC Converter Code	Worst Case Time from NEOS to EOS (Months)		
				10% Duty Cycle	33% Duty Cycle	50% Duty Cycle
3.5	20	1000	2	2.1	0.8	0.6
3.5	20	1000	3	2.3	0.9	0.7
3.5	20	1000	5	2.8	1.1	0.8
3.5	20	1000	7	3.1	1.3	0.9
3.5	30	130	2	4.8	2.3	1.7
3.5	30	130	3	5.0	2.5	1.8
3.5	30	130	5	5.2	2.7	2.0
3.5	30	130	7	5.4	2.8	2.1
3.5	30	500	2	2.5	1.0	0.7
3.5	30	500	3	2.8	1.1	0.8
3.5	30	500	5	3.2	1.3	1.0
3.5	30	500	7	3.7	1.6	1.2
3.5	30	1000	2	1.6	0.6	0.5
3.5	30	1000	3	1.8	0.7	0.5
3.5	30	1000	5	2.1	0.8	0.6
3.5	30	1000	7	2.4	1.0	0.7

Limited Replacement Warranty

LivaNova USA, Inc. warrants the VNS Therapy™ generator and lead against any defects due to faulty material or workmanship for a period of two (2) years from the date of implantation. This warranty applies only to the original purchaser of the VNS Therapy generator and lead and the patient implanted with it. This Limited Replacement Warranty also applies only when the product is used in accordance with the product's physician's manual and excludes damage due to improper handling, defacing, accident (including dropping), or misuse. This product is not warranted when used or implanted by a person(s) not trained in or familiar with the VNS Therapy system. This Limited Replacement Warranty is not a representation that any one VNS Therapy generator or lead will last the entire time of the Limited Replacement Warranty.

In no event shall LivaNova USA, Inc. be liable for any special, incidental, indirect, or consequential damages based on the failure of the device to function within normal tolerances, or resulting from damage to the device by external forces, whether the claim is based on warranty, contract, tort, or otherwise, or in connection with the purchase, use, or surgical implantation of this device or associated components or costs over and above the original purchase price from LivaNova USA, Inc.

To qualify for the Limited Replacement Warranty, the following conditions must be met:

1. A properly completed Implant and Warranty Registration form for both the VNS Therapy generator and the VNS Therapy lead must be returned to LivaNova USA, Inc. within sixty (60) days of device implantation;
2. The battery in the VNS Therapy generator cannot have been depleted as a result of programming to unusually high output currents, pulse widths, or duty cycles, which will cause a high energy / current drain;
3. The VNS Therapy lead cannot have been cut or damaged due to excessive handling or abuse during surgical implantation;
4. The product must have been used and prescribed in accordance with the VNS Therapy and programming system physician's manuals;
5. The VNS Therapy generator or lead must have been implanted prior to its "use by date";
6. The defective VNS Therapy generator or lead must be returned to LivaNova USA, Inc. with an accompanying Authorization number and confirmed defective by the Quality Assurance Department;
7. To obtain an authorization number contact "Technical Support" on page 223;
8. All returned VNS Therapy generators and leads shall become the property of LivaNova USA, Inc.

⚠ CAUTION: **Return explanted generators and leads** to LivaNova USA, Inc. for examination and proper disposal, along with a completed returned product form. Before returning the lead, disinfect the device components with Betadine®, Cidex® soak, or another similar disinfectant, and double-seal them in a pouch or other container properly labeled with a biohazard warning.

If the VNS Therapy generator or lead becomes defective within the warranty period, contact LivaNova USA, Inc. Customer Service for a no-cost replacement. LivaNova USA, Inc. reserves the right to replace a defective

product with the most comparable product currently available. Returned biohazardous product should be clearly identified as such on the outside surface of the package. To access an electronic copy, see "Return Product Form " on the next page.

No implied warranty, including, but not limited to, any implied warranty of merchantability or fitness for a particular purpose, shall extend beyond the period specified above. This replacement warranty shall be the exclusive remedy available to any person. No person has any authority to bind LivaNova USA, Inc. to any representation, condition, or warranty except this Limited Replacement Warranty.

While this warranty gives you specific legal rights, you may also have other rights that vary from state to state or that encroach upon the above.

Contacts and Resources

For information and support in use of the system or any of its accessories, contact LivaNova.

Contacts

	 LivaNova USA, Inc. 100 Cyberonics Blvd Houston, Texas 77058 USA
Tel:	+1 281 228 7200 (Worldwide)
Toll free:	+1 800 332 1375 (US/Canada)
Fax:	+1 281 218 9332
Website:	www.livanova.com

Technical Support

Available 24 hours per day	
Toll free:	+1 866 882 8804 (US/Canada)
Tel:	+1 281 228 7330 (Worldwide)

Regulatory Authority Websites

Report all adverse events related to the device to LivaNova and to your local regulatory authority.

US	https://www.fda.gov

Return Product Form

A Returned Product Form is used for the return of any VNS Therapy system component. Call first for a Return Goods Authorization (RGA) number, available from "Technical Support" above. Before device components are returned, disinfect them with Betadine®, Cidex® soak, or other similar disinfectant, and double seal them in a pouch or other container properly labeled with a biohazard warning.

Return Product Forms are posted at www.livanova.com.

Implant and Warranty Registration Form

Download a copy of the Implant and Warranty Registration form at www.livanova.com.

Find your preferred language and complete the form online (or print and complete by hand).

Print 3 copies of the completed form:

- Return one to LivaNova
- Keep one for the patient chart
- Give one to the patient

NOTE: A pre-printed triplicate copy is provided in the generator sales pack.