

Tech Corner

Dual Sensor

NOTE: PLEASE NOTE THAT THE FOLLOWING INFORMATION IS A GENERAL DESCRIPTION OF THE FUNCTION. DETAILS AND PARTICULAR CASES ARE NOT DESCRIBED IN THE ARTICLE. FOR ADDITIONAL EXPLANATION PLEASE CONTACT YOUR SALES REPRESENTATIVE.

Table of Contents

Summary	4
Designed solution	4
Background	5
Availability	5
Clinical need	5
Indication	5
Description of operation	6
Accelerometer (G)	6
Minute Ventilation (MV)	8
Dual sensor (Twin Trace)	10
Rate Response Settings	10
Auto-calibration	10
Sensor Cross-Checking.....	12
Programming rate response	15
MicroPort pacemakers (except SYMPHONY)	15
SYMPHONY pacemakers.....	16
Automatic programming.....	16
Studies and results	17

Dual Sensor

The goal of rate adaptive pacing is to provide an increase in heart rate via an increase in cardiac pacing in response to metabolic needs. This would include during periods of exercise, but also during disease states and emotional reactions. The system response is a combination of both the ability of the sensor to recognize changes, and the software that can interpret those changes and respond accordingly.



SUMMARY

The dual sensor technology is a combination of an accelerometer and minute ventilation for efficient rate response to chronotropic incompetence¹.

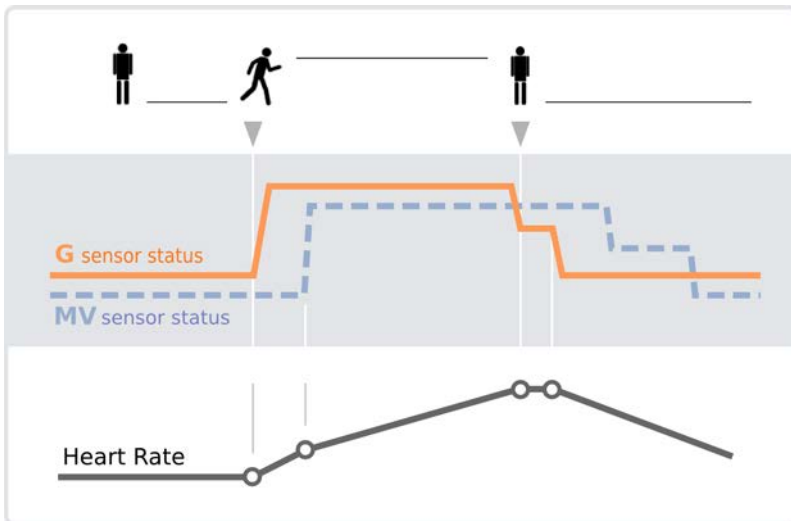


Image 1

Designed solution

Dual sensor has been designed to blend information from accelerometer and minute ventilation sensors for a more physiologic rate response.

Accelerometer (G): Provides fast response at beginning of exercise and indicates end of exercise.

Minute ventilation (MV): Offers a physiological and gradual response to exercise, detects increased metabolic need and adapts pacing rate in proportion to exercise.

Blended-Sensor Operation: During dual sensor operation, the minute ventilation sensor is dominant and solely determines the rate response when both sensors detect exercise.

Cross-checking of both sensors: The sensors continually cross check each other at the beginning and end of exercise. Rate response will continue only if both sensors simultaneously detect activity. The combination of two sensors also prevents rate increases due to artifacts. Any increase not confirmed by the second sensor results in a return to the basic escape rate.

Auto-calibration of both sensors: Shortly after implantation, rate response is set to “Learn”: the device learns about the patient’s activity but does not change the pacing rate. This enables an immediate activation of rate response when needed.

BACKGROUND

Rate adaptive pacing has been available since 1963^{2,3}. The ability for the pacemaker to track the atrium, maintaining AV synchrony, provides ventricular rate adaptive pacing. The advent of artificial sensors has largely supplanted this concept of adaptive pacing, but the healthy sinus node remains the best indicator of metabolic demand.

Nowadays, a pacemaker is said to be rate adaptive when it incorporates a mechanism by which it can determine that the patient requires a changing heart rate in response to some metabolic need, and will therefore correspondingly alter its pacing rate. Two mechanisms are currently commercially available: accelerometer (G) and Minute Ventilation (MV). The combination of these two sensors is called Dual Sensor (Twin Trace).

AVAILABILITY

Dual Sensor is available in all Microport rate-responsive pacemakers, except ESPRIT pacemakers (only the Accelerometer (G) is available).

CLINICAL NEED

Dual sensor has been designed to restore chronotropic response in pacemaker patients and provide rate response as close to normal sinus rhythm as possible. Chronotropic incompetence can be predictive of an increased incidence of mortality and coronary disease in both otherwise healthy patients⁴, and in those with heart disease⁵.

INDICATION

Rate adaptive pacing is indicated in patients who may benefit from increased pacing rates concurrent with increases in minute ventilation and/or activity.

DESCRIPTION OF OPERATION

Accelerometer (G)

The accelerometer sensor (G) uses a moving plate embedded between two electrodes to measure vibrations within a physiologic bandwidth (0.5 Hz to 10 Hz). It is a small electronic component fixed on the pacemaker circuit board.

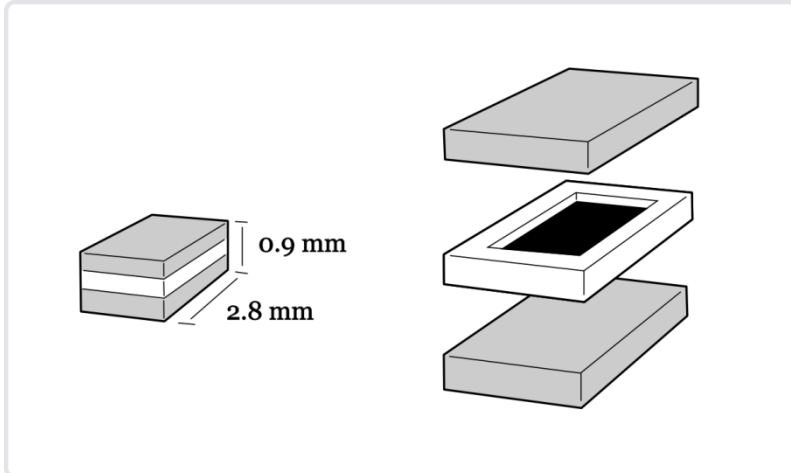


Image 2 - Accelerometer. A plate (black) is allowed to move within two stationary electrodes (grey), responding to movement. The distance between the moving plate and the electrodes is measured in capacitance to determine motion.

The accelerometer has been widely accepted by the medical industry and practitioners alike for several reasons: it is reliable, predictable and very energy efficient. It is acknowledged, however, that it is not very physiological, and can still be fooled by many activities.

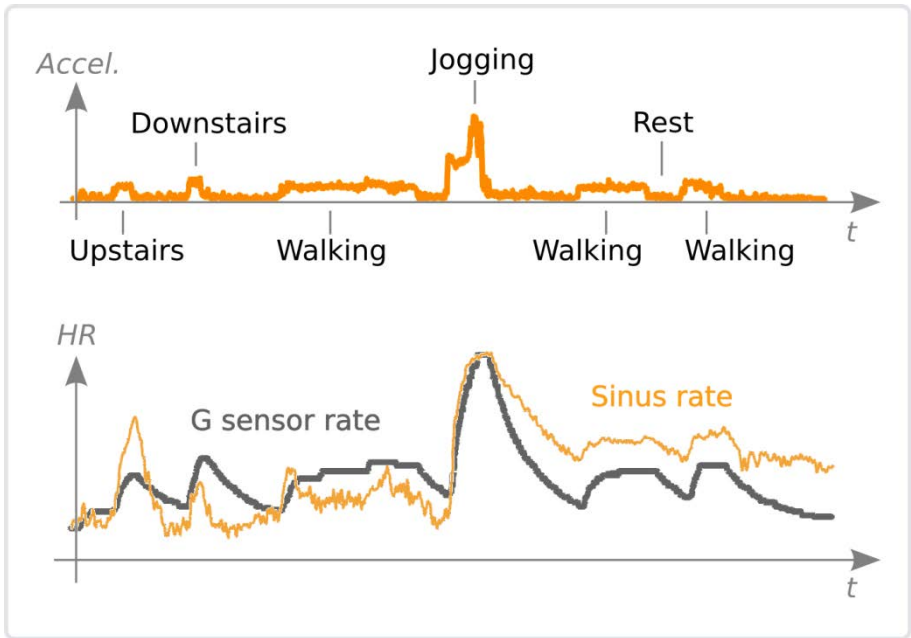


Image 3

The accelerometer has a somewhat ‘all-or-nothing’ approach to rate response, in that it cannot discriminate well between varying amounts of low level exercise. In the heart plot above, various activities and associated sensor signal are demonstrated in the upper tracing. Walking upstairs and downstairs are roughly equal in terms of accelerometer output, but clearly have different physiological demands on the patient. Only during more strenuous physical activity, here represented by jogging, does the accelerometer register a large increase. The interpretation of this signal output into a pacing rate is plotted in the lower tracing in grey versus the study subject’s intrinsic rate in orange. As can be seen, walking upstairs has a greater heart rate response than walking downstairs, but in fact the accelerometer has a greater response to walking downstairs. This is likely due to the increased impact of the foot on the stairs in descending, as well as likely a faster rate versus ascending. The peak rates in jogging are well matched, but rate support post peak exercise is below that of the intrinsic rate. Some of these issues may be corrected with programming, but others cannot be easily overcome.

Minute Ventilation (MV)

Minute ventilation (MV) is estimated using transthoracic impedance. By emitting very low pulses of electrical current between the lead tip and the pacemaker, the device is able to measure the transthoracic impedance as it changes with inspiration and expiration. Thus the frequency and depth of breathing can be assessed, providing insight into the patient's metabolic needs. This has proven to be much more physiological than the accelerometer, and therefore more desirable as an artificial sensor.

The main limitation of MV is a slow response to initiation of exercise. For this reason it is most often combined with the accelerometer sensor to try to benefit from the strengths of each.

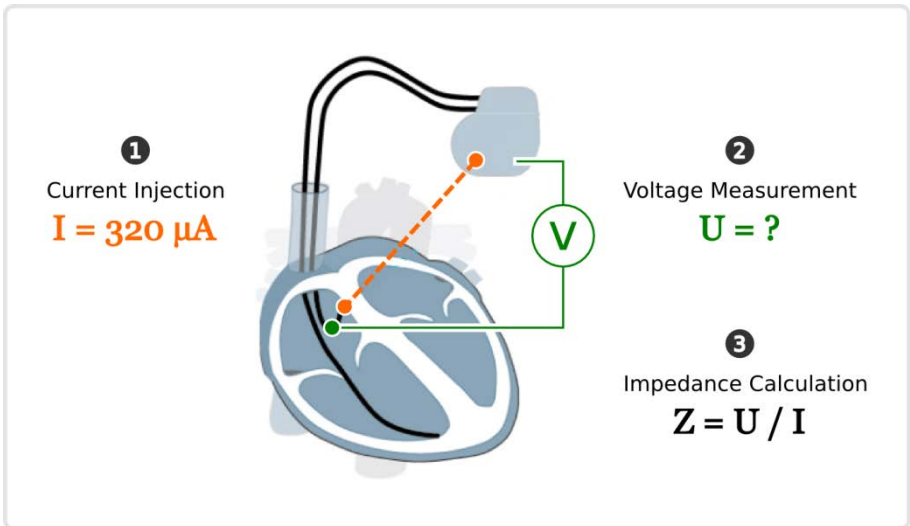


Image 4 - Minute Ventilation. Current is injected into the system between the tip electrode and pacemaker. The voltage between the ring electrode and the pacemaker is measured, and the resultant impedance (Z) is calculated.

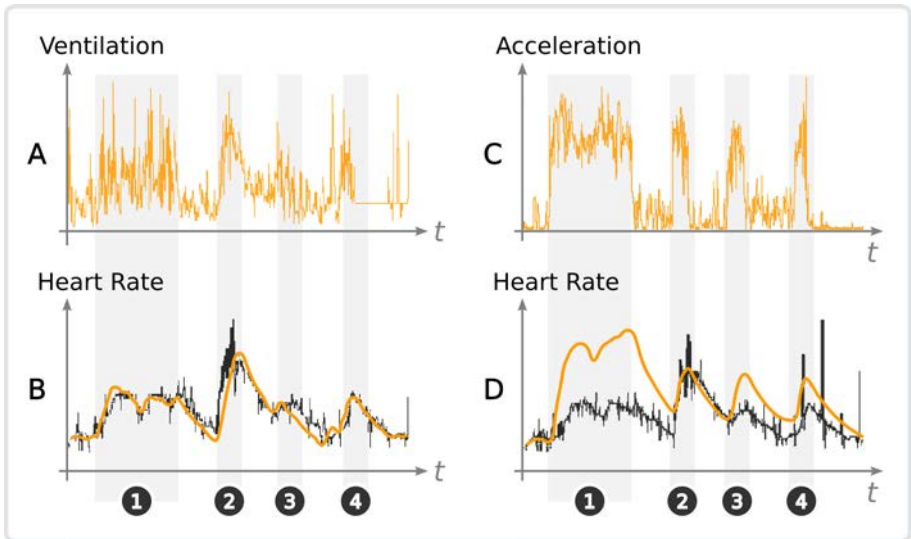


Image 5 - System response to activities: ① 6 minute walk. ② 1.5 minute going upstairs.

③ 1.5 minute going downstairs. ④ Go back to physician's office

1. Signal derived from the MV sensor.
2. Sensor derived pacing rate in orange and the patient's actual rate in gray. There is good association between the two.
3. Signal derived from accelerometer.
4. Patient's heart rate in gray, and the sensor response in orange.

On the image 5, we can see that MV response closely matches the actual heart rate, whereas the accelerometer frequently overshoots it. The accelerometer is good at the onset and termination of the activities, but cannot deliver a physiologic response.

Dual sensor (Twin Trace)

The combination of both sensors G and MV allows for the rapid onset of accelerometer, and the physiologic response of MV. Furthermore, in MicroPort devices, the operation of the MV sensor has been greatly improved such that the energy expenditure is less than that of the accelerometer. Enabling Dual sensor (Twin Trace) also allows for dual sensor cross-checking, so that rate excursions by either sensor must be verified by the other.

Depending on the exercise state, the device decides upon the appropriate pacing rate (target rate) based on its programmed setting. The algorithm will not suddenly step to that pacing rate; rather it will accelerate or decelerate smoothly to the target rate thereby avoiding symptoms. Thus at any point in time, the device knows the exercise status of the patient, it has a target rate and a strategy to achieve the target rate. That strategy is called the sensor driven rate.

Rate Response Settings

The rate response can be programmed to:

- **Off**
- **Learn**, where there is passive collection of data and the slope is adjusted automatically.
- **RR auto**, where the device will automatically adjust the slope according to patient activity levels.
- **RR fixed**, where the clinician chooses which slope, thereby limiting the aggressiveness of the sensor. This is often used in patients with known angina.
- **DDD/DDIR auto**, used in patients that are chronotropically competent, except when in Mode Switch for atrial fibrillation with an auto adaptive rate response slope.
- **DDD/DDIR fixed**, used in patients that are chronotropically competent, except when in Mode Switch for atrial fibrillation with a fixed rate response slope.

Auto-calibration

In the **auto** mode, the device uses patient data to continually adjust the rate response settings, tailoring it to the needs of the patient. Both the resting point and the exercise point are adaptable. The rate response slope is applied based on these two points.

In the **auto** mode, if the dual sensor is programmed, the auto-calibration applies to the MV sensor only, the G sensor slope is fixed to Medium.

MV auto-calibration

The MV measurement is performed every 125 ms. Then the device computes the respiratory cycles and averages 8 cycles (MV_8); it is then compared to the most recent absolute measurement. This dictates the increase or decrease of pacing rate. The maximum value during exercise is also evaluated. If the maximal MV_8 is greater than the previously recorded $MV_8 + 6\%$, then the current MV_8 becomes the new maximum MV_8 . If the variance is less than 6%, no change is made.

Any time the rest MV point is modified, the exercise MV is limited to 2 to 16 times that value. This includes changes either to a greater or lesser value. Every day, the exercise MV is reduced by 3% as long as it is above the maximum ventilation reached by the patient over the last 24 hours, but never less than 2 times the rest MV.

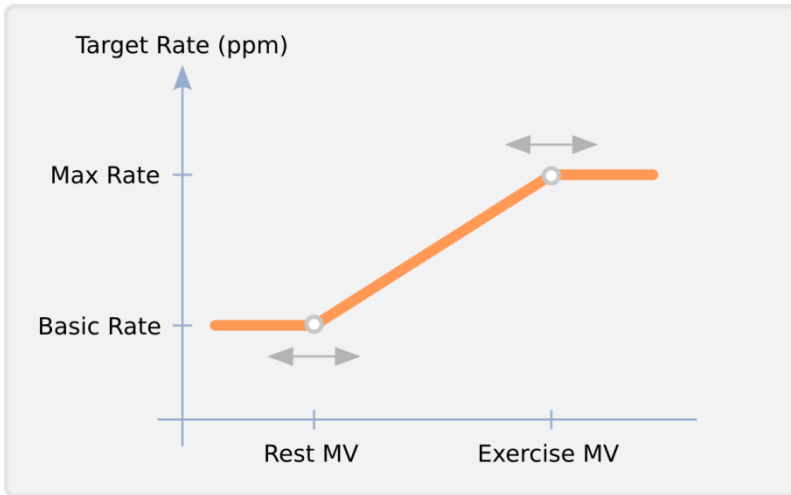


Image 6 - The Max rate and Basic rate are programmed by the physician while Rest MV and Exercise MV are daily calculated by the device. Based on the Rest MV and Exercise MV, the slope will be automatically adapted.

G auto-calibration

The G auto calibration is used if the G sensor only is programmed to Auto.

Every 1.56 seconds, the accelerometer signal (G) is measured, and four successive samples are averaged together (G_4). Then the device determines the calibration curve, defining the rest and maximal activity.

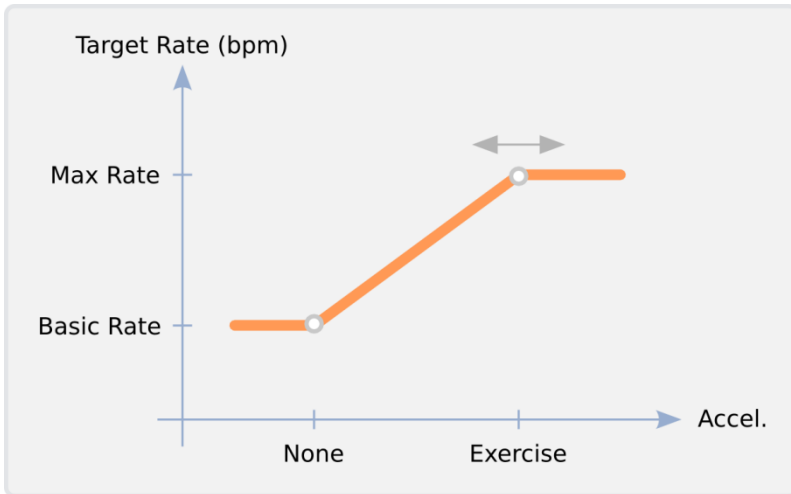


Image 7 - The G transfer function assigns to the Basic rate and to the Max rate programmed by the physician, respectively a rest acceleration and an acceleration that corresponds to maximum exercise in daily life. Between these two points, respectively called the low and high points, the device assigns a linear relation.

Sensor Cross-Checking

An increase in sensor-indicated rate is triggered by the first active sensor, which is generally G (giving the G target rate), and then is continued by the MV sensor (giving the MV target rate). Upon initial increase in rate due to the G sensor, the device must see a corresponding increase based on the MV sensor within 64 cardiac cycles. Failure to do so declares a false positive and results in a return of the pacing rate to the lower rate limit.

When used together, the G and MV sensors can provide a physiologic response to exercise.

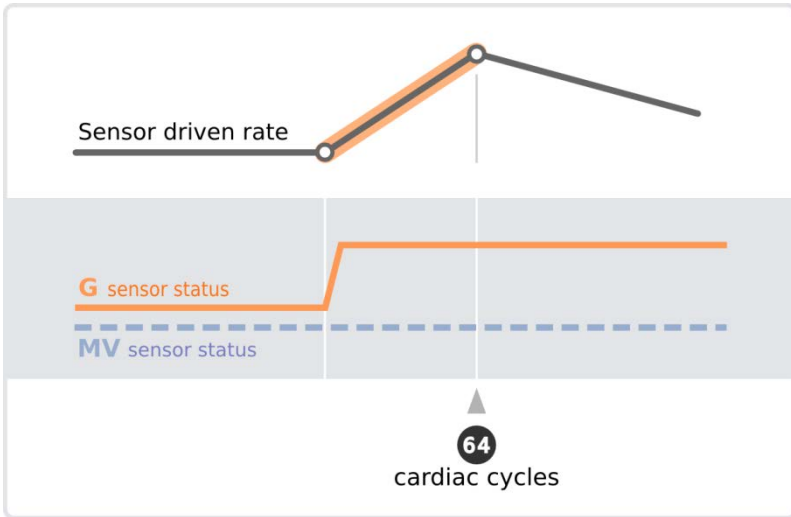


Image 8 - False or brief exercise

As soon as both sensors detect increasing or decreasing activity, the target rate follows the MV sensor. The device will apply a rate plateau only if MV target rate is lower than the sensor driven rate, for as long as MV target rate remains below the rate of the plateau (see image 9 below).

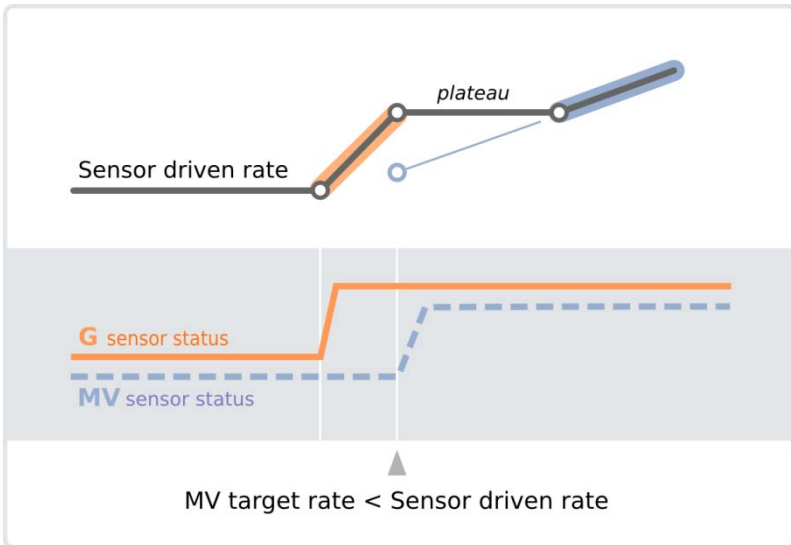


Image 9

If this is not the case (i.e. the MV target rate is higher or equal to the sensor driven rate), no plateau will be applied, and the only effect of switch from G target rate to MV target rate will be a modification of the paced rate curve slope (see image 10 below).

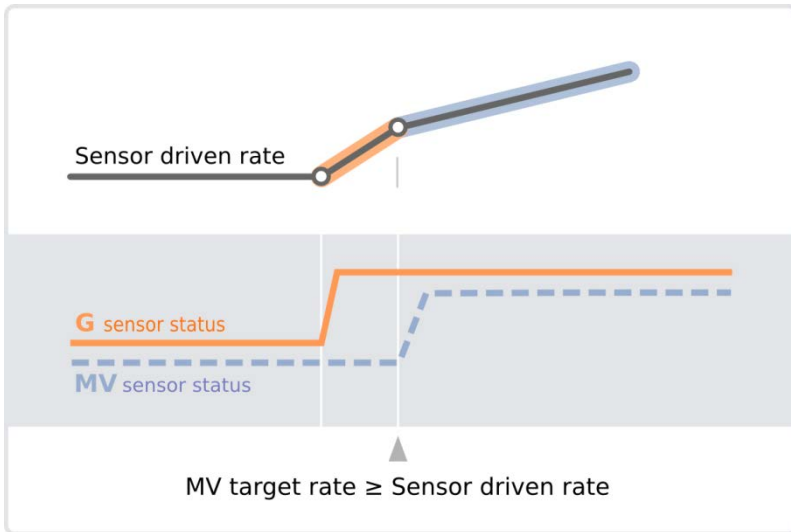


Image 10 - No plateau is applied, the target rate follows the MV sensor.

End of exercise

Likewise, immediately post-peak exercise, should the G sensor decrease (recovery phase) but the MV sensor remain stable, the pacing rate will plateau. Once the G sensor confirms the end of exercise, the sensor driven rate will decrease, even if the MV sensor data are still high.

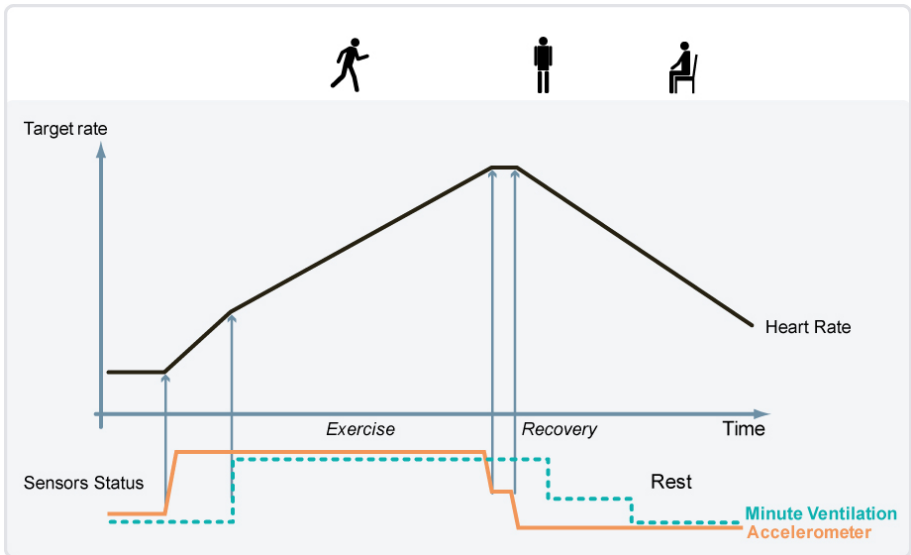


Image 11 - A plateau is applied as long as the G sensor is in recovery status. When one or 2 sensors enter rest status, sensor driven rate decreases.

PROGRAMMING RATE RESPONSE

MicroPort pacemakers (except SYMPHONY)

When programming rate response in the MicroPort pacemakers, a rate responsive mode (-R) is selected. Then the rate response submenu is accessed by selecting the chevron [>] button beside the Rate Response Parameters heading. This presents the Rate Response Parameters window, which allows selection of the rate response setting (Twin Trace, G or MV), sensor selection and activity level (of the patient). Note that the activity level is used to set the slope, and is only available to the user in the 'fixed' slope operation. In this 'fixed' slope operation, the slope is programmed by identifying the **patient's** current activity level. This is a descriptive assessment, using the values Very Low (sedentary) through Very High (athletic).

Basic Parameters		Pacing/Sensing		Advanced parameters		
Mode	SafeR-R (AAIR<=>DDDR)	A sensitivity	0.4 mV	Bipolar	Prevention of A arrhythmia >>	
Basic Rate	60 min-1	Atrial Pacing	3.5 V	0.35 ms	Unipolar	Rate Response Parameters >>
Rest Rate	60 min-1	V sensitivity	2.5 mV	Bipolar	SafeR : AA=>DDD criteria >>	
Max Rate	130 min-1	V Pacing	3.5 V	0.35 ms	Unipolar	Refractory period >>
Hysteresis	0 %				Implantation Auto Detection >>	
AVD Rest/Exerc.	155 ms 80 ms	Basic Functions				
AVD Paced/Sensed Offset	65 ms	Smoothing	Off			
		Mode Switch				
		Anti-PMT				
		Special Functions				
		Auto-sensing A / V				
		V AutoThresh				
				Rate Response Parameters		
		Rate response	RR auto			
		Sensor	Twin Trace			
		Activity	Low			

SYMPHONY pacemakers

When programming rate response in the SYMPHONY pacemakers, rate response is treated as a feature that is enabled in the current mode. Therefore, the mode could be programmed to DDD, for example, and rate response programmed to RR auto. Note that the mode will not show “DDDR”. Once the rate response is programmed on, then the sensor becomes enabled, allowing selection of the rate response setting (Twin Trace, G or MV).

If the rate response choice is either RR fixed or DDD/DDIR fixed, then the patient’s activity can be programmed Very low, Low, Medium, High, Very high. In general, the physical activity of the patient shall be programmed High or Very high, when the patient is considered ‘fit’ and therefore has greater exercise tolerance.

Automatic programming

- Programming rate response mode ON immediately activates both the accelerometer and minute ventilation sensors
- Twin Trace automatically combines the information from both sensors and paces the patient at the optimal rate.

STUDIES AND RESULTS

1. Bonnet JL, G eroux L, Cazeau S et al. Evaluation of a Dual Sensor Rate Responsive Pacing System Based on a New Concept. *Pacing Clin Electrophysiol*. 1998;21:2198-203.
2. Lagergren, H., Johansson, L., Karlof, I., and Thornander, H. (1966). Atrial-triggered pacemaking without thoracotomy: Apparatus and results in twenty cases. *Acta chir. scand.*, 132, 678.
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6. Epstein AE, DiMarco JP, Ellenbogen KA, et al. ACC/AHA/HRS guidelines for devicebased therapy of cardiac rhythm abnormalities: executive summary. *Circulation*. 2008;117:2820-2840.

Refer to user's manual furnished with the device for complete instructions for use (www.microportmanuals.com).