SE 3K04
Assignment 2
Pacemaker Simulink

L01 - Group 5
Submitted: December 3, 2023

Pacemaker Project Summary

Simulink Model

For clarity, all text from Assignment 1 documentation is in grey font whereas assignment two changes is in black font. The Simulink model allows us to program the pacemaker to produce nine different modes of pacing: AOO, VOO, VVI, and AAI, AOOR, VOOR, AAIR, VVIR, DDDR. Incorporating a modular design and hardware hiding, our team ensures that the current model is easy to comprehend, and can be easily modified moving forward. The model will be able to take user-provided inputs to modify the pacing modes, and some modes like VVI will be able to modify the pacing based on heart activity detection. The user can also choose to implement a —R mode, which allows the pacemaker to adapt to the patient's activity level, increasing the BPM when the patient is doing any physical activity. This document highlights the essential requirements, documentation, and design decisions used to create the model and the test results on heartview.

Requirements

This section highlights the requirements to help construct the Simulink model such as the programmable parameters, and the conditions for the four different pacing modes. The parameters may be edited by a user to change certain qualities of the pacing.

Programmable Parameters

Parameters	Description	Values allowed	Nominal
Mode	Selecting the mode in which the pacemaker is operating (VOO, AAI, AOO, VVI, VOOR, AOOR, VVIR, AAIR, DDDR, respectively)	1,2,3,4,5,6,7, 8,9	—
Lower Limit Rate (LRL)	The lowest rate the pacemaker will pace at. This rate is also used as a set rate for asynchronous pacing.	30-175 ppm	60 ppm
Upper Rate Limit (URL)	The highest rate the pacemaker will pace at.	50-175 ppm	120 ppm
A or V Pulse Width	Width of the electrical stimulation to pace the heart.	1-30 ms	1 ms
A or V Sensitivity	The threshold for sensing ventricular or atrial activity.	0-5V	—
VRP	The period following ventricular activity where ventricular activity does not trigger pacing or inhibition.	150-500 ms	320 ms
ARP	The period following an atrial activity where atrial activity does not trigger pacing or inhibition.	150-500 ms	250 ms

Hysteresis Rate Limit	Lowest rate before pacing in hysteresis mode.	Off or same choices as LRL	Off
AV Delay	The delay between atrial and ventricular pacing in dual pacing modes.	Off, -10 to -100 ms	-10 ms
Response Factor	The factor determining the rate at which pacing changes.	1-16	8

Table 1: Programmable Parameters

AOO

The AOO mode paces the atrial chamber asynchronously, meaning that the atrium is paced at a set rate regardless of atrial activity. The following parameters are needed to operate AOO: lower rate limit, Upper rate limit, Atrial amplitude, and Atrial pulse width. Where the lower rate limit is the slowest the pacemaker can pace, the upper rate limit is the highest the pacemaker can pace, Amplitude is the amplitude of the paced pulse, and Pulse width is the time the amplitude is high during the pacing pulse.

Conditions	Actions
- AOO mode is selected by the user	- The system goes to AOO sub chart
- After a full period (LRL in msec)	- Pulse the atrial chamber
- After waiting for (period) - (the atrial pulse width)	- Reset and charge the pacemaker for the next pulse

Table 2: AOO Conditions and actions

VOO

The VOO mode paces the ventricle chamber asynchronously, meaning that the ventricle is paced at a set rate regardless of ventricle activity. The following parameters are needed to operate VOO: lower rate limit, Upper rate limit, Ventricle amplitude, and Ventricle pulse width. Where the lower rate limit is the slowest the pacemaker can pace, the upper rate limit is the highest the pacemaker can pace, Amplitude is the amplitude of the paced pulse, and Pulse width is the time the amplitude is high during the pacing pulse.

Conditions	Actions
- VOO mode is selected by the user	- The system goes to VOO sub chart
- After a full period (LRL in msec)	- Pulse the ventricular chamber
- After waiting for (period) - (the atrial pulse width)	- Reset and charge the pacemaker for the next pulse

Table 3: VOO Conditions and actions

AAI

The AAI mode is a type of demand pacing that produces atrial pacing at a user-defined rate unless inhibited by a sensed event from the atrium. The following parameters are needed to operate AAI: Lower rate limit, Upper rate limit, Atrial amplitude, Atrial pulse width, Atrial sensitivity, and ARP. Where the Atrial sensitivity determines how sensitive the sensing for the Atrial chamber events is, and ARP is the minimum delay between successive sensed Atrial events.

Conditions	Actions
- AAI mode is selected by the user	- The system goes to AAI sub-chart
- After ARP, if atrial heart activity is sensed	- Inhibit atrial pulsing
- If no atrial heart activity is detected, after a full period (LRL in msec)	- Pulse the atrial chamber
- After waiting for (period) - (the atrial pulse width)	- Reset and charge the pacemaker for the next pulse

Table 4: AAI Conditions and actions

VVI

The VVI mode is a type of demand pacing that produces ventricular pacing at a user-defined rate unless inhibited by a sensed event from the ventricle. The following parameters are needed to operate VVI: Lower rate limit, Upper rate limit, Ventricle amplitude, Ventricle pulse width, Ventricle sensitivity, and VRP. Where the Ventricular sensitivity determines how sensitive the sensing for ventricle chamber events is, and VRP is the minimum delay between successive sensed events.

Conditions	Actions
- VVI mode is selected by the user	- The system goes to AAI sub-chart
- After VRP, if ventricle heart activity is sensed	- Inhibit ventricle pulsing
- If no ventricle heart activity is detected, after a full period (LRL in msec)	- Pulse the ventricle chamber
- After waiting for (period) - (the ventricular pulse width)	- Reset and charge the pacemaker for the next pulse

Table 5: VVI Conditions and actions

AOOR

The AOOR mode paces the atrial chamber at the user-defined lower rate limit and changes dynamically with respect to physical activity (activity level). The following parameters are used for AOOR pacing: lower rate limit, upper rate limit, atrial amplitude, atrial pulse width, and response factor. Where the response factor determines the rate of which the pulsing period changes during rate adaptive modes.

Conditions	Actions
- AOOR mode is selected by the user	- The system goes to AOOR sub chart
- After a full rate adaptive period (in msec)	- Pulse the atrium
- Activity level change	- Change rate adaptive period
- Current period does not match rate adaptive period	- Change period according to response factor
- After waiting for (period) - (the arterial pulse width)	- Reset and charge the pacemaker for the next pulse

Table 6: AOOR Conditions and actions

VOOR

The VOOR mode paces the ventricle at the user-defined lower rate limit, and changes dynamically with respect to physical activity (activity level). The following parameters are used for VOOR pacing: lower rate limit, upper rate limit, ventricular amplitude, ventricular pulse width, and response factor. Where the response factor determines the rate of which the pulsing period changes during rate adaptive modes.

Conditions	Actions
- VOOR mode is selected by the user	- The system goes to VOOR sub chart
- After a full rate adaptive period (in msec)	- Pulse the ventricle
- Activity level change	- Change rate adaptive period
- Current period does not match rate adaptive period	- Change period accordingly
- After waiting for (period) - (the Ventricular pulse width)	- Reset and charge the pacemaker for the next pulse

Table 7: VOOR Conditions and actions

AAIR

The AAIR mode paces the atrial chamber at the user defined lower rate limit, and changes dynamically with respect to physical activity (activity level). Pacing should be inhibited if an event is sensed in the atrium. The following parameters are used for AAIR pacing: lower rate limit, upper rate limit, atrial amplitude, atrial pulse width, ARP, and response factor.

Conditions	Actions
- AOOR mode is selected by the user	- The system goes to AOOR sub chart
- After a full rate adaptive period (in msec)	- Pulse the atrium
- Atrial event is detected after ARP	- Inhibit atrial pacing
- Activity level change	- Change rate adaptive period
- Current period does not match rate adaptive period	- Change period according to response factor
- After waiting for (period) - (the arterial pulse width)	- Reset and charge the pacemaker for the next pulse

Table 8: AAIR Conditions and actions

VVIR

The VVIR mode paces the ventricle chamber at the user-defined lower rate limit, and changes dynamically with respect to physical activity (activity level). Pacing should be inhibited if an event is sensed in the ventricle. The following parameters are used for VVIR pacing: lower rate limit, upper rate limit, ventricular amplitude, ventricular pulse width, VRP, and response factor.

Conditions	Actions
- VVIR mode is selected by the user	- The system goes to VVIR sub chart
- After a full rate adaptive period (in msec)	- Pulse the ventricle
- Ventricular event is detected after VRP	- Inhibit ventricular pacing
- Activity level change	- Change rate adaptive period
- Current period does not match rate adaptive period	- Change period according to response factor
- After waiting for (period) - (the ventricular pulse width)	- Reset and charge the pacemaker for the next pulse

Table 9: VVIR Conditions and actions

DDDR

The DDDR mode paces the atrium and subsequently the ventricle after the AV delay, at the user-defined lower rate limit, and changes dynamically with respect to physical activity (activity level). The pacing of the ventricle should be inhibited if an event is sensed in the SW3 push button. The following parameters are used for DDDR pacing: lower rate limit, upper rate limit, atrial amplitude, atrial pulse width, ventricular amplitude, ventricular pulse width, AV delay, and response factor. Where the AV delay determines the delay between the Ventricular pacing after Atrial pacing

Conditions	Actions
- DDDR mode is selected by the user	- The system goes to DDDR sub chart
- After a full rate adaptive period (in msec)	- Pulse the atrium
- After AV delay	- Pulse the ventricle
- Button is pushed	- Inhibit ventricular pacing
- Activity level change	- Change rate adaptive period
- Current period does not match rate adaptive period	- Change period according to response factor
- After waiting for (period) - (the ventricular pulse width) - (AV_delay)	- Reset and charge the pacemaker for the next pulse

Table 10: DDDR Conditions and actions

Model Construction

The model was initially separated into three subsystems: inputs, system, and outputs (Figure1). In Assignment 2, the team split the model up into 5 subsystems: serial inputs, serial outputs, internal calculations, main system, and general outputs (Figure 2).

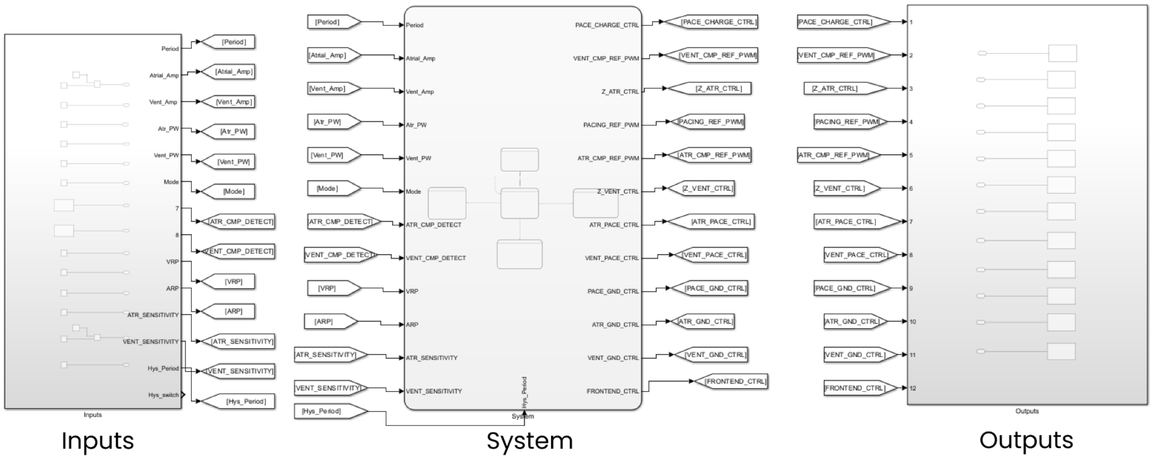


Figure 1: Model Overview Assignment 1

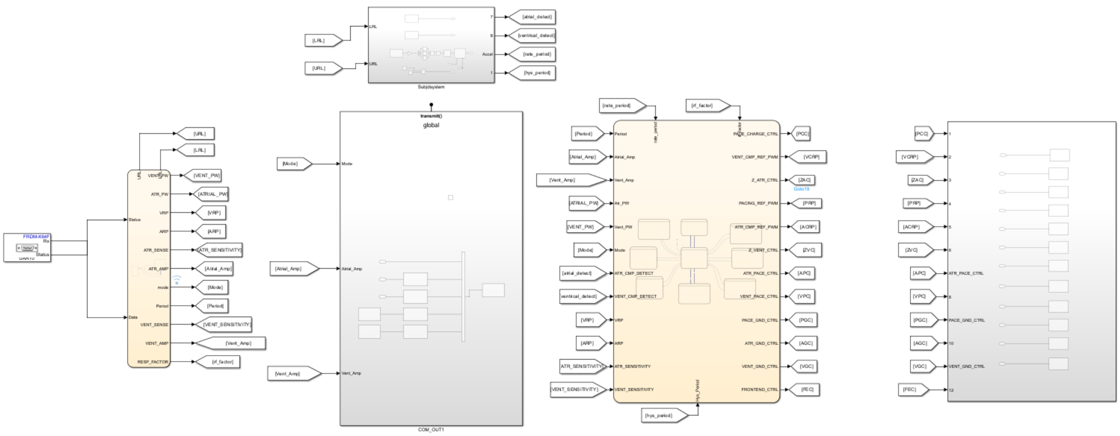


Figure 2: Model Overview Assignment 2

Serial Inputs

In Assignment 2, serial communication was implemented. All serial inputs are controllable from the DCM. In the initial state, before any information is received by the DCM, parameters are set to starting values. The pacemaker does not use these parameters to start but rather to build the system. The system does not start until it receives information from the DCM (and will continue to work until turned off).

The input block also controls whether the DCM is asking to receive or is sending information. This is done with a transmit bit. When the string of bits starts with a 1, the DCM is sending information to the Simulink model. When the DCM sends a 0, it is looking to receive signals from the pacemaker. This can be best seen in the images below.

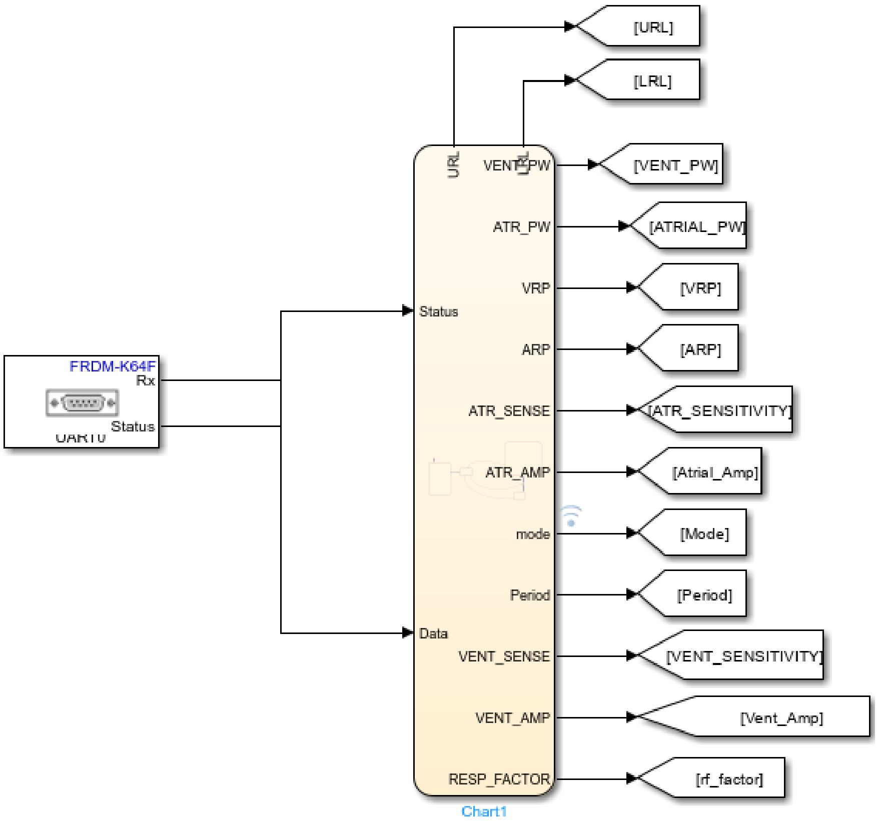


Figure 3: Serial Inputs Block

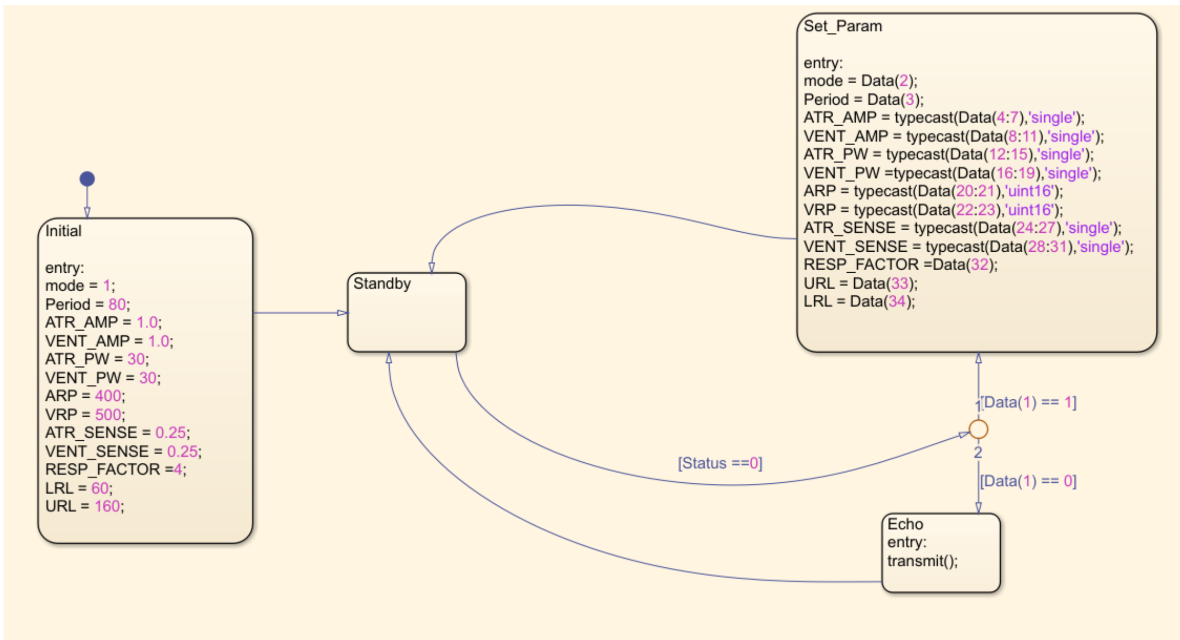


Figure 4: Serial Inputs Internal

Internal Calculations

A new feature added in Assignment 2 was the use of an accelerometer. This sets the heart rate based on a given threshold set by the user. In the internal calculations block, the model takes the Lower Rate and Upper Rate limit from the user and calculates a set of intervals that the heart should be at when at a certain activity level. This can be seen in figure 6.

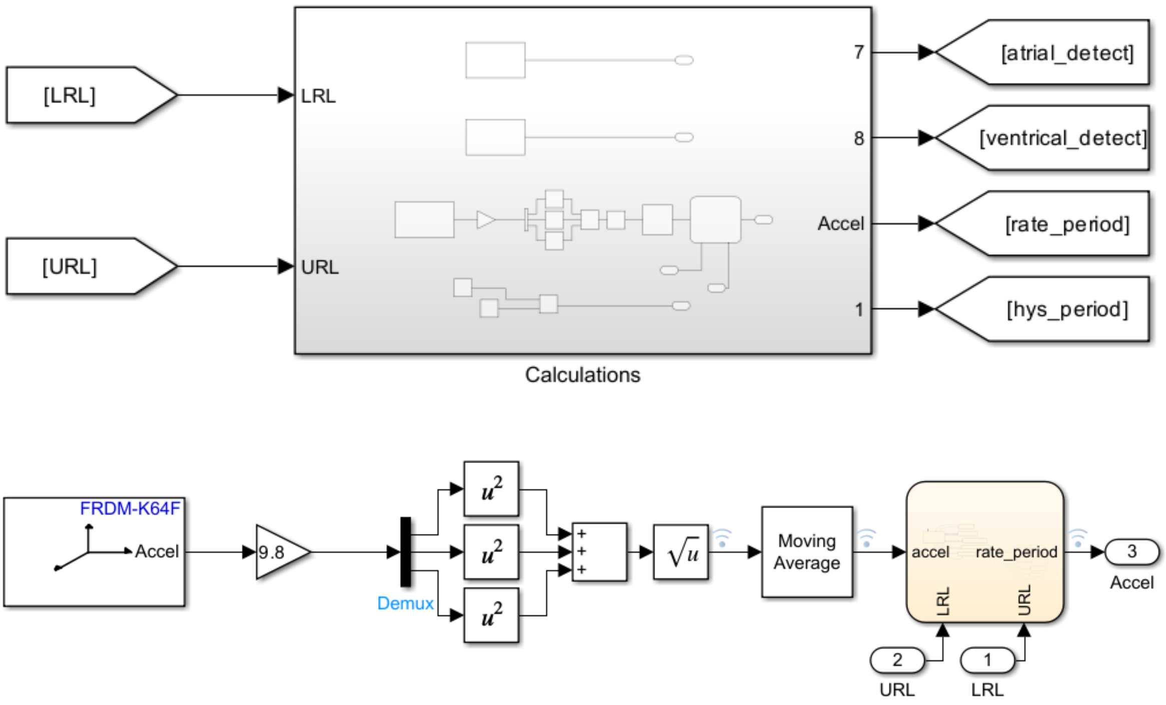


Figure 5: Internal Calculations Acceleraometer

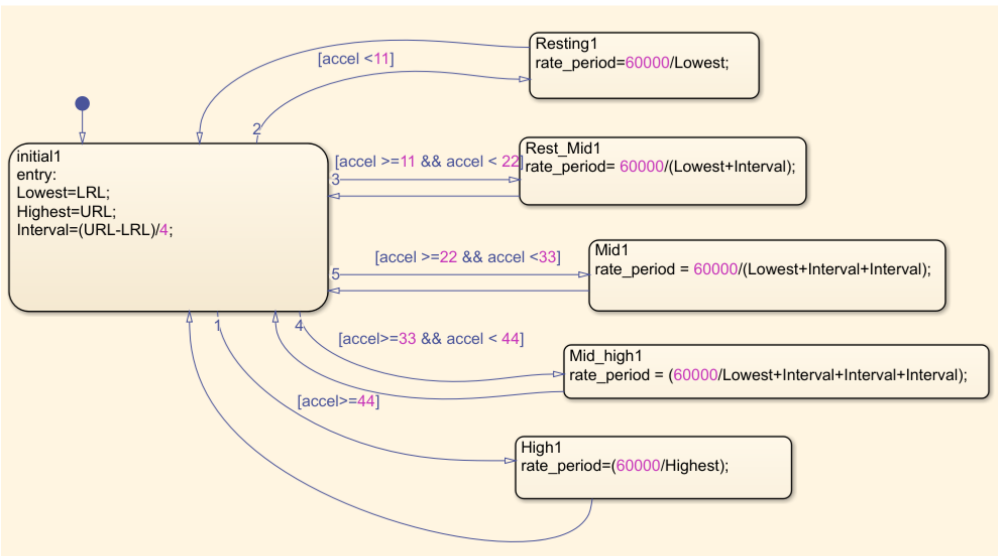


Figure 6: Required Period Calculation

An example graph has also been included below to further explain how the system works. The accelerometer output sets the activity level and this activity level is split into 3 thresholds which use the LRL and URL to determine the required bpm at these different thresholds. These calculations are hidden from the user. It is important to note that these functions are influenced by the user inputs, but the DCM cannot control how these functions operate. These thresholds are visualized below.

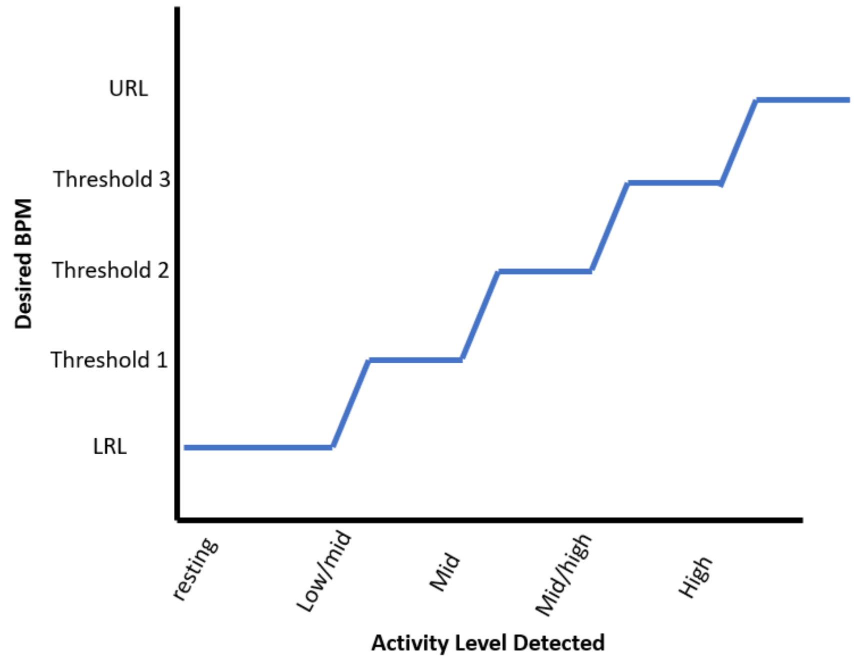


Figure 7:Activity Level Overview

Below is the black box design of how these calculations control the rate adaptive pacing modes, and how the user-defined response factor, lower rate limit, and upper rate limit help determine the required rate of change and final bpm.

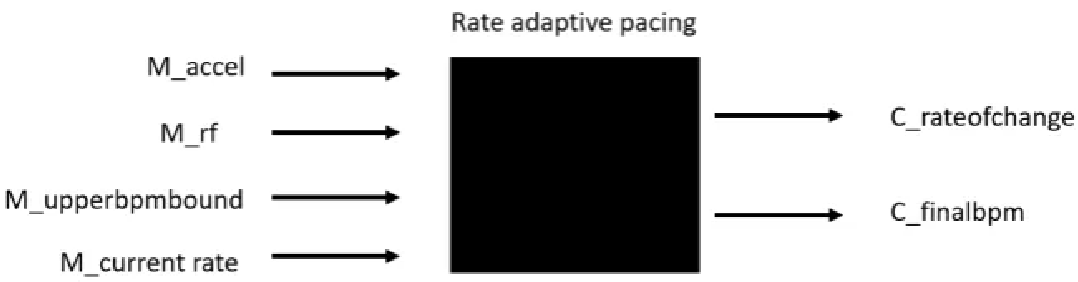


Figure 8: Rate Adaptive Black Box Design

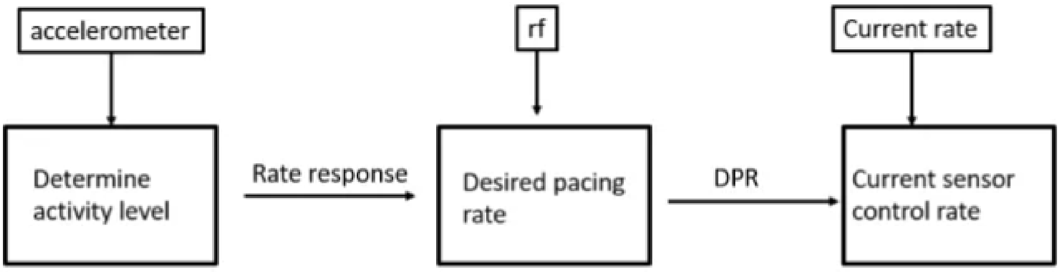


Figure 9: Rate Adaptive Stateflow

System

As the Simulink model is executed, a transition arrow guides the program's initiation from the 'Mode_Start' chart. Depending on the user's selected mode, the model transitions into one of the 9 distinct pacing modes.

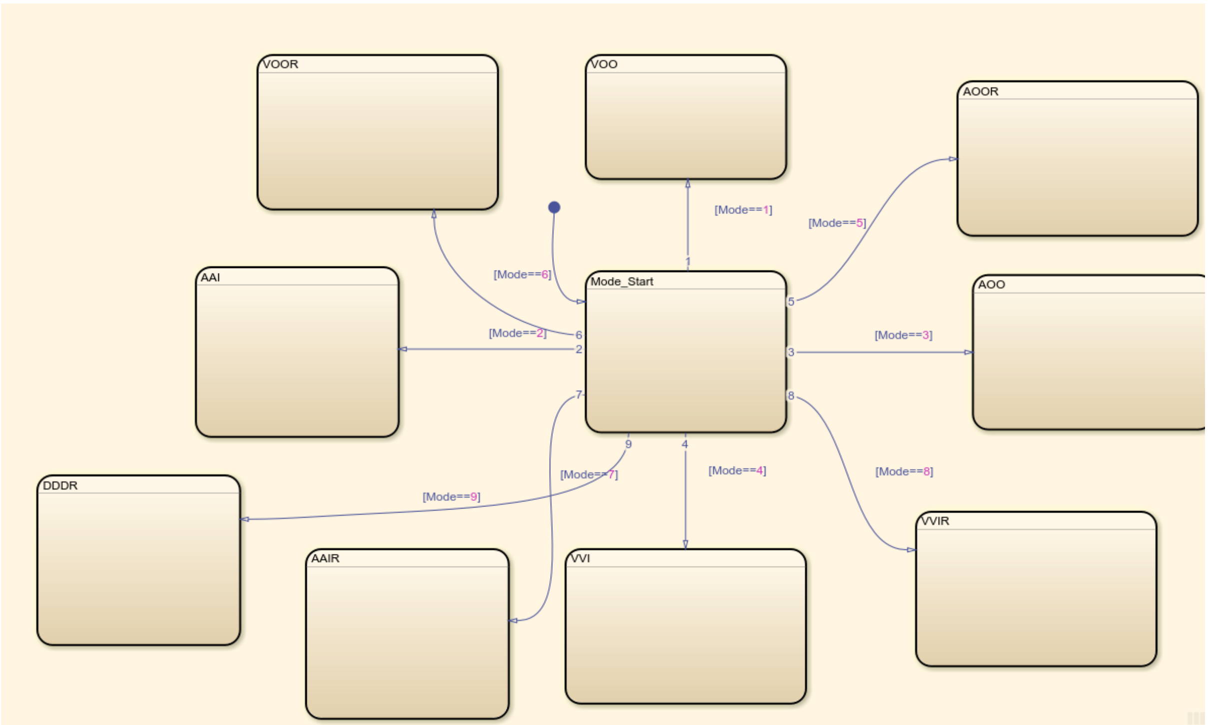


Figure 10: System Overview

AOO

The AOO state was implemented using two states called Charging and Pacing. Within the pacing mode, we decided to implement the charging of C22 for pacing alongside the discharging of an excess charge to C21 in order to improve efficiency as the two actions can occur without interference. After the completion of the charge state, the program is set to wait a delay time of Period-Atr_PW representing the time between pulses. The Pacing state then enables the discharge of the capacitor C22 which then pulses for the duration of Atr_PW before charging the capacitor once more.

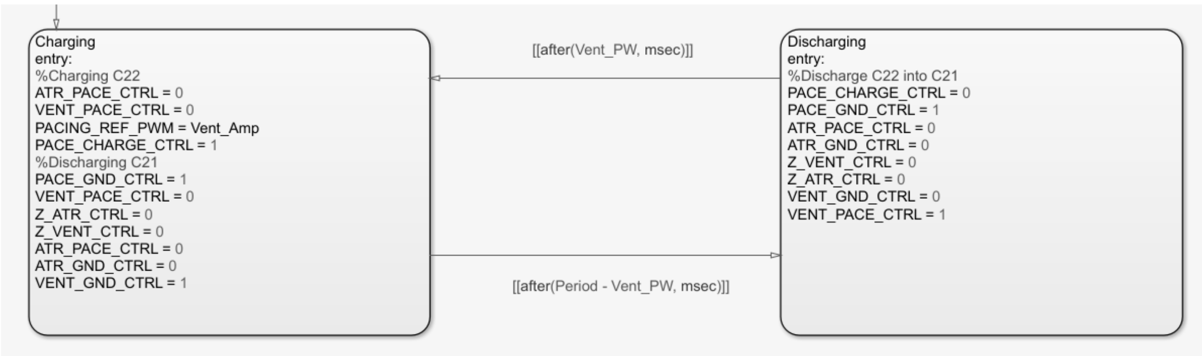


Figure 11: AOO State

VOO

The VOO state was implemented using two states called Charging and Pacing. Within the pacing mode, we decided to implement the charging of C22 for pacing alongside the discharging of an excess charge to C21 in order to improve efficiency as the two actions can occur without interference. After the completion of the charge state, the program is set to wait a delay time of Period-Vent_PW representing the time between pulses. The Pacing state then enables the discharge of the capacitor C22 which then pulses for the duration of Vent_PW before charging the capacitor once more.

Figure 12: VOO State

AAI

The AAI state was implemented using two states, Charging_sensing as well as pacing. In the Charging_sensing state, an input parameter of ATR_SENSITIVITY is checked to determine a threshold for monitoring pacing activity. The charging of C22 and the discharging of C21 are also performed simultaneously. The system then goes on to check for a refractory period determined by Set_ARP where, in the event that a refractory period is triggered the system will then include the delay timing of ARP where atrial events will not trigger nor inhibit pacing. In the case that no refractory period is set the default timing will continue. After which, the system proceeds to discharge C22 and pulse for the duration of Atr_PW and restart the cycle.

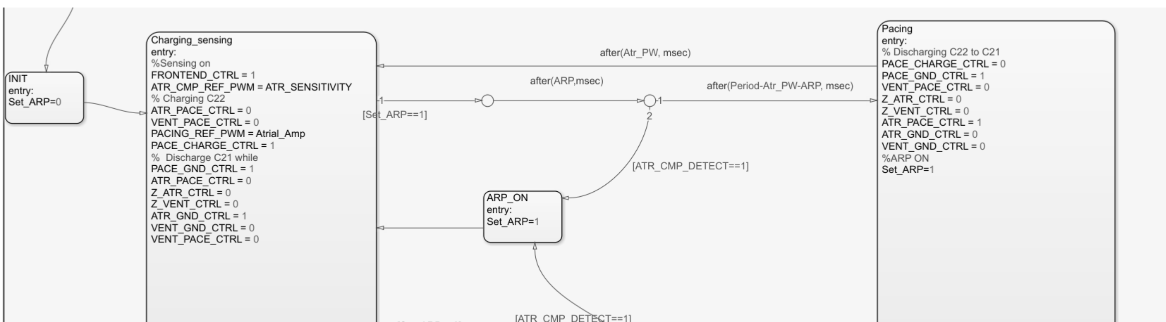


Figure 13: AAI State

VVI

The VVI state was implemented using two states, Charging_sensing as well as pacing. In the Charging_sensing state, an input parameter of VENT_SENSITIVITY is checked to determine a threshold for monitoring pacing activity. The charging of C22 and the discharging of C21 are also performed simultaneously. The system then goes on to check for a refractory period determined by Set_VRP where, in the event that a refractory period is triggered the system will then include the delay timing of VRP where ventricle events will not trigger nor inhibit pacing. In the case that no refractory period is set the default timing will continue. After which, the system proceeds to discharge C22 and pulse for the duration of Vent_PW and restart the cycle.

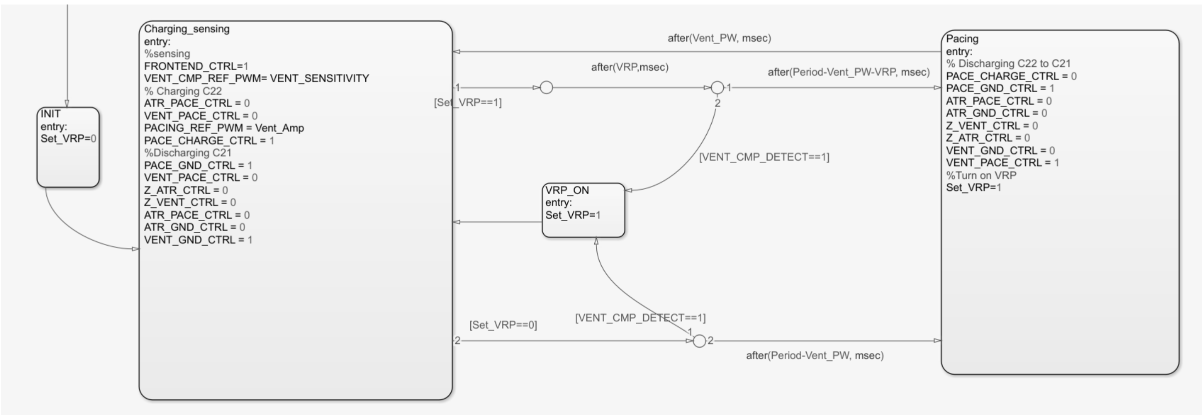


Figure 14: VVI State

AOOR

The AOOR state is implemented by creating a new local variable for the atrial period, which is adjusted incrementally by the response factor after every pace. It will either increase or decrease until it reaches the appropriate bpm, as calculated according to the activity level detected by the pacemaker. If the pacing rate for the activity level is equal to the current pacing rate, no change will be made. Other than that, the state transitions from charging to pacing for the atrium.

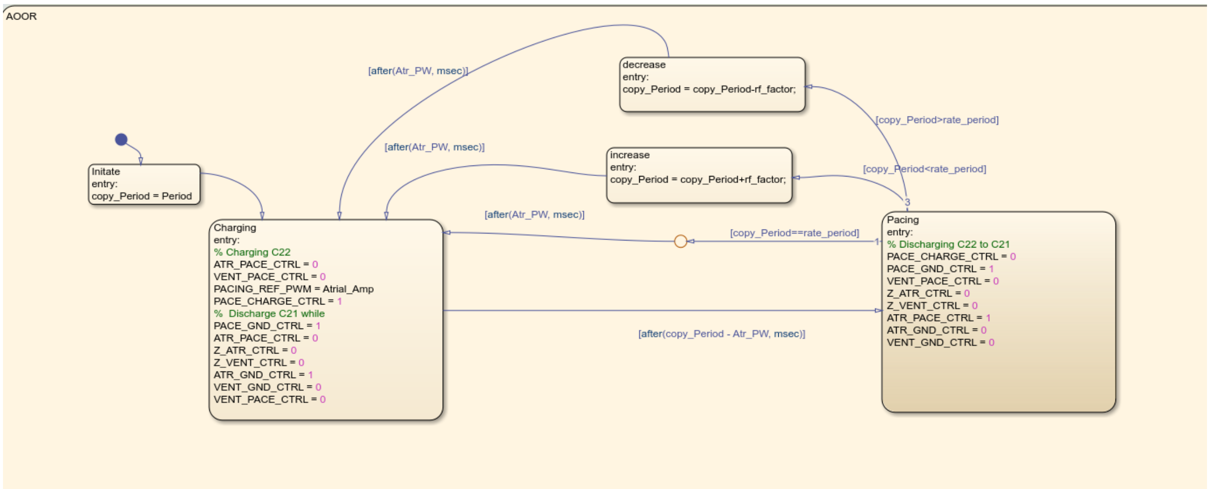


Figure 15: AOOR State

VOOR

The VOOR state is implemented by creating a new local variable for the ventricular period, which is adjusted incrementally by the response factor after every pace. It will either increase or decrease until it reaches the appropriate bpm, as calculated according to the activity level detected by the pacemaker. If the pacing rate for the activity level is equal to the current pacing rate, no change will be made. Other than that, the state transitions from charging to pacing for the ventricle.

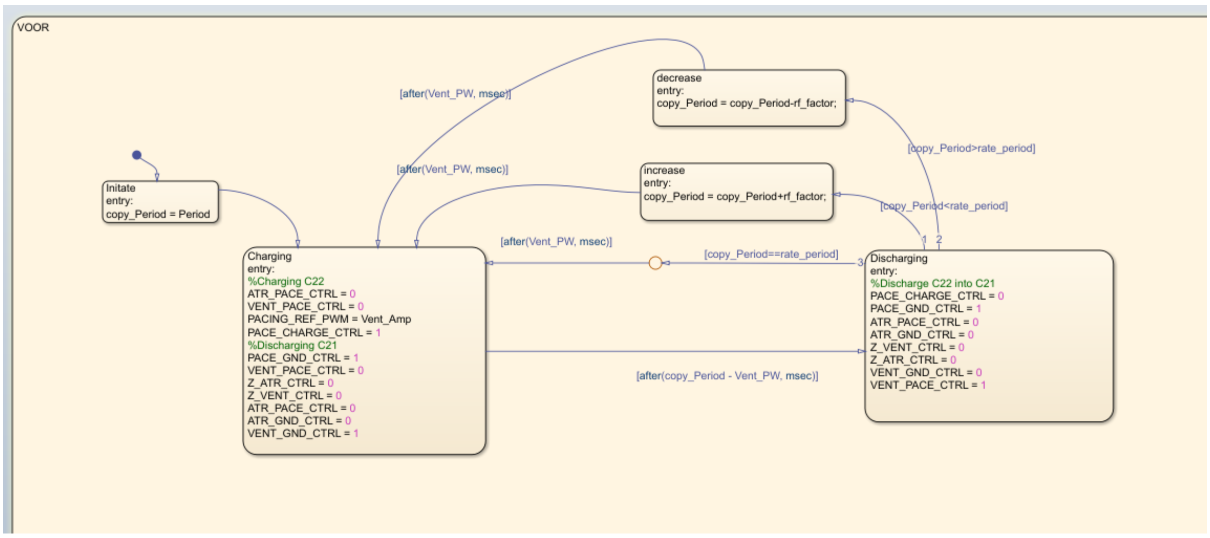


Figure 16: VOOR State

AAIR

The AAIR state is implemented by creating a new local variable for the atrial period, which is adjusted incrementally by the response factor after every pace. It will either increase or decrease until it reaches the appropriate bpm, as calculated according to the activity level detected by the pacemaker. If the pacing rate for the activity level is equal to the current pacing rate, no change will be made. The state transitions from charging to pacing for the atrium unless an atrial event is detected. In this case, atrial pacing is inhibited. Event detection can only take place following a set time (ARP) after the previous pace.

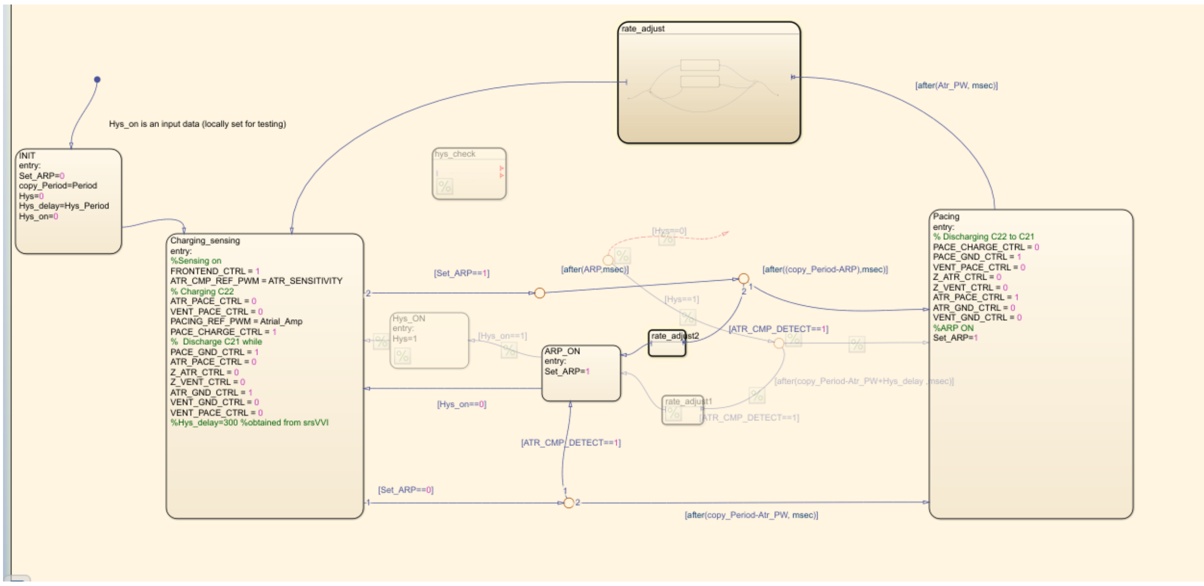


Figure 17: AAIR State

VVIR

The VVIR state is implemented by creating a new local variable for the ventricular period, which is adjusted incrementally by the response factor after every pace. It will either increase or decrease until it reaches the appropriate bpm, as calculated according to the activity level detected by the pacemaker. If the pacing rate for the activity level is equal to the current pacing rate, no change will be made. The state transitions from charging to pacing for the ventricle unless a ventricular event is detected. In this case, ventricular pacing is inhibited. Event detection can only take place following a set time (VRP) after the previous pace.

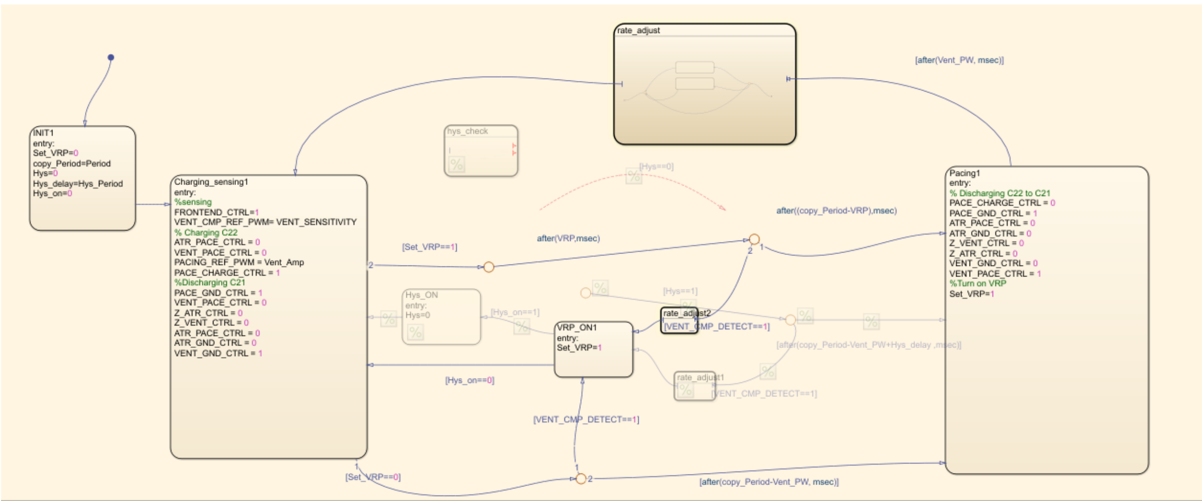


Figure 18: VVIR State

DDDR

The DDDR state is implemented by creating a new local variable for the atrial period, which is adjusted incrementally by the response factor after every pace. It will either increase or decrease until it reaches the appropriate bpm, as calculated according to the activity level detected by the pacemaker. If the pacing rate for the activity level is equal to the current pacing rate, no change will be made. The state transitions from charging to pacing for the atrium, then from charging to pacing for the ventricle, unless a push button (SW3) signal is detected. In this case, ventricular pacing is inhibited.

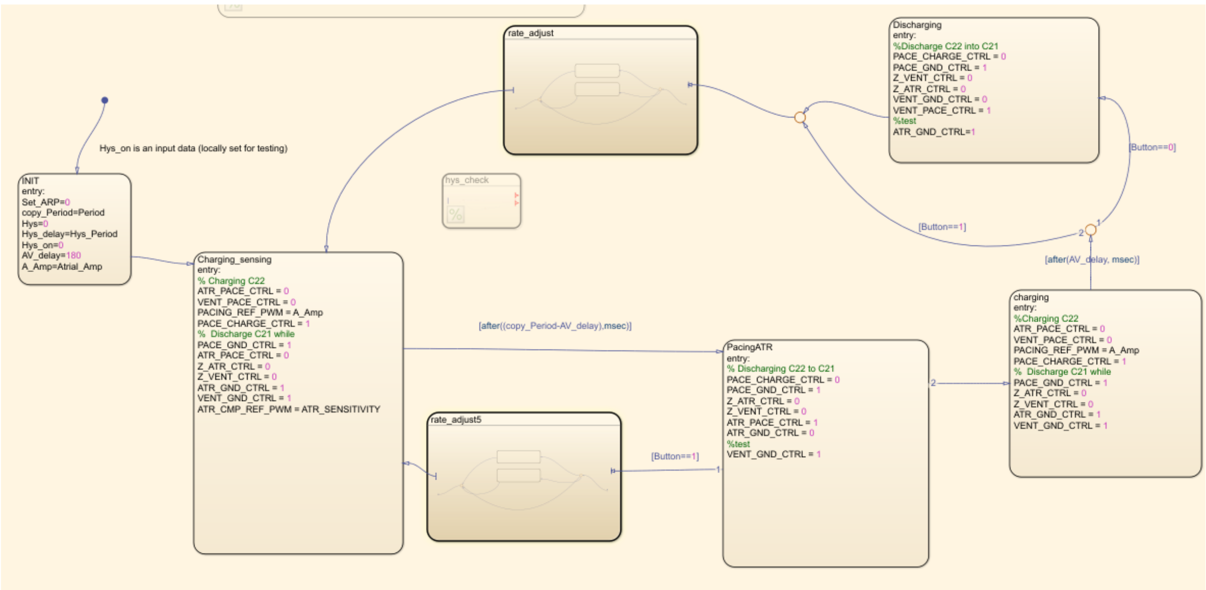


Figure 19: DDDR State

Outputs

These parameters are hidden in the subsystem ‘outputs’ which will send information to the pacemaker’s pins.

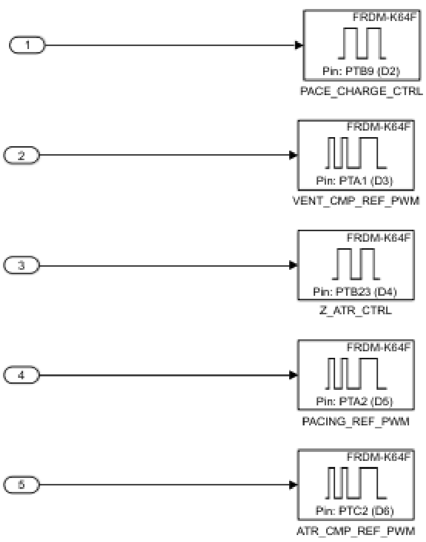
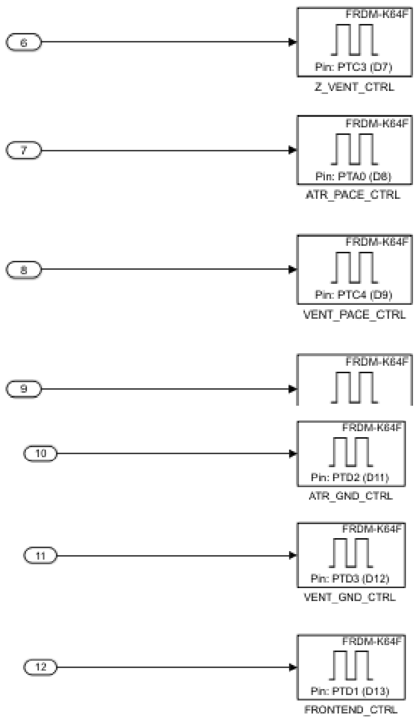


Figure 8:



Outputs

Figure 20: Outputs

Serial Outputs

With serial communication being used in Assignment 2, the serial outputs block was created. In this block, when the DCM sends a receive package (transmit bit = ‘0’), the system sends back the mode, atrial amplitude, ventricle amplitude, atrial detect signal (voltage within the atrium) and the ventricle detect signal (voltage within the ventricle). The mode is sent back to verify that the transmission was sent successfully, whereas the other 4 signals are used to create egram plots on the DCM side.

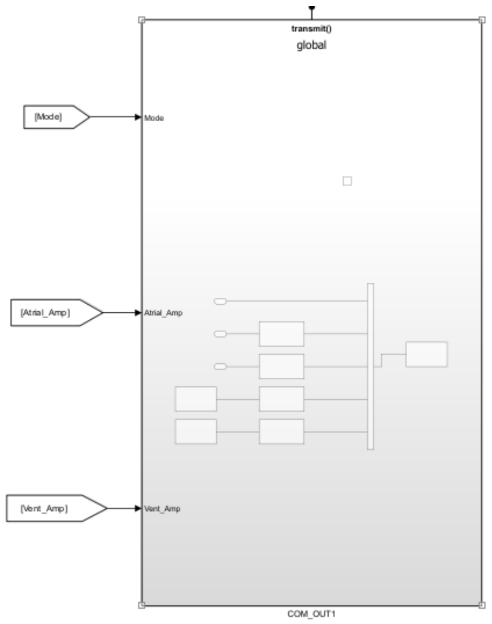


Figure 21: Serial Outputs Overview

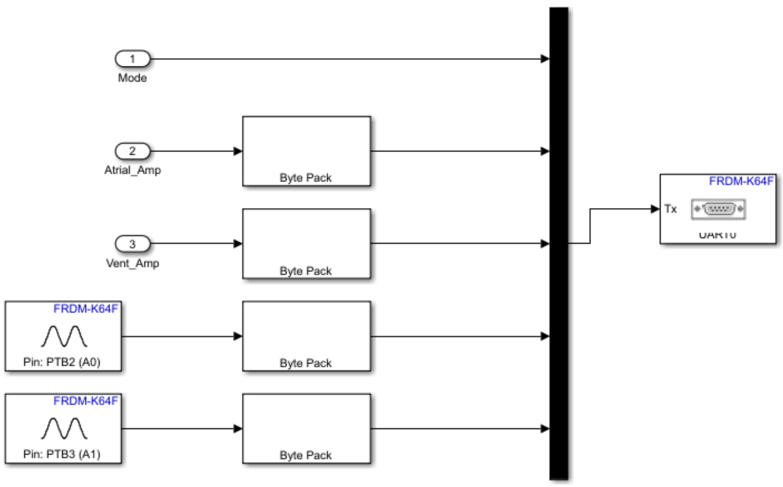


Figure 22: Serial Outputs Internals

Design Decisions

Simulink Model Overview

Our approach is grounded in a modular design philosophy with an emphasis on hardware hiding. Our team decided to separate the model into three subsystems to promote a more modular design which includes the following: serial inputs, inputs, internal calculations, system, serial outputs, and outputs. When connecting subsystems within a complex model, using Goto and From tags can offer several advantages that contribute to a cleaner and more organized appearance compared to using numerous wires. The tags facilitate modular design by enabling clean connections between different components. They provide named and labeled connections, aiding organization, documentation, and troubleshooting. Another integral design choice within the system pertains to the calculation of the pacing period. This calculation is performed by dividing 60000 by the Lower Rate Limit (LRL). To enhance user experience and maintain model simplicity, we have concealed this period calculation within the Internal Calculations subsystem. This strategic decision involves pre-computing the period, shielding the user from the underlying calculations within the primary system (refer to Figure 10).

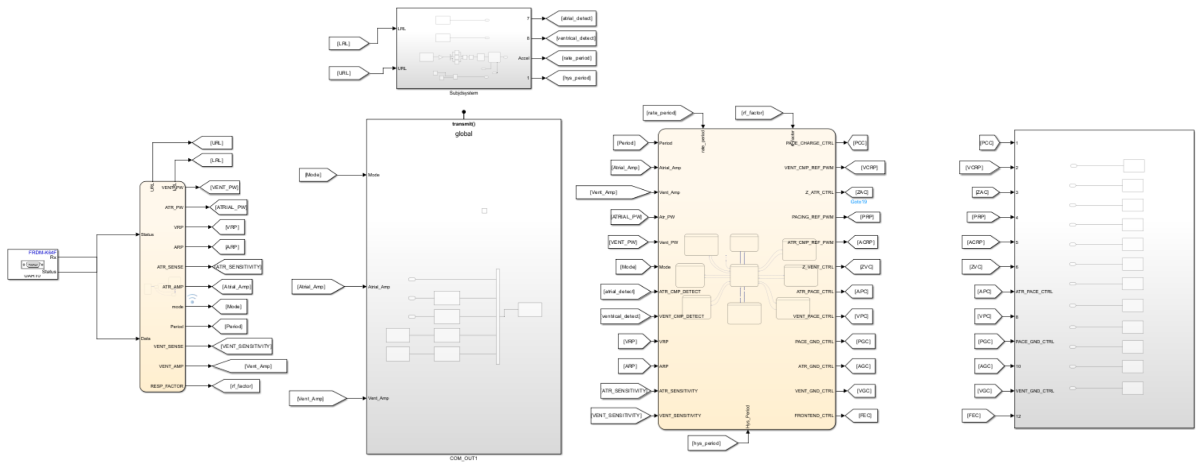


Figure 23: Model Overview

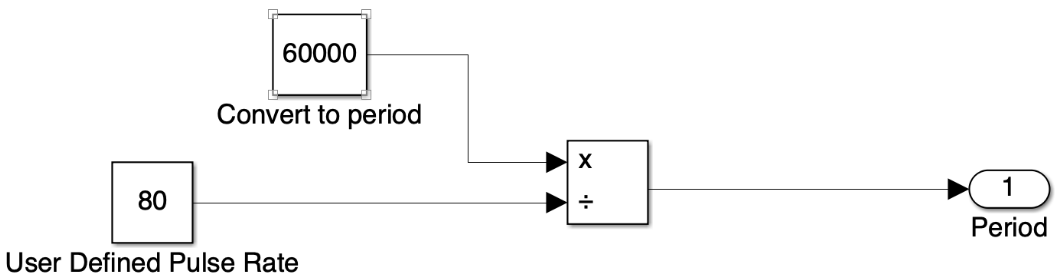


Figure 24: Period Calculations

Maintenance and Future Changes

To maintain this system, accelerometer data will have to be looked at twice a year. This is to ensure that the accelerometer is active and the safety systems are not controlling the required heart rate. If the accelerometer is determined to be faulty or decreasing in precision, the user will have to determine whether the accelerometer needs to be replaced or whether the model needs to be adjusted.

Future Changes that could be implemented to the model include: new mode additions for different pacing requirements, additional serial outputs for DCM improvements and improvement of input requirement to better control what the user can and cannot control within the system.

Assurance Cases

With safety being a top priority in the pacemaker setup, probable hazards were investigated before designing the model. This was documented in Figure 25:

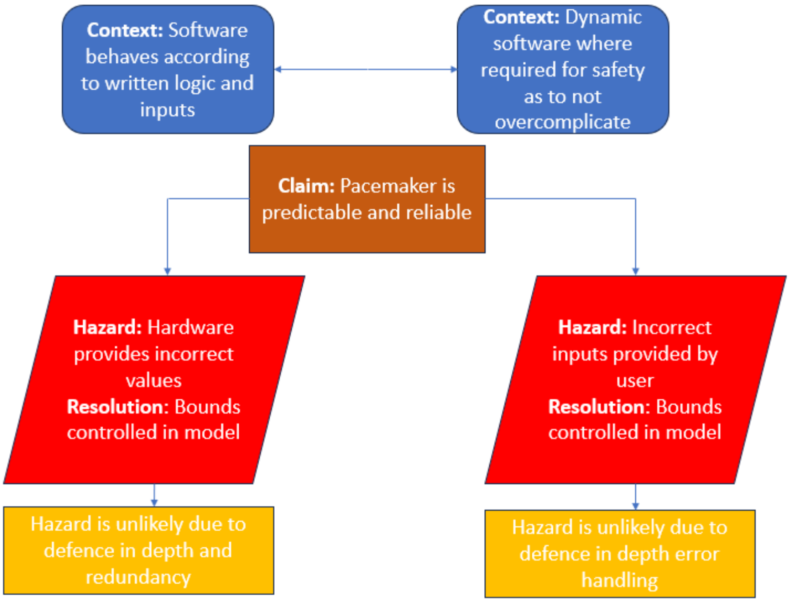


Figure 25:Risk Analysis

With the following hazards in mind, the model was set up with two main systems to make sure that the patient is always safe.

The first system that was created helps with redundancy and defence in depth. As talked about in the Internal Calculations section, the model controls the maximum allowable heart rate based on the user's input LRL and URL. This is important to note because it means that the heart rate is not directly controlled by the pacemaker's accelerometer. There is a layer of depth control that stops the pacemaker from beating the heart too quickly. On a high level, the system controls the limits that the accelerometer provides and checks them against user inputs. In testing, the accelerometer reached an activity level of 45, so a maximum bound of 44 was set. This means that even if the accelerometer goes higher than 45, the user will still only have a heartbeat of the URL.

The second system that is used is hardware hiding through modularization. The system is set up to separate user-controlled inputs from the model itself. That way users can only control what the preferred rate is rather than how they interact with the system. This also means that the pacemaker program controls what the heart is doing with the help of user inputs rather than the user controlling the heart. This limits failures and errors in calculations, protecting the patient.

Testing

For the testing of the AOO, VOO, AAI and VVI modes the default test parameters are listed below

Pulse rate = 80ppm
Vent amp = 2.5V
Vent PW = 1ms
Vent Refractory Period = 320ms
Vent Sensitvity = 90%
Atr amp = 2.5V
Atr PW = 1ms
Atr Refractory Period = 250ms
Atr Sensitvity = 90%

For the testing of the AOOR, VOOR, AAIR and VVIR and DDDR modes the default test parameters are listed below

Lower Rate Limit = 60
Upper Rate Limit = 160
Vent amp = 2.5V
Vent PW = 1ms
Vent Refractory Period = 320ms
Vent Sensitvity = 90%
Atr amp = 2.5V
Atr PW = 1ms
Atr Refractory Period = 250ms
Atr Sensitvity = 90%
RF = 16

VOO

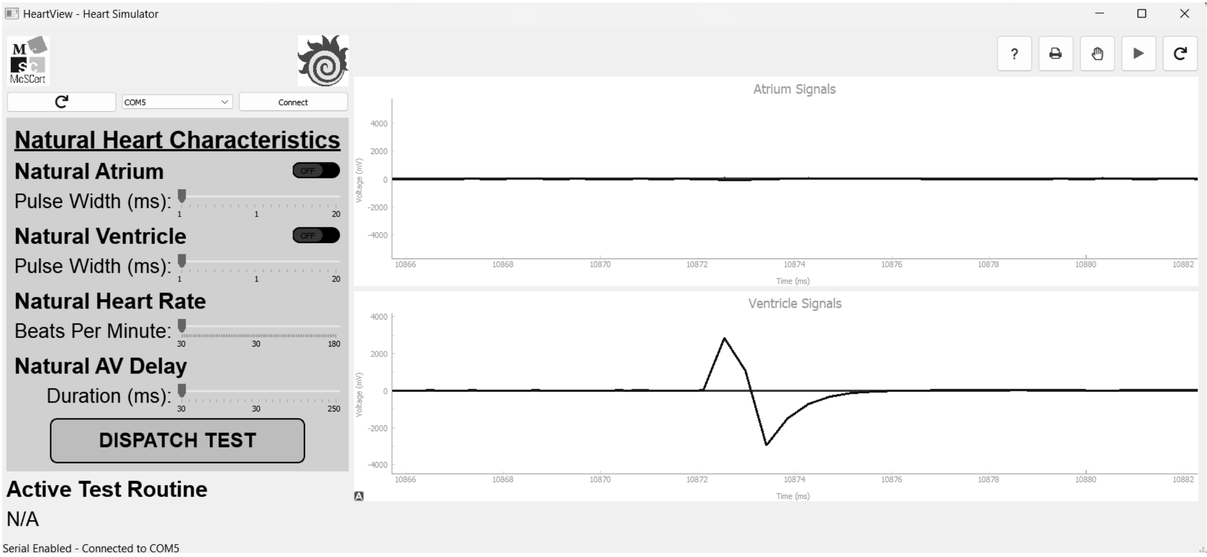
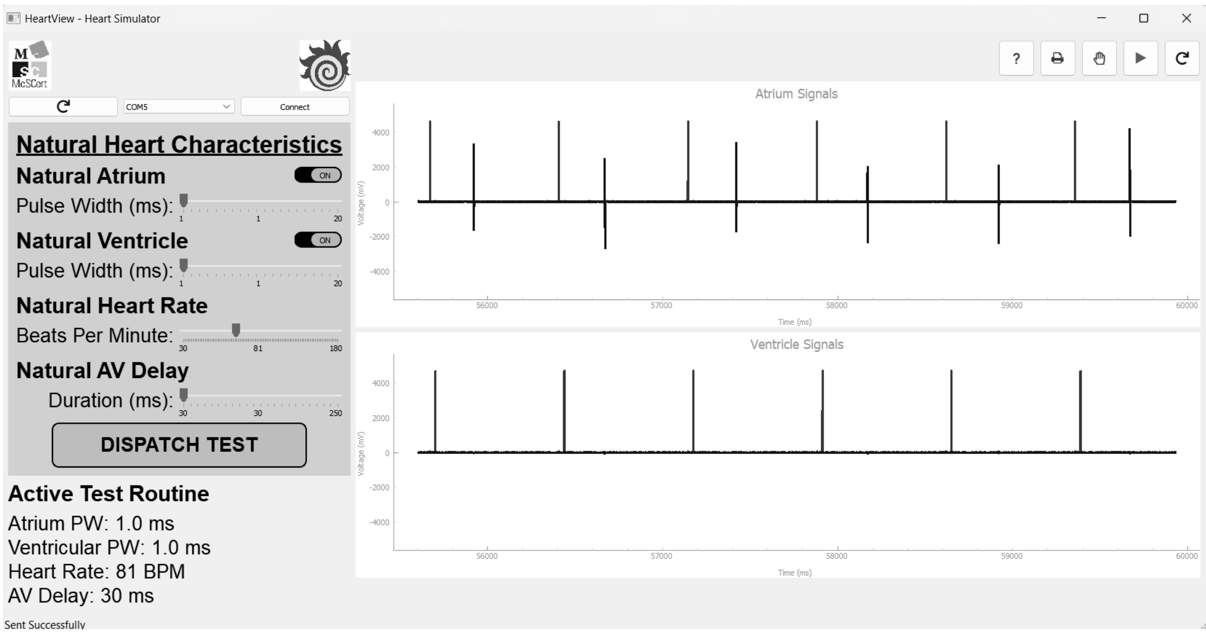


Figure 11: VOO behavior

As seen from figure 11, the ventricle is pulsed independently at a constant rate with no effect from the atrial or ventricle events, which is expected of VOO. The signal amplitude seems to hover around 2.5V. These are well within the expected outputs.

AOO



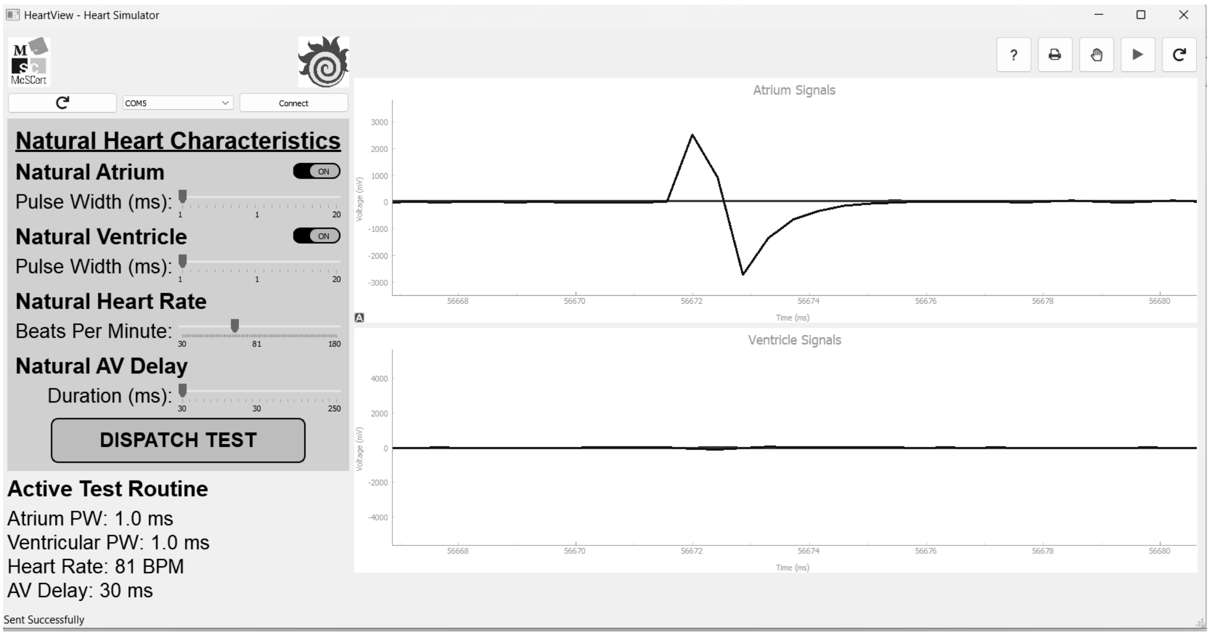


Figure 12: AOO Behavior

As seen from the figure 12, the atrium is pulsed independently at a constant rate with no effect from the atrial or ventricle events, which is expected of AOO. The signal amplitude seems to hover around 2.5V. These are well within the expected outputs.

VVI

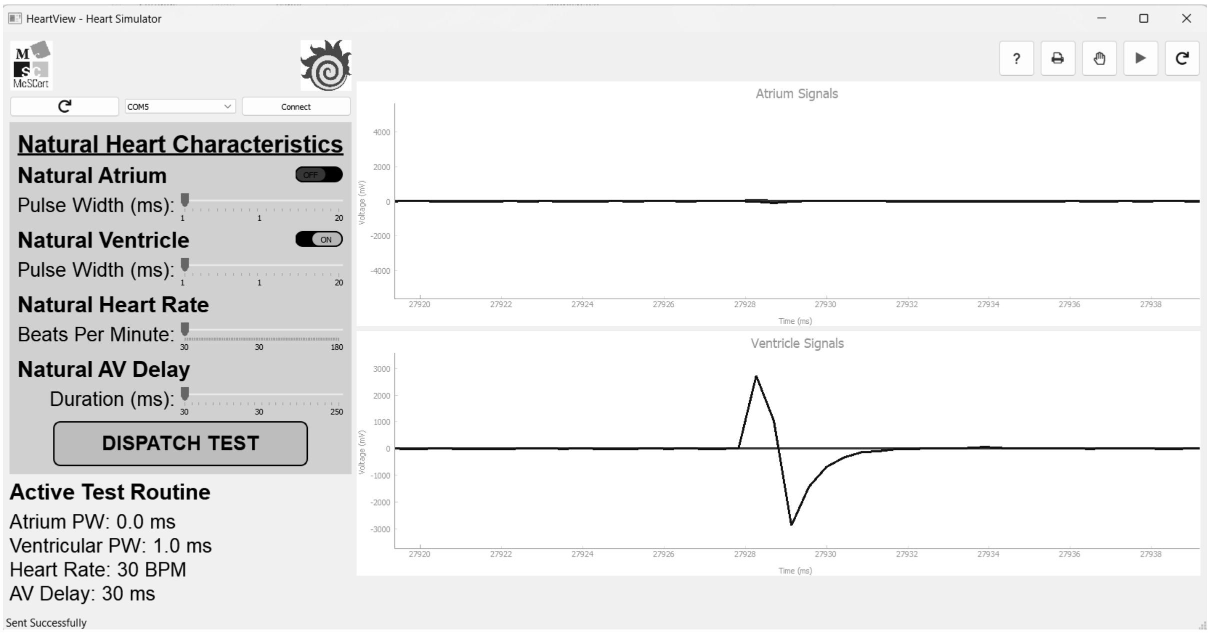
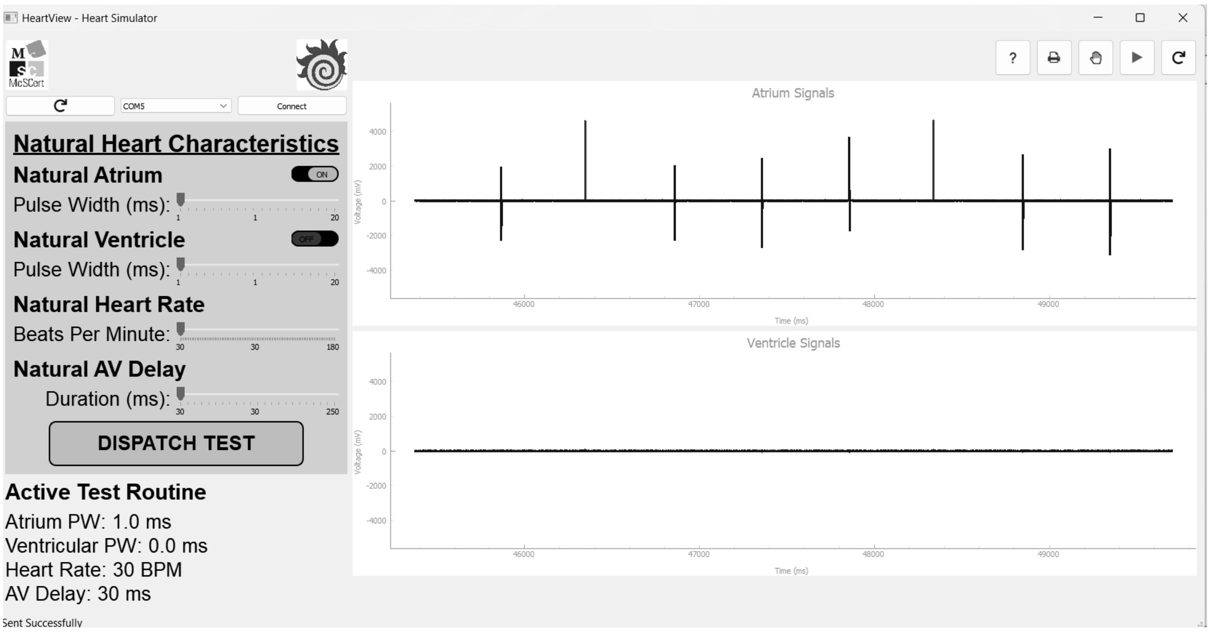


Figure 13: VVI behavior

As seen from the figure 13, the ventricle is pulsed at the set rate of 80ppm while inhibiting during a ventricular event, which is expected of VVI. The signal amplitude seems to hover around 2.5V. These are well within the expected outputs.

AAI



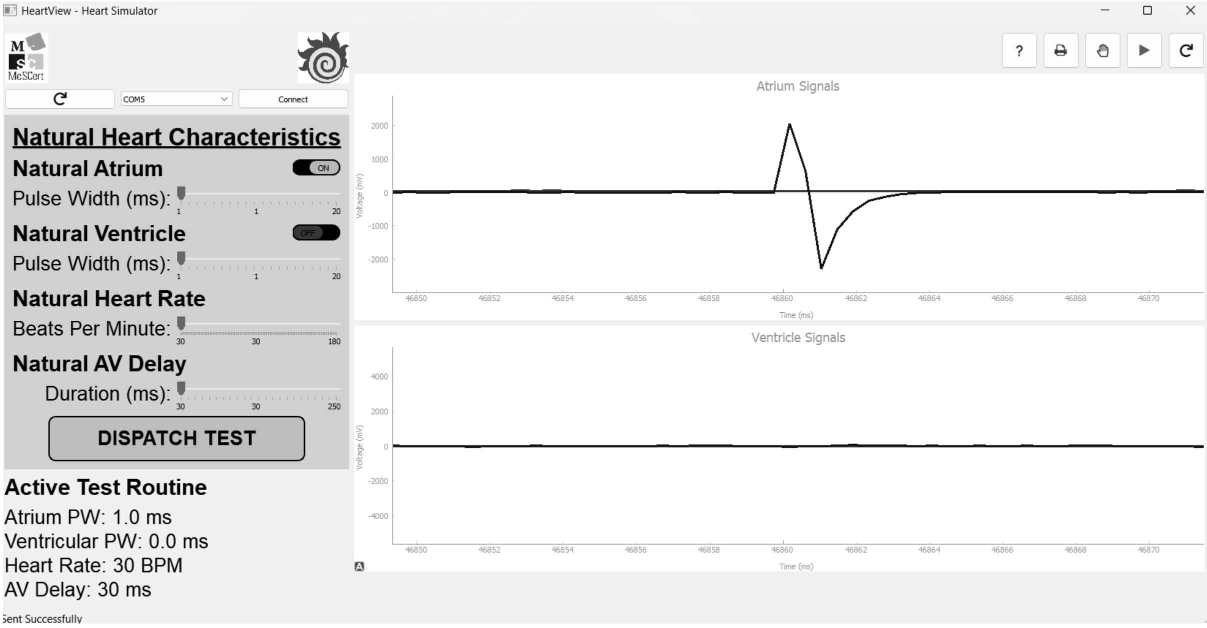
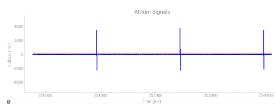
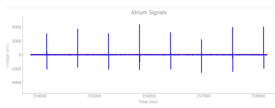
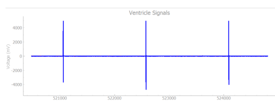
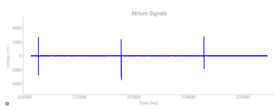
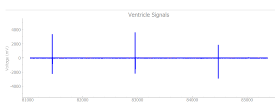
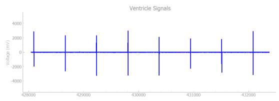
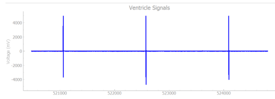
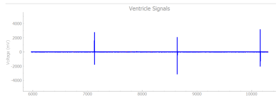
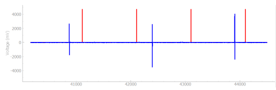
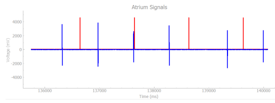
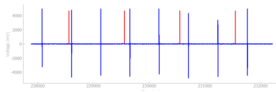
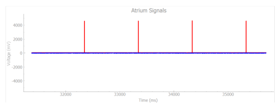
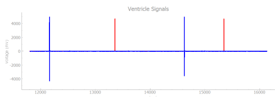
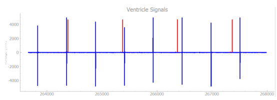
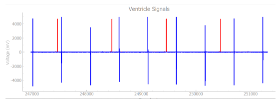
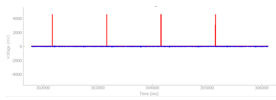
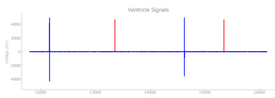
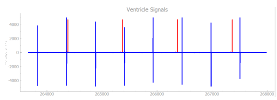
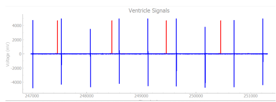


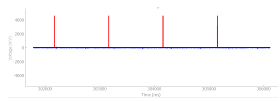
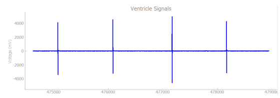
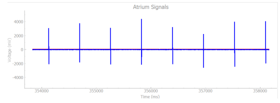
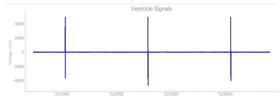
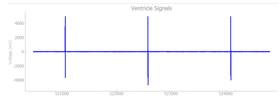
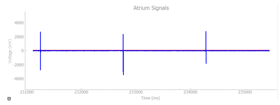
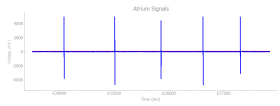
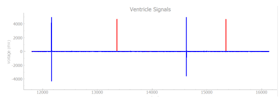
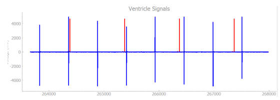
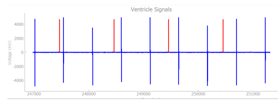
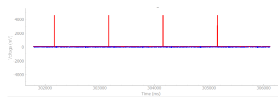
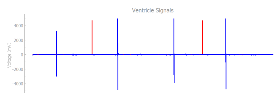
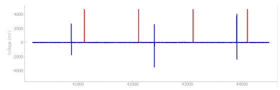
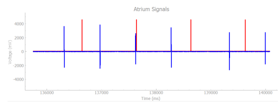
Figure 14:AAI behavior

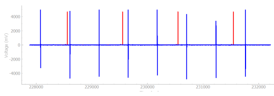
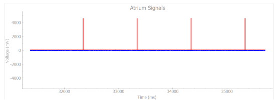
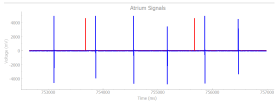
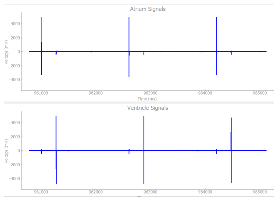
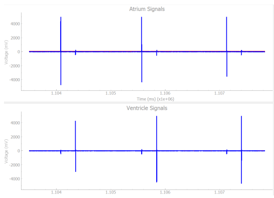
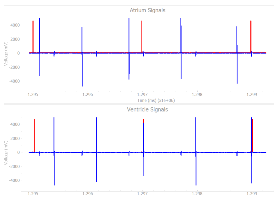
As seen from the figure 14, the atrium is pulsed at the set rate of 80ppm while inhibiting during an atrial event, which is expected of AAI. The signal amplitude seems to hover around 2.5V. These are well within the expected outputs.

The purpose of these tests is to ensure that each mode functions as expected. For atrial or ventricular modes, this means pacing either the atrium or ventricle when necessary, respectively. For rate adaptive modes, this means having the bpm increase or decrease when the accelerometer receives an input.

Mode	Test	Actual Output	Result
AOO	Pacing at LRL		Pass
	Pacing at URL		Pass
	Atrial Amp 100		Pass
	Regular		Pass
VOO	Pacing at LRL		Pass

	Pacing at URL		Pass
	Ventricle Amp 100		Pass
	Regular		Pass
AAI	Pacing at LRL w/ heart at 30		Pass
	Pacing at URL w/ heart at 60		Pass
	Atrial Amp = 100		Pass
	Pacing at 45 with heart at 60		Pass
VVI	Pacing at LRL w/ heart at 30		Pass
	Pacing at URL w/ heart at 60		Pass
	Ventricle Amp = 100		Pass
	Pacing at 45 with heart at 60		Pass
VOOR	Pacing at LRL w/ heart at 30		Pass
	Pacing at URL w/ heart at 60		Pass
	Ventricle Amp = 100		Pass

	Pacing at 45 with heart at 60		Pass
	Max Activity level		Pass
AOOR	Pacing at LRL w/ heart at 30		Pass
	Pacing at URL w/ heart at 60		Pass
	Atrial Amp = 100		Pass
	Pacing at 45 with heart at 60		Pass
	Max Activity Level		Pass
VVIR	Pacing at LRL w/ heart at 30		Pass
	Pacing at URL w/ heart at 60		Pass
	Ventricle Amp = 100		Pass
	Pacing at 45 with heart at 60		Pass
	Max Activity level		Pass
AAIR	Pacing at LRL w/ heart at 30		Pass
	Pacing at URL w/ heart at 60		Pass

	Atrial Amp = 100		Pass
	Pacing at 45 with heart at 60		Pass
	Max Activity level		Pass
DDDR	Pacing at LRL w/ heart at 30		Pass
	Pacing at URL w/ heart at 60		Pass
	Max Activity level		Pass