Simulink-Pacemaker Documentation

Requirements

The requirements for the pacemaker involve the pacing modes it must provide, as well as configurable parameters that are changed via the DCM interface. The pacing modes required are AOO, VOO, VVI, and AAI, whose functionality shall be described in a section below. A rate adaptive pacing mode was also required for each of these four modes. The table below displays the required parameters and relevant modes. Note that only the highlighted parameters are implemented as per the assignment specification.

Parameter	Relevant Modes	Nominal
Lower Rate Limit (unit: /min) (pos natural)	AOO, VOO, VVI, AAI, AOOR, VOOR, VVIR, AAIR	60 ppm
Upper Rate Limit (unit: /min) (pos natural)	AOO, VOO, VVI, AAI	120 ppm
Max Sensor Rate (unit /min) (pos natural)	AOOR, VOOR, VVIR, AAIR	120 ppm
Atrial Amplitude (unit: V) (pos rational)	AOO, AAI, AOOR, AAIR	5 V
Ventricular Amplitude (unit: V) (pos rational)	VOO, VVI, VOOR, VVIR	5 V
Atrial Sensitivity (unit: V) (pos rational)	AAI, AAIR	-
Ventricular Sensitivity (unit: V) (pos rational)	VVI, VVIR	-
VRP (unit: msec) (pos rational)	VVI, VVIR	320 ms
ARP (unit: msec) (pos rational)	AAI, AAIR	250 ms
Atrial Pulse Width (unit: msec) (pos rational)	AOO, AAI, AOOR, AAIR	1 ms
Ventricular Pulse Width (unit:	VOO, VVI, VOOR, VVIR	1 ms

msec) (pos rational)		
PVARP (unit: msec) (pos rational)	AAI, AAIR	250 ms
Hysteresis	AAI, AAIR, VVI, VVIR	Off
Rate Smoothing	AAI, AAIR, VVI, VVIR	Off
Activity Threshold	AOOR, VOOR, AAIR, VVIR	Med
Reaction Time	AOOR, VOOR, AAIR, VVIR	30 sec
Response Factor	AOOR, VOOR, AAIR, VVIR	8
Recovery Time	AOOR, VOOR, AAIR, VVIR	5 min

AOO:
Regardless of how the heart would naturally beat, the AOO mode paces the atrium at a set interval. The Lower Rate Limit determines the pace at which pacing takes place. The pulse amplitude and width determine the features of the pulse. This mode does not utilize the atrial or ventricular refractive periods.

Relevant Parameters	Chambers Paced	Chambers Sensed	Response to Sensing
Lower Rate Limit, Upper Rate Limit, Atrial Amplitude	Atrium	None	None

VOO:
Regardless of how the heart would naturally beat, the VOO mode paces the ventricle at a set interval. The Lower Rate Limit determines the pace at which pacing takes place. The pulse amplitude and width determine the features of the pulse. This mode does not utilize the atrial or ventricular refractive periods.

Relevant Parameters	Chambers Paced	Chambers Sensed	Response to Sensing
Lower Rate Limit, Upper Rate Limit, Ventricular Amplitude	Ventricle	None	None

AAI:
If the atrium is not already pacing itself to meet the Lower Rate Limit parameter, the AAI mode will do so.

Relevant Parameters	Chambers Paced	Chambers Sensed	Response to Sensing
Lower Rate Limit, Upper Rate Limit, Atrial Amplitude, Atrial Sensitivity, ARP, PVARP, Hysteresis, Rate Smoothing	Atrium	Atrium	Inhibited

VVI:
If the ventricle is not already pacing itself to meet the Lower Rate Limit parameter, the VVI mode will do so.

Relevant Parameters	Chambers Paced	Chambers Sensed	Response to Sensing
Lower Rate Limit, Upper Rate Limit, Ventricular Amplitude, Ventricular Sensitivity, VRP, Hysteresis, Rate Smoothing	Ventricle	Ventricle	Inhibited

Furthermore, gitattributes were set up to matlab's merge methods for Simulink development and for indicating binary file types to git to avoid any issues with development.

Rate Modes:

Each of the four pacing modes also had a rate mode variant, specified by an 'R' at the end of the pacing mode name. This letter specified that rate modulation would take place, and additional parameters required for these modes were Maximum Sensor Rate, Activity Threshold, Reaction Time, Response Factor, and Recovery Time.

Expected Changes to Requirements:

Pacing modes will also include dual pacing modes which will have the option to work with rate modulation. Modes with triggered response to sensing will also be implemented. Additionally, more programmable parameters will be added to allow for more customized pacing beyond what parameters are currently able to be changed.

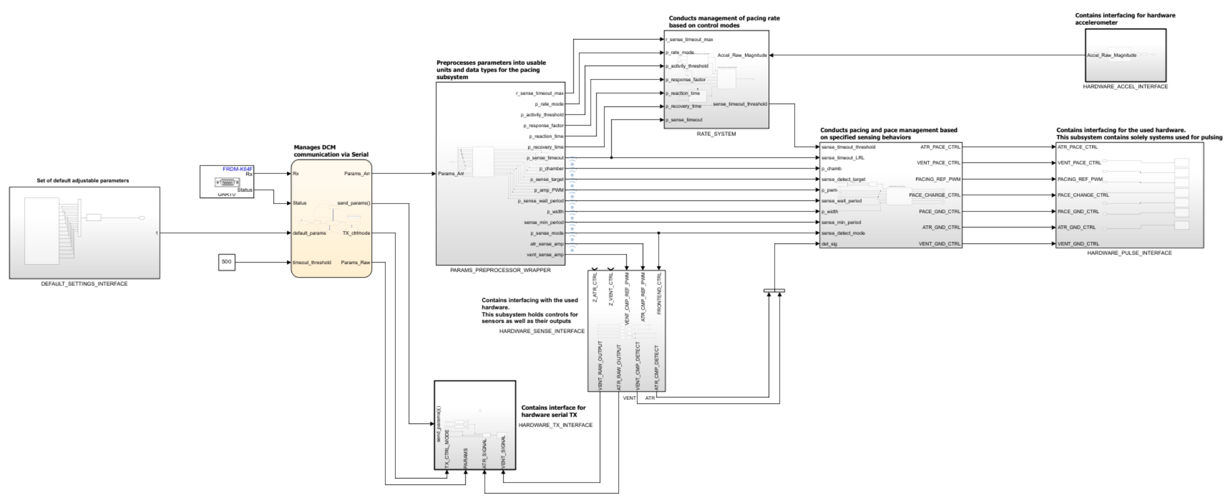
Design Decisions:

To implement hardware hiding, it was decided that subsystems would be used in combination with a main state flow so that the implementation of pacing modes would not rely on the correct hardware for acceptable inputs and outputs. There are separate subsystems for hardware input, hardware output, parameter preprocessing, and rate modulation. A stateflow for communication between the DCM and pacemaker connects to a serial receive block, which can be changed to reflect the correct hardware being used. The default settings subsystem allows for testing that does not rely on the DCM. The use of subsystems also allows for increased modularity, since the hardware input and output subsystems can easily be changed to work with different boards by changing what the inports and outports are mapped to.

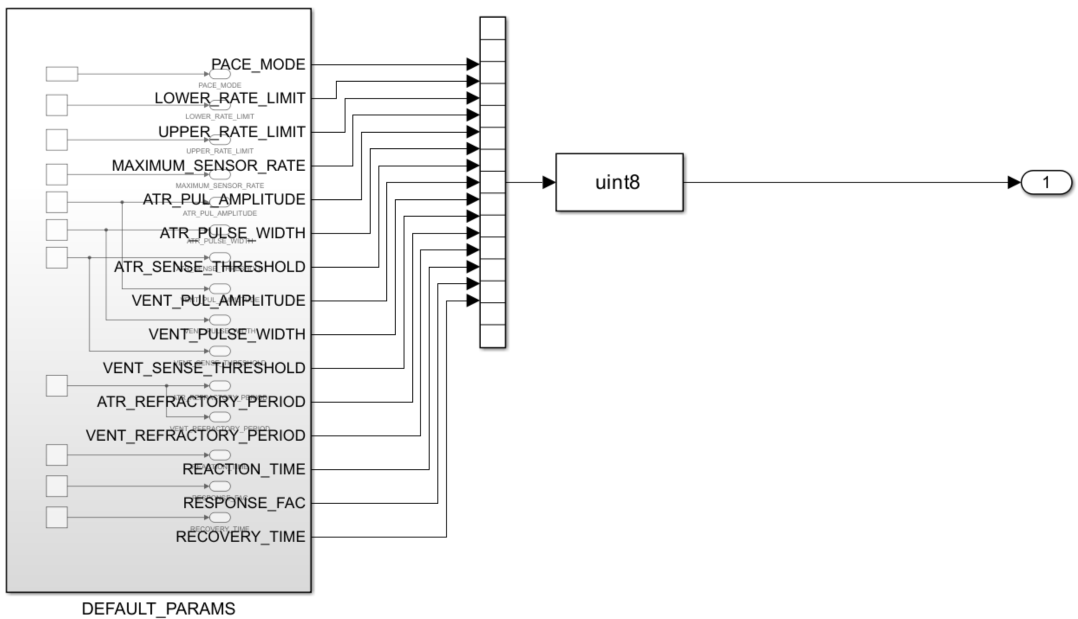
The entire design was modularized to allow for maintainability and the implementation of additional requirements in a stable manner. This will allow for any other pin mapping to be added without breaking anything preexisting. We will also be able to add assurance to the system, and all hardware hiding/abstraction will be maintained in the HAL developed.

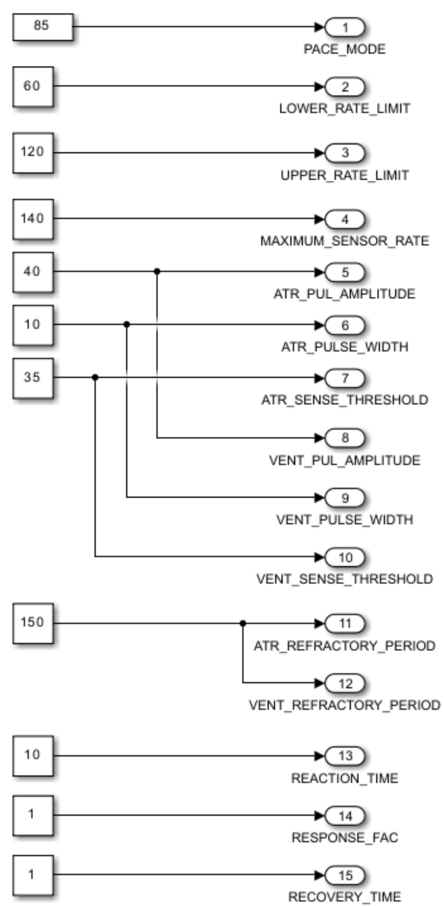
Simulink Model

Eight primary modules were used to implement the required pacing modes with serial communication. Seven of these modules made use of subsystems, and some subsystems had other subsystems integrated. All subsystems were sequentially linked to a subsystem that included the main state flow to process parameters from the DCM, hardware inputs, hardware outputs, and transmit data back to the DCM via serial communication. A module for default parameters was also included in the event nothing was received via the DCM.

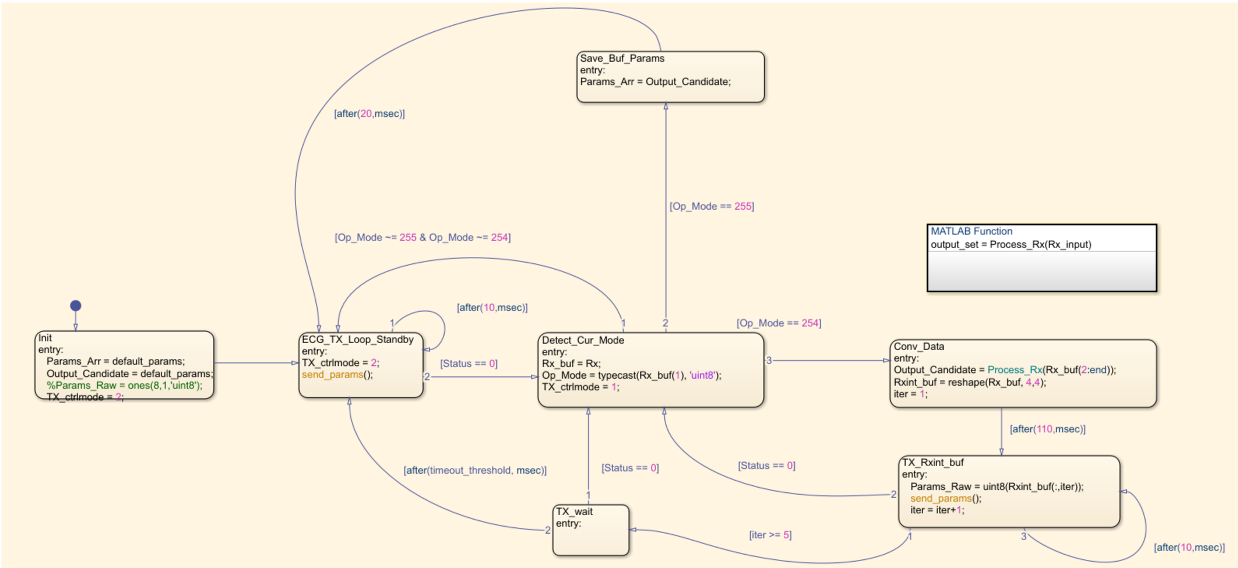


The default settings module uses constant blocks that can be modified to change the default parameter values in case the DCM is not used to set these values. These values are concatenated into a vector and converted to a uint8 to be used in the serial communication stateflow accordingly.

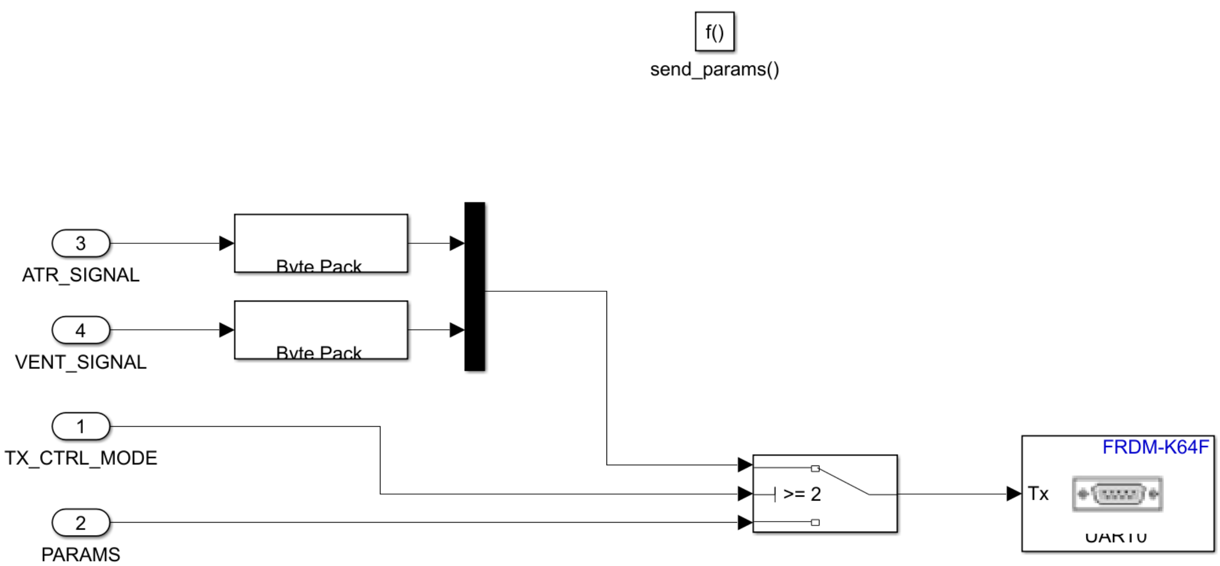




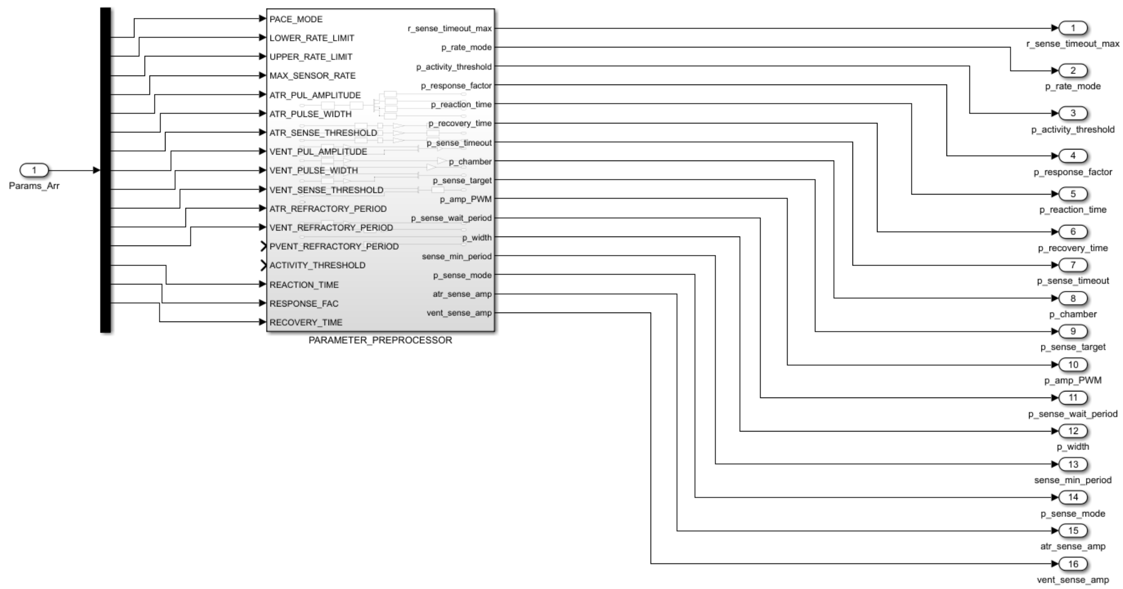
The module for serial communication receives inputs from the DCM and sends these inputs to be processed in parameter preprocessing, as well as sends them back to the DCM to verify that the inputs processed are indeed the inputs that were received. Some delays are implemented in the stateflow to prevent any errors in data processing and ensure that the actual behaviour matches the desired and expected behaviour.

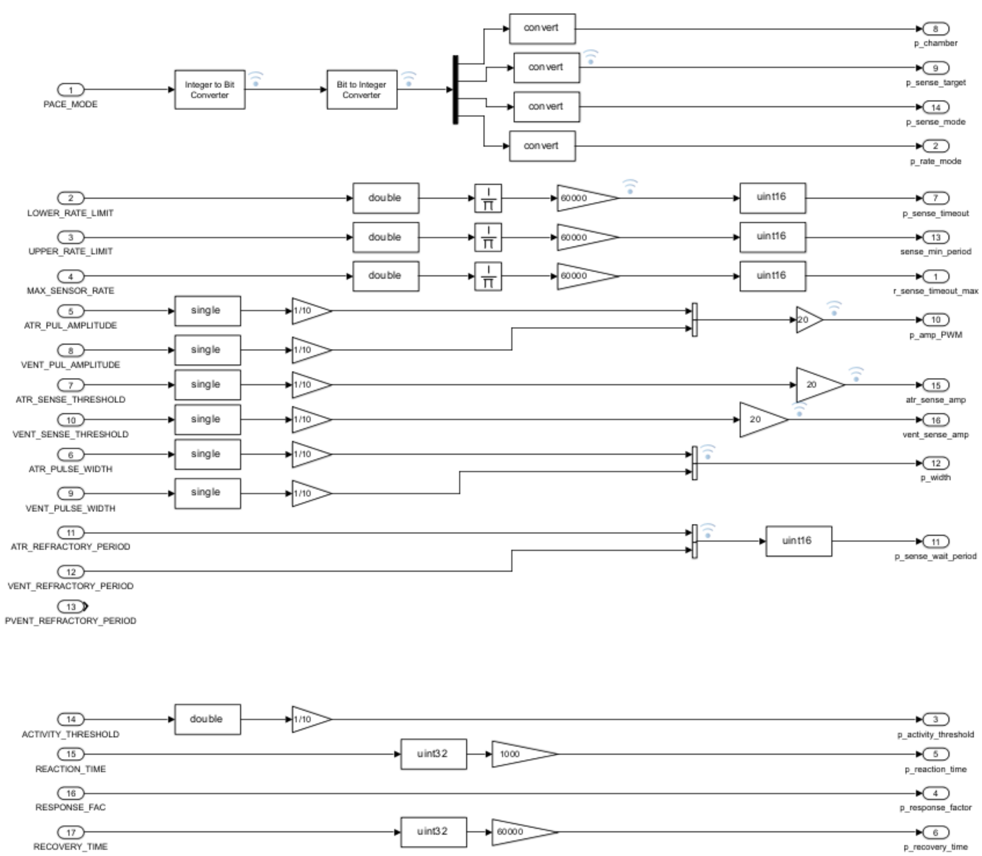


The hardware TX interface module is used to send data back to the DCM. The data sent is used for parameter verification, as well as the atrium and ventricle signals that the DCM needs for egram data.

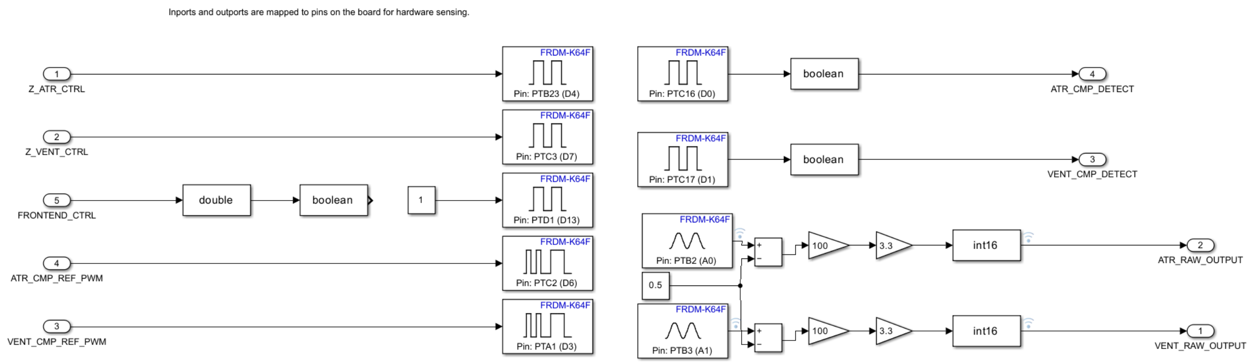


The parameter preprocessing module uses inports received from a demux that use the DCM parameters specified in serial communication and processes and converts the data accordingly based on the parameter so that the outports can be used in the main state flow, the hardware sense interface, and the rate adaptive system. It is also determined during parameter preprocessing which pacing mode is being requested, and this is done through conversion blocks that use the pace mode parameter and set corresponding outports based on the requested pacing mode.

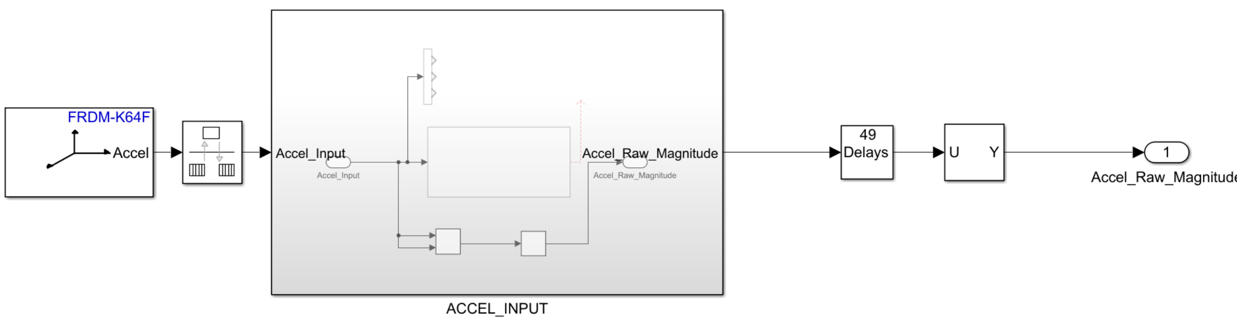




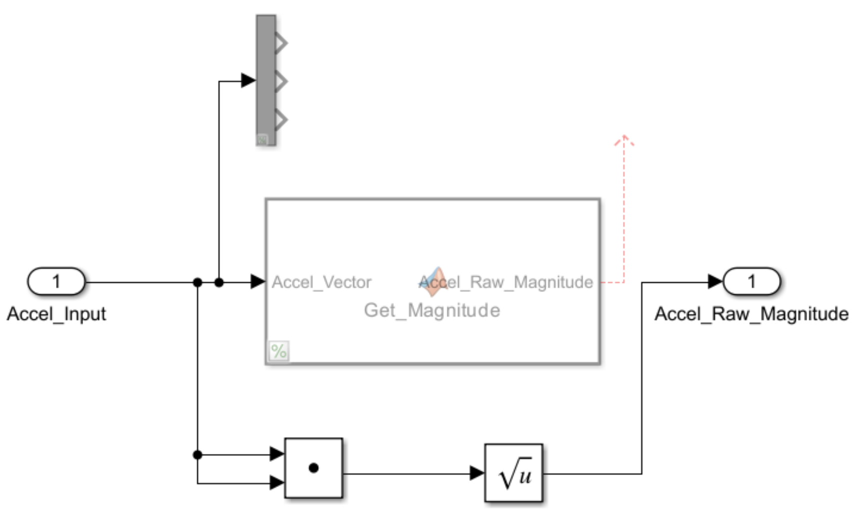
The hardware sensing interface module uses the outports from parameter preprocessing as inports, and maps those ports to pins on the FRDM-K64F board. Similarly, some pins on the board are mapped to outports which are used in the main state flow and serial transmission.



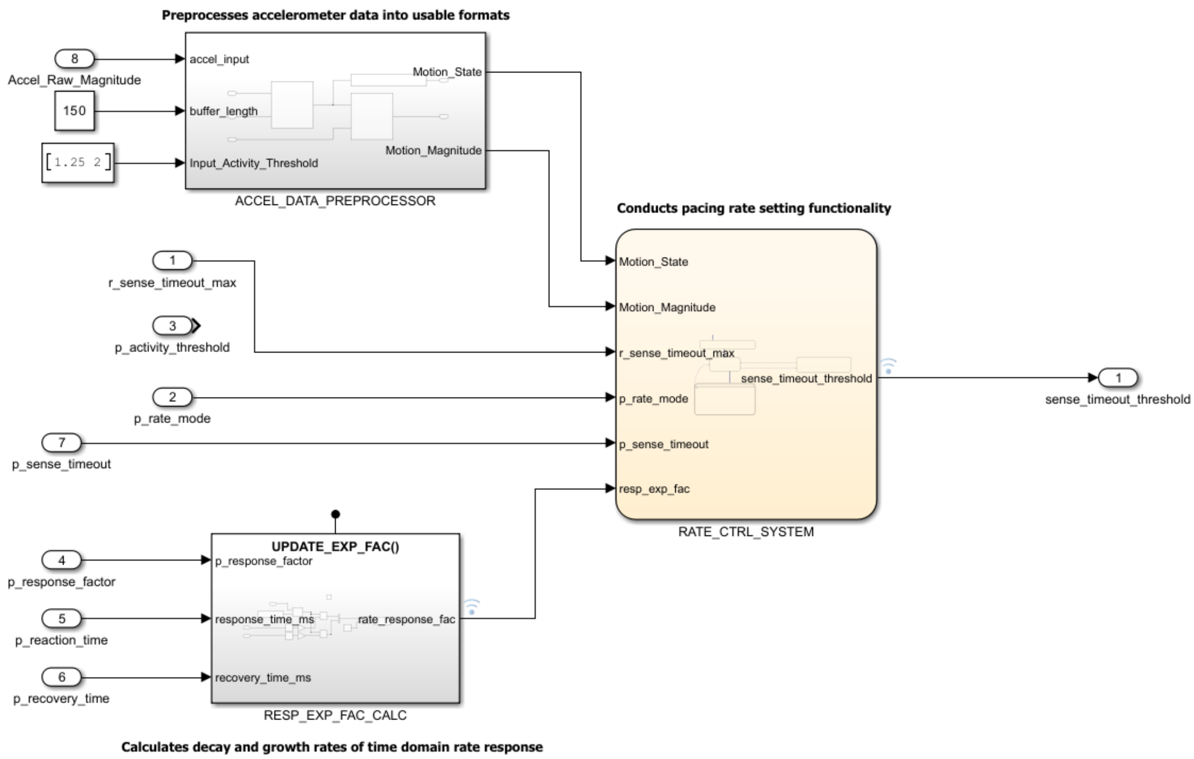
The hardware acceleration interface module processes raw accelerometer data from the board so that it can be used in the rate modulation module.



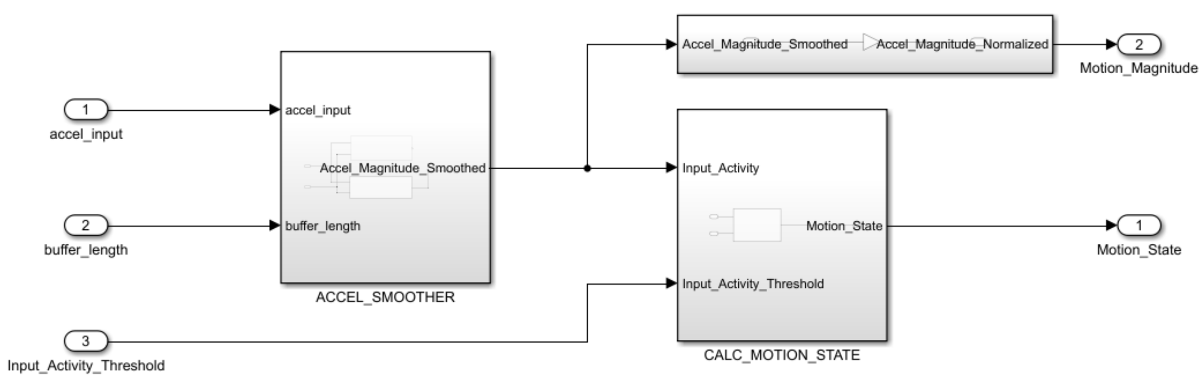
The accelerometer data is processed through a subsystem that performs operations on the data to make it usable.



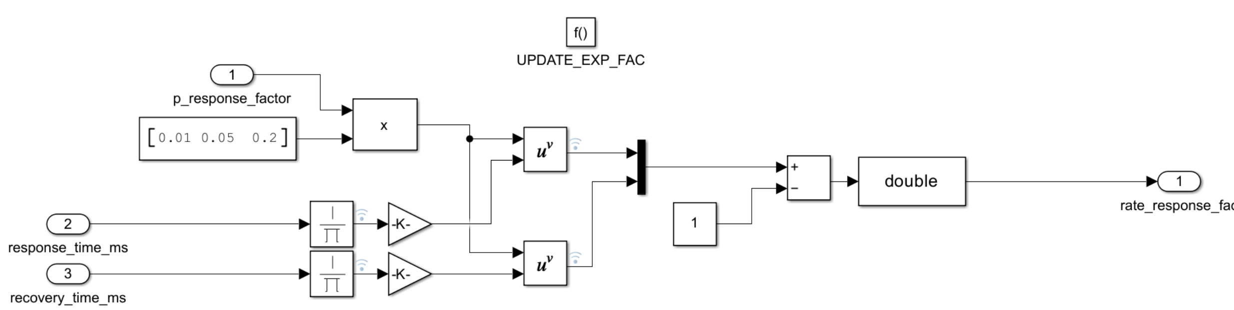
The rate modulation module has three components. This includes the preprocessing of the accelerometer data, calculating the rate response, and setting the pacing rate functionality.



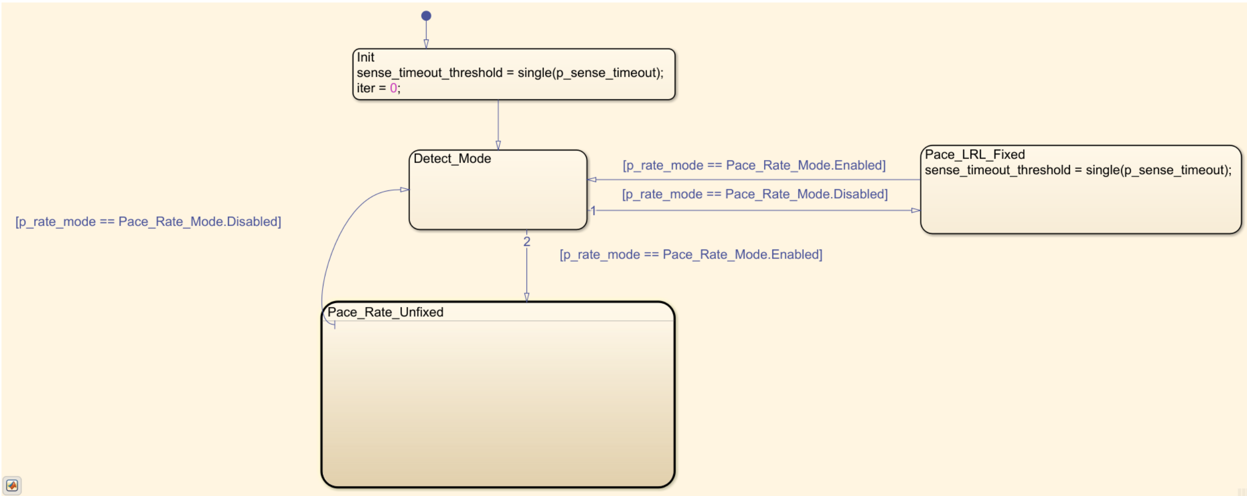
During the data preprocessing, smoothing of the accelerometer input takes place through a MATLAB function, which is used to calculate the motion state and motion magnitude.



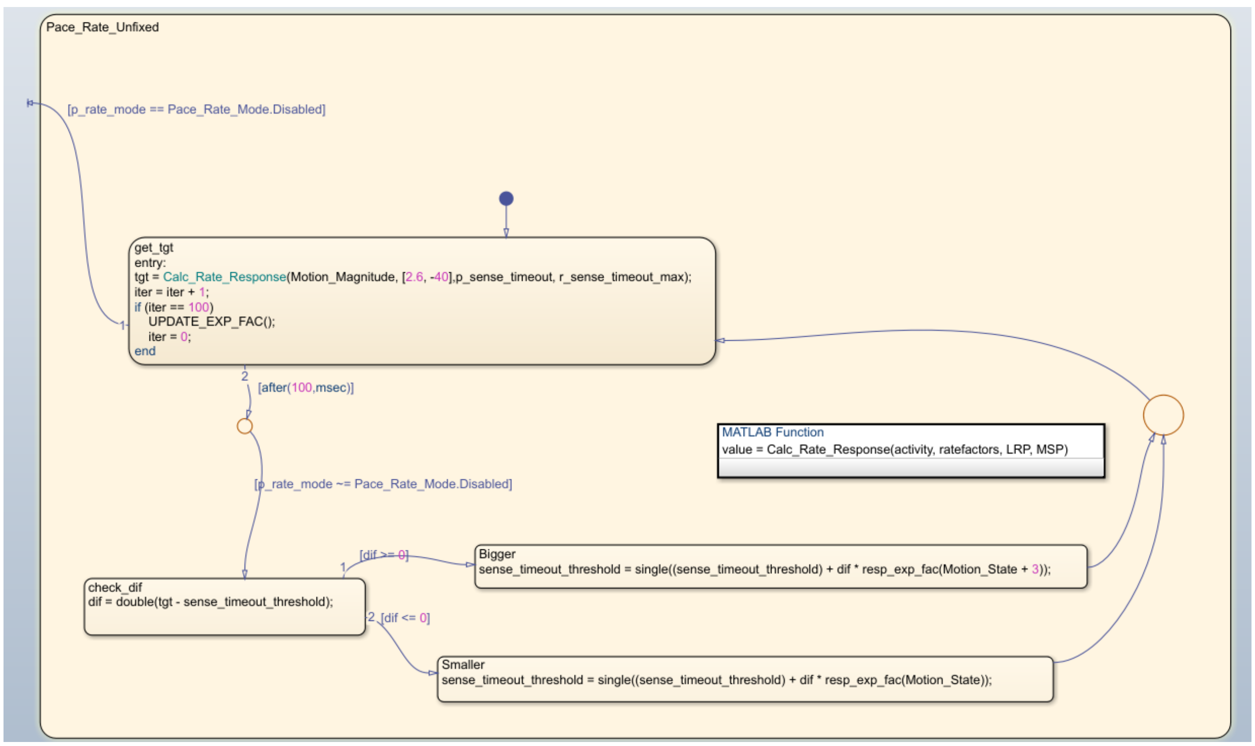
The rate response is determined through calculations performed based on the response factor, response time, and recovery time.



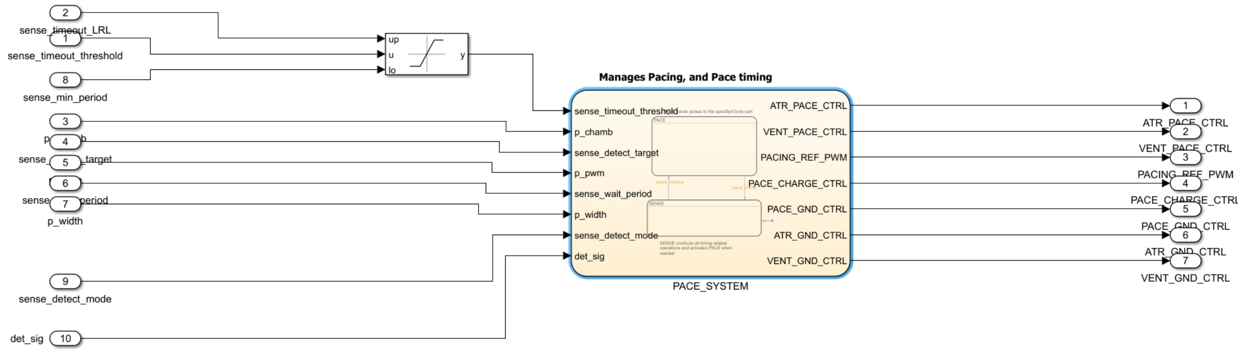
The pacing rate functionality takes place through a stateflow that also contains a secondary stateflow.



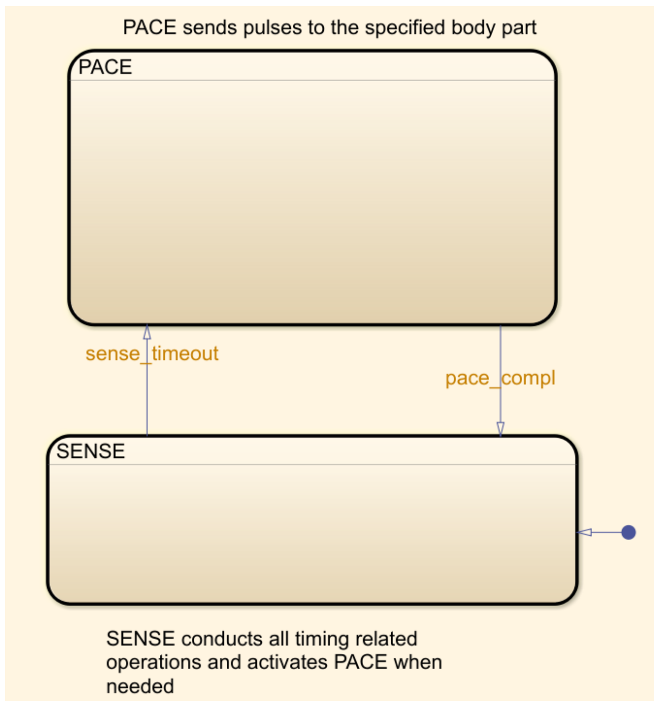
The secondary stateflow is used to set the rate adaptive pacing and whether or not to continue pacing based on different thresholds.



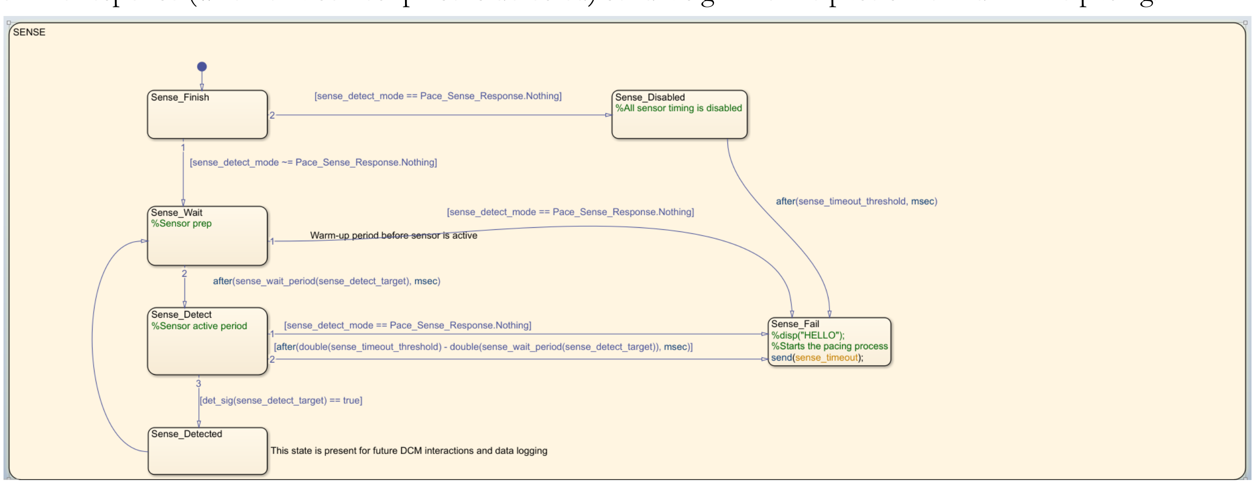
The main state flow module is contained within a subsystem that uses outports from other subsystems as inports, and outports of the subsystem are outputs from the state flow.



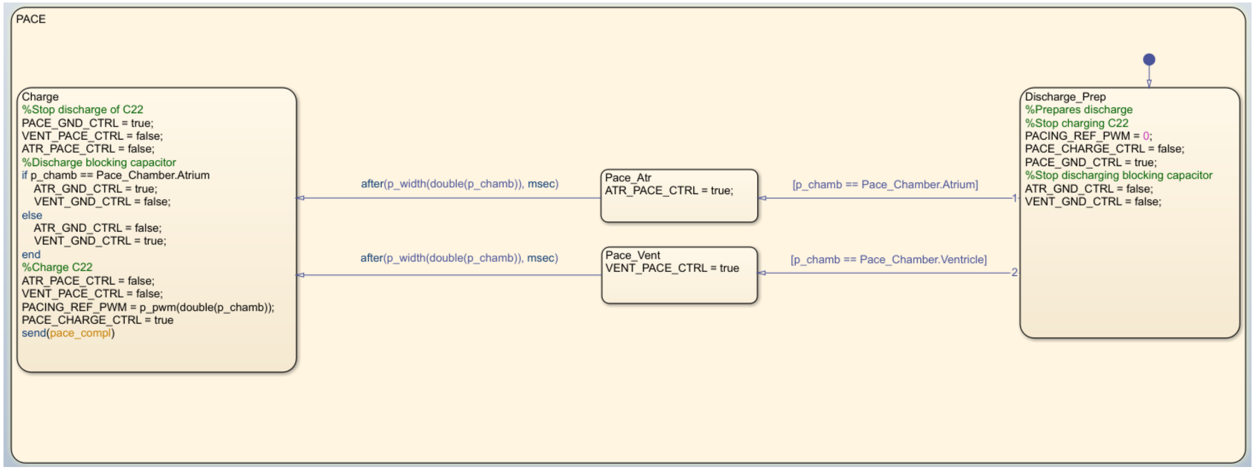
The main state flow has two components which are sensing and pacing.



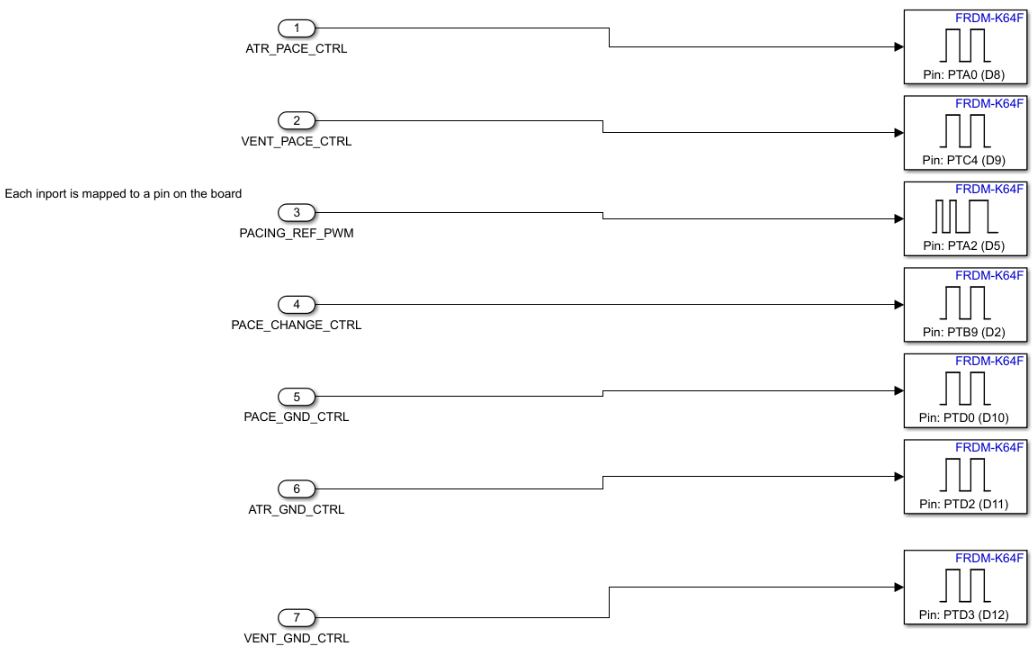
Sensing is the default state and the purpose of this state is to use sensors from the board as inputs and based on the response (whether a correct pulse is detected) send a signal to the pace state and initiate pacing.



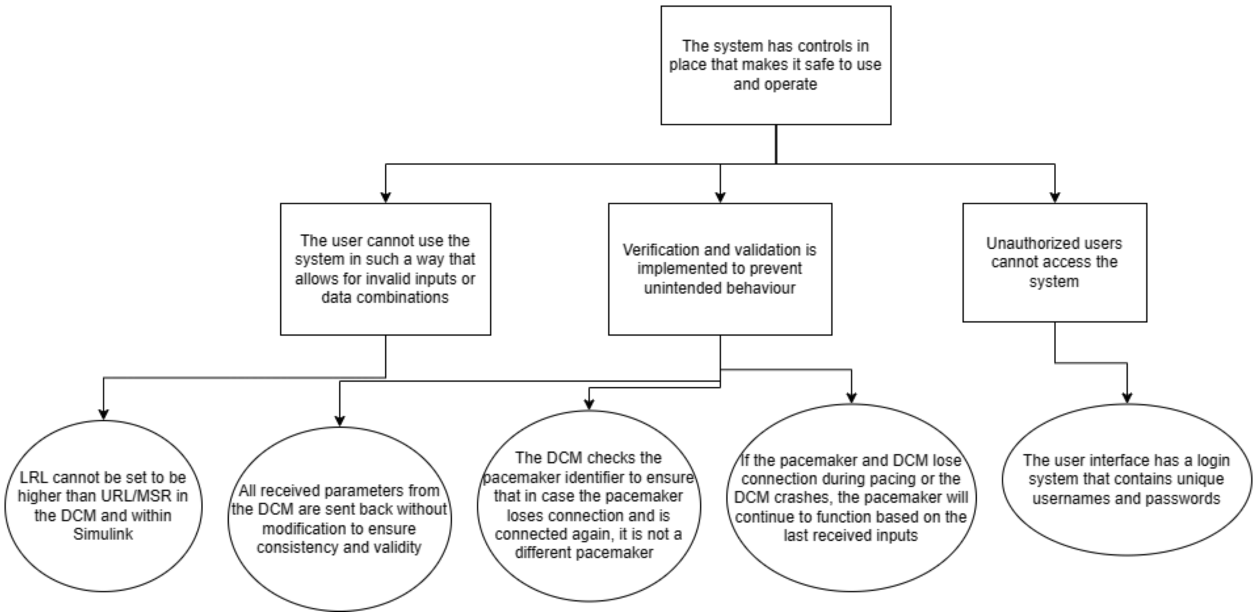
The pacing process involves charging and discharging the primary capacitor (C22) and the blocking capacitor (C21). Depending on whether charging or discharging is taking place, control pins are set to true or false, and after charging has been completed, a signal is sent back to the sense state to determine if pacing needs to continue depending on what the sense state detects after the pace.



The hardware pulse interface module is similar to the hardware sense interface module since this module also maps inports to relevant pins on the FRDM-K64F board. The inports in this module come from outputs in the main state flow module.



Assurance Case



Since a pacemaker is a safety-critical system, various methods of assurance were implemented in the design. As seen in the diagram above, the different circles are evidence that demonstrates that the system is safe in different aspects. Refer to the DCM documentation for details on the different assurance cases, including those that are not explicitly shown in the diagram.

Testing and Results

Testing procedures were conducted in order to ensure the functioning of the system. A series of tests were devised to ensure the implemented system satisfied the requirements.

Tested Requirement	Test name	Tested Subsystem	Measured parameters	Methodology
Implementation of specified parameters for configuration of system	Data processing test	DATA_PREPROCESSOR	Accuracy of pre-processed parameters	The program will be simulated in simulink. All outputs of DATA_PREPROCESSOR will be logged, and compared to manually calculated figures. The program will operate with the default parameters as specified in the appendix, excluding the pulse mode.
Generation of pacing pulses	Pulse test	Main stateflow; PACE	Generation of output pulse Refractory period sinking Pulse duration Pulse amplitude	The program will operate in AOO mode, no natural beats. This test is done concurrently to the AOO test. Pulses will be measured on heartview, and compared to the expected results. The program and heartview will operate with the default parameters as specified in the appendix.
Operation through specified pulse modes	AOO Test	Main stateflow; SENSE	Adherence to the specified timing behavior of AOO mode.	The program will be uploaded to the testing hardware, and attached to a heartview device. Natural pulses will be simulated at rates of 0, 30, 60, and 90 bpm. Only 0 and 30 bpm are tested for non sensing modes (AOO, VOO), with both chambers active. A singular test at 30bpm of the opposite chamber to the sensed one will be tested for both sensing modes (AAI, VVI). Rate minimums and maximums will be tested in AOO mode. The program and heartview will operate with the default parameters as specified in the appendix, excluding the pulse mode for simulink, and natural heartbeat for the sensed chamber in heartview.
	VOO Test	Main stateflow; SENSE	Adherence to the specified timing behavior of VOO mode.	
	AAI Test	Main stateflow; SENSE	Adherence to the specified behavior of AAI mode.	
	VVI Test	Main stateflow; SENSE	Adherence to the specified behavior of VVI mode	
	Rate response test	Main stateflow; RATE_SYSTEM	Adherence to the specified behavior of rate response modes	The program will be operated in simulink's internal simulation mode, whereby time response characteristics of the rate subsystem are assessed given constant initial conditions.

Tested Requirement	Test name	Tested Subsystem	Measured parameters	Methodology
Communication with external interface	Serial IO Test	SERIAL_INPUT	Adherence to defined communication protocol	The program will be connected to a computer, whereby manual control commands of the specified type will be transmitted to the device. The device will be assessed in terms of response signals and timeout periods. Output data will be additionally assessed for the correct format and response.
	Serial Data Processing Test	DATA_PREPROCESSOR, SERIAL_INPUT	Accuracy of data translation from serial data input Response to device mode changes	The program will be connected to the DCM module which at this time is already verified for accuracy. The DCM module will command the system to switch between a spread of modes in order to cover variations in all parameters. The accuracy towards which the system is capable of accommodating these changes will be assessed. Transitions between different operation mode feature sets(non-sensing, inhibited, and rate) will be assessed for accurate operation.

These tests are to be conducted in sequential order, from top to bottom. This is due to the dependency of some subsystems on the functioning of others, causing difficulty in error attribution in the event that dependent subsystems are at fault. The specified test order ensures that all subsystems except the one being tested are in a state of functionality. In addition, as the tested system is the software component of pre-established hardware, it was justified to constrict all pulse generation tests to the AOO pulse mode. Testing with ventricle output is redundant within the stateflow logic, and the hardware used is identical to the atrium's. Any errors incurred in such a scenario would be a hardware fault and outside the scope of this project.

The bpm output rates in the AAI and VVI tests are designed to ensure that all boundary and nominal states are accounted for. This is also the reason that the non-sensing modes only require two output rates, as only response to natural beats needs to be assessed given their featureset.

Case type	Operating Case	Operating mode logic	Intended behavior
Corner	No natural pulsing	Sensed rate = lowest possible	Generate all pulses
Nominal	30 bpm pulsing	Sensed rate < minimum rate	Generates some but not all pulses the heart experiences
Boundary	60 bpm pulsing	Sensed rate = minimum rate	Pacemaker does not generate any pulses as natural rate is on the minimum rate
Nominal	90 bpm pulsing	Sensed rate > minimum rate	Pacemaker does not generate any pulses as rate minimum is exceeded

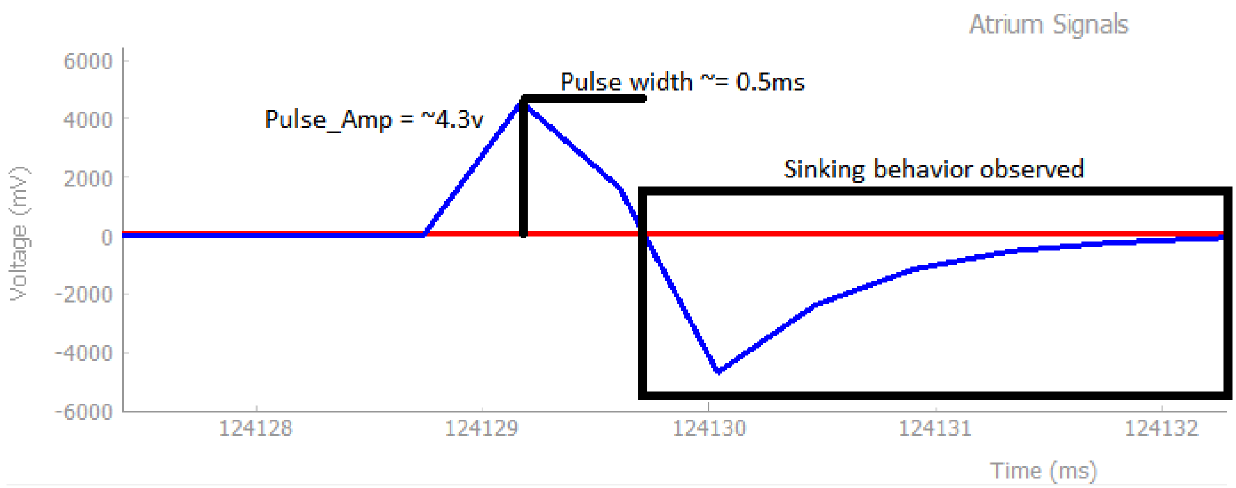
Data Processing Test

Parameter	Unit	Input Value	Output Unit	Output	Expected Output Value	Pass/Fail
PACE_MODE	uint8	0b01000001	P_chamber P_sense_target P_sense_mode P_rate_mode	P_chamber: Atrium P_sense_target: None_sense P_sense_mode: Nothing P_rate_mode: enabled	P_chamber: Atrium P_sense_target: None_sense P_sense_mode: Nothing P_rate_mode: enabled	Pass Pass Pass Pass
LOWER_RATE_LIMIT	bpm	60	ms	1000	1000	Pass
UPPER_RATE_LIMIT	bpm	120	ms	500	500	Pass
MAXIMUM_SENSOR_RATE	bpm	140	ms	428.57	428.57	Pass
ATR_PUL_AMPLITUDE VENT_PUL_AMPLITUDE	V/10	40	% duty cycle	80	80	Pass
ATR_SENSE_THRESHOLD VENT_SENSE_THRESHOLD	V/10	35	% duty cycle	70	70	Pass
ATR_PULSE_WIDTH VENT_PULSE_WIDTH	ms/10	5	ms	0.5	0.5	Pass
ATR_REFRACTORY_PERIOD VENT_REFRACTORY_PERIOD	ms	150	ms	150	150	Pass
REACTION_TIME	s	10	ms	10000	10000	Pass
RESPONSE_FAC	-	1	-	1	1	Pass
RECOVERY_TIME	min	1	ms	60000	10000	Pass

Data processing went smoothly, and all parameters were able to reach the calculated results from the default parameters.

AOO/Pulse Test

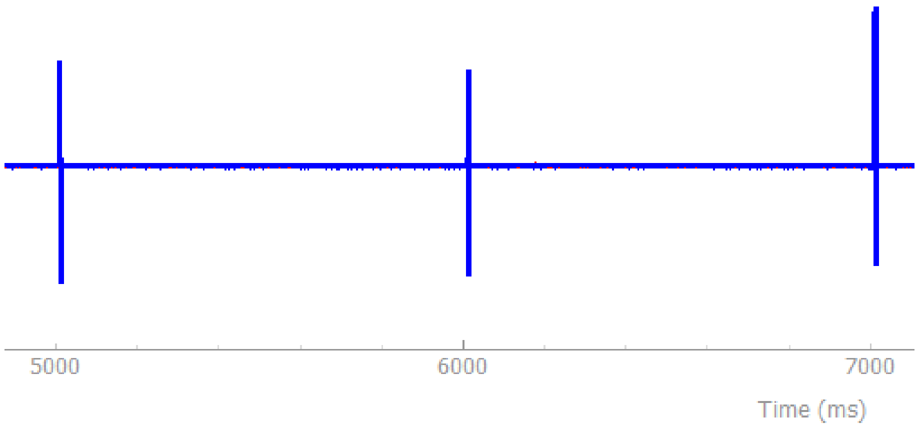
Pulse behavior test



Measurement	Spec	Observed	Pass/Fail
Generation of output pulse	Yes	Yes	Pass
Pulse width	0.5ms	~0.5ms	Pass
Pulse amplitude	4V	4.3V	Marginal
Sinking behavior	Yes	Yes	Pass

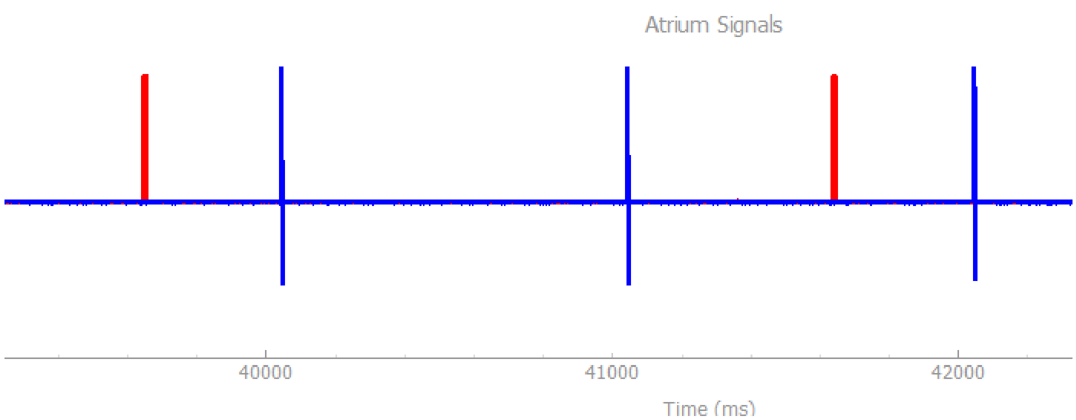
Overall, all required features of the specified pulse were generated, and most parameters had differences under the measurement limits of the heartview device. One particular feature of note was the rather substantial variance in pulse amplitude between different pulses.. The specific measured pulse had an offset of +0.3V, or approximately 7.5% deviation. A plausible solution of explicitly stopping the PWM signal during pulses was also tested, with no observable changes. After further problem assessment, we have attributed these issues to hardware limitations, possibly from the limited sample rate and accuracy of the heartview device.

0 bpm Natural Test



Measurement	Spec	Observed	Pass/Fail
Generation of output pulse	Yes, Atrium	Yes, Atrium	Pass
Pulse Period	1000ms	~1000ms	Pass

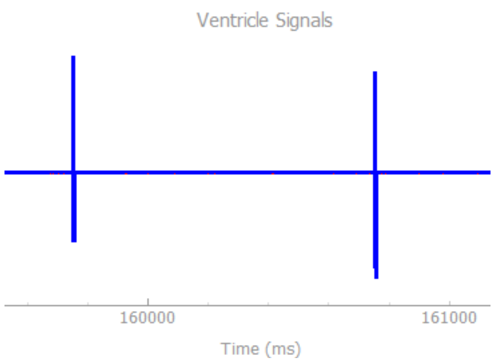
30 bpm Natural Test



Measurement	Spec	Observed	Pass/Fail
Generation of output pulse	Yes, Atrium	Yes, Atrium	Pass
Pulse Period	1000ms	~1000ms	Pass
Response to natural pulse	N/A	N/A	Pass

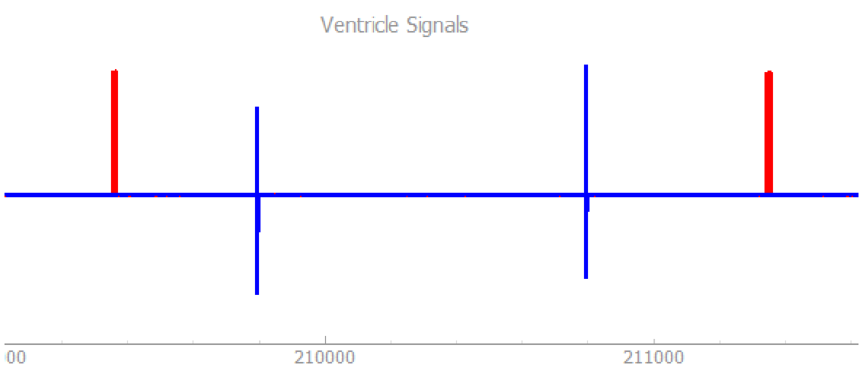
VOO test

0 bpm Natural Test



Measurement	Spec	Observed	Pass/Fail
Generation of output pulse	Yes, Ventricle	Yes, Ventricle	Pass
Pulse Period	1000ms	~1000ms	Pass

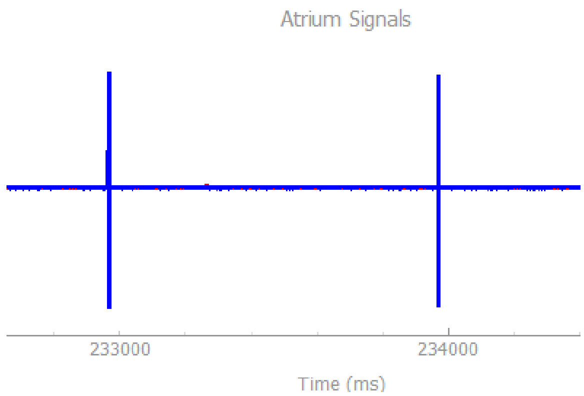
30 bpm Natural Test



Measurement	Spec	Observed	Pass/Fail
Generation of output pulse	Yes, Ventricle	Yes, Ventricle	Pass
Pulse Period	1000ms	~1000ms	Pass
Response to natural pulse	N/A	N/A	Pass

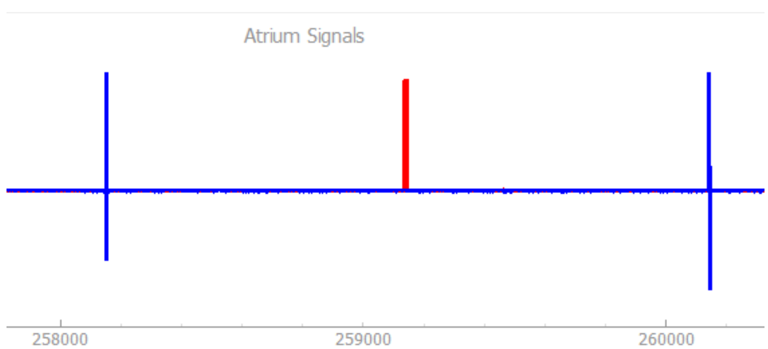
AAI test

0 bpm Natural Test



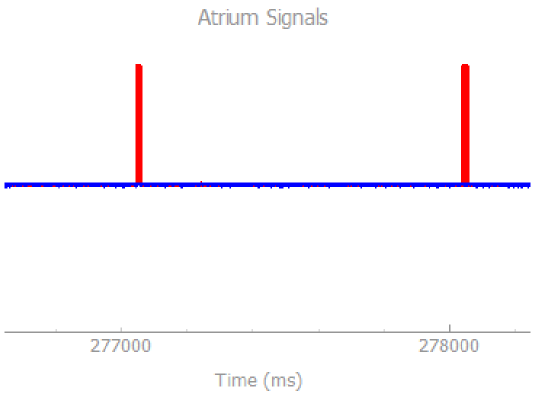
Measurement	Spec	Observed	Pass/Fail
Generation of output pulse	Yes, Atrium	Yes, Atrium	Pass
Pulse Period	1000ms	~1000ms	Pass

30 bpm Natural Test



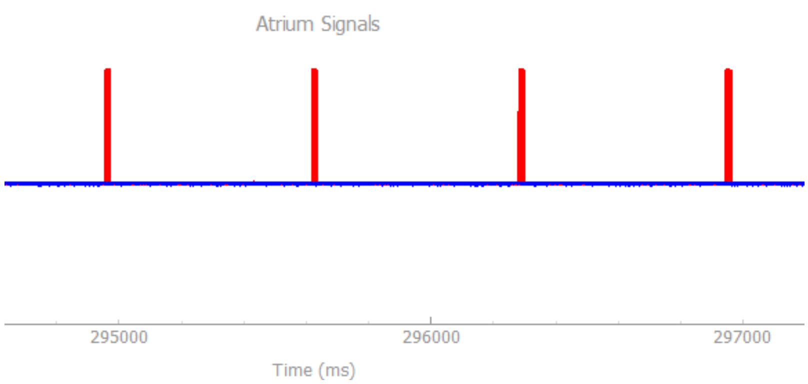
Measurement	Spec	Observed	Pass/Fail
Generation of output pulse	Yes, Atrium	Yes, Atrium	Pass
Generated pulse delay after last pulse	1000ms	~1000ms	Pass
Response to natural pulse	On Atrium pulse: Inhibits pulse, resets pulse delay	On Atrium pulse: Inhibits pulse, resets pulse delay	Pass

60 bpm Natural Test



Measurement	Spec	Observed	Pass/Fail
Generation of output pulse	No	No	Pass
Generated pulse delay after last pulse	N/A	N/A	Pass
Response to natural pulse	Inhibits pulse, resets pulse delay	Inhibits pulse, resets pulse delay	Pass

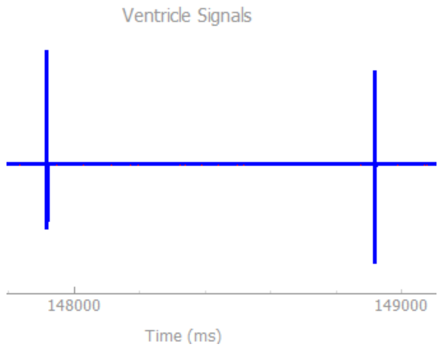
90 bpm Natural Test



Measurement	Spec	Observed	Pass/Fail
Generation of output pulse	No	No	Pass
Generated pulse delay	N/A	N/A	Pass
Response to natural pulse	Inhibits pulse, resets pulse delay	Inhibits pulse, resets pulse delay	Pass

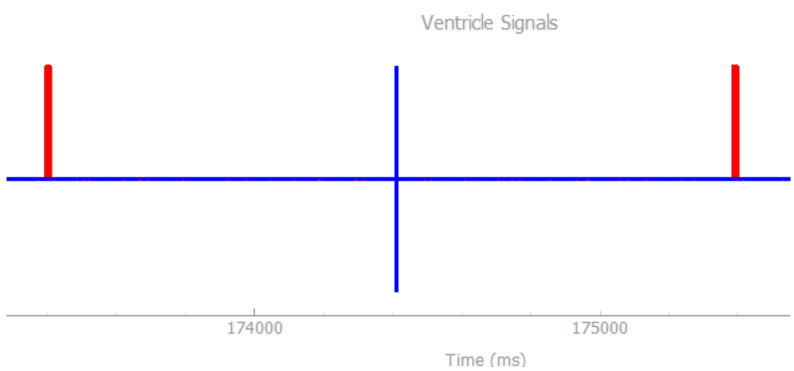
VVI test

0 bpm Natural Test



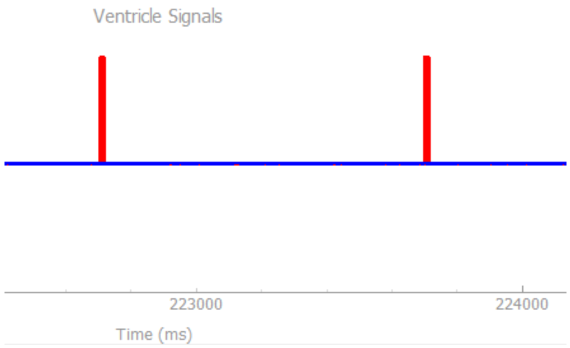
Measurement	Spec	Observed	Pass/Fail
Generation of output pulse	Yes, Ventricle	Yes, Ventricle	Pass
Pulse Period	1000ms	~1000ms	Pass

30 bpm Natural Test



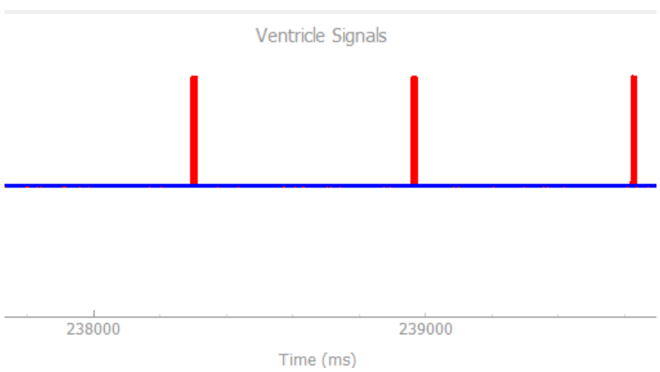
Measurement	Spec	Observed	Pass/Fail
Generation of output pulse	Yes, Ventricle	Yes, Ventricle	Pass
Generated pulse delay after last pulse	1000ms	~1000ms	Pass
Response to natural pulse	On Ventricle pulse: Inhibits pulse, resets pulse delay	On Ventricle pulse: Inhibits pulse, resets pulse delay	Pass

60 bpm Natural Test



Measurement	Spec	Observed	Pass/Fail
Generation of output pulse	No	No	Pass
Generated pulse delay after last pulse	N/A	N/A	Pass
Response to natural pulse	Inhibits pulse, resets pulse delay	Inhibits pulse, resets pulse delay	Pass

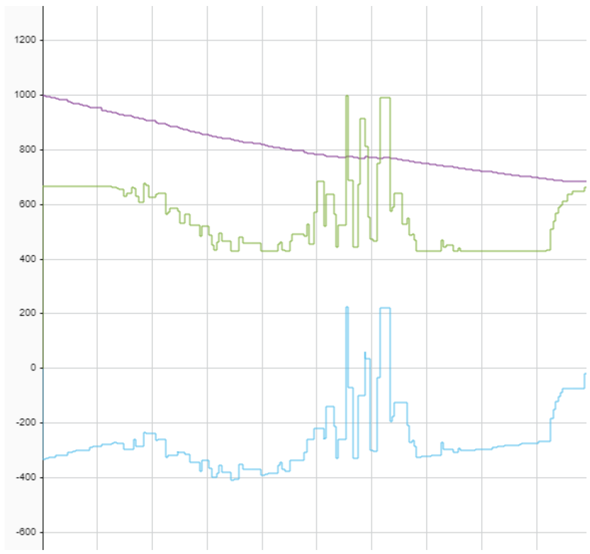
90 bpm Natural Test



Measurement	Spec	Observed	Pass/Fail
Generation of output pulse	No	No	Pass
Generated pulse delay	N/A	N/A	Pass
Response to natural pulse	Inhibits pulse, resets pulse delay	Inhibits pulse, resets pulse delay	Pass

Rate Mode Test

Rate mode is tested using simulink's internal simulation feature. The rate mode is activated using the default figures specified in the appendix. The rate subsystem's input parameters will be set to fixed values. Verification of time response function and behavior is done by measuring the % remaining distance towards target pace rate after the recovery time.



(Purple is the pacing period, green is the target period)

Inputs	Value
Activity Level	2/medium
Activity	60
Reaction Time	10sec
Initial Pacing Period	1000ms

Relevant Fixed Parameters	Value
Target remaining % at end of time period	5% * activity level

Measurement	Spec	Observed	Pass/Fail
Targeted pace period	600ms	600ms	Pass
Pace period at Reaction Time	620ms	620ms	Pass

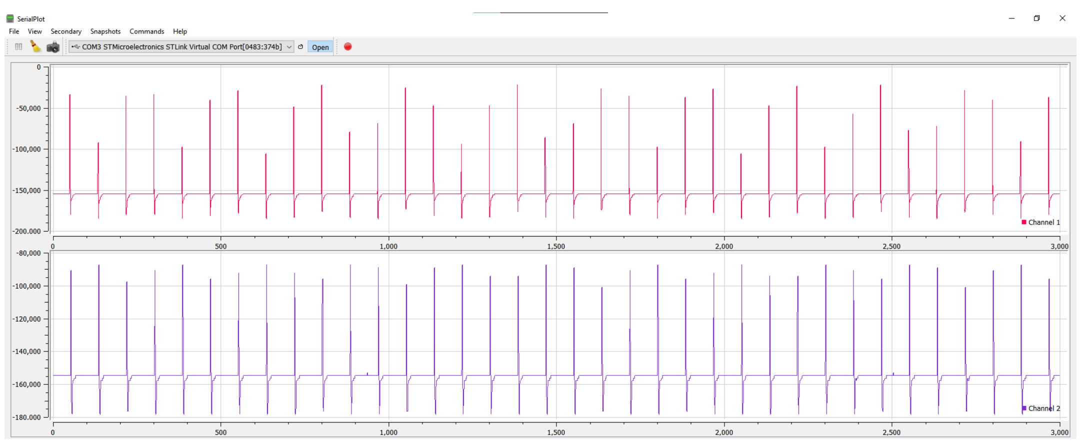
As the exponential time response behavior satisfies the spec, the system is verified to correctly respond to pace rate changes as well as set pace rate targets based on activity.

Serial IO Test

The Serial IO test comprises two main parts. First, the system nominally outputs ECG readouts within the system. Secondly, when the system receives a message, it will conduct a response operation. The test modes are listed below:

Test	Input	Expected output
ECG Test	N/A	ECG data, format int16 on both channels
Data Setting/Timeout Test	16 byte DCM parameter config bytestream	Input message should be looped back. ECG data should return after 0.5 seconds.
Invalid Data/Timeout test	Same as data setting test, with invalid message type byte	ECG data in standard format

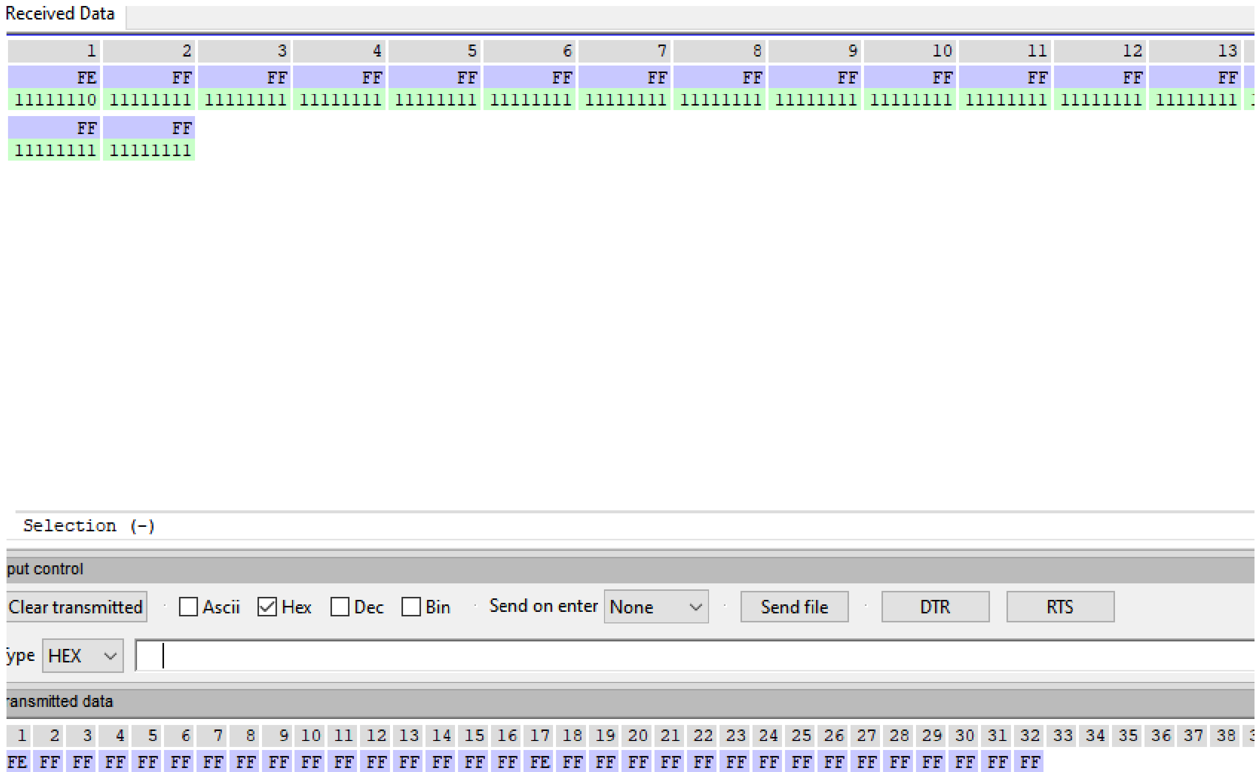
ECG Test



Measurement	Spec	Observed	Pass/Fail
ECG data visible with correct output data type	Visible with int16, 2 channels	Visible with int16, 2 channels	Pass
Pulse frequency	~5 pulses per sample	~5 pulses per sample	Pass

Heartview was used to set the heart to output 60BPM on the ventricle and atrium. As the polling rate was set to 5ms, it is expected that we should see ~5 pulses in a 500 sample timeframe.

Data Setting/Timeout



15 bytes of 0xFF were transmitted to the pacemaker, alongside the 0xFE message indication byte. The response behavior should be to mirror the transmission bytes

Measurement	Spec	Observed	Pass/Fail
Pacemaker response to parameter setting command	Duplicate message should be returned	Duplicate message should be returned	Pass
Timeout occurrence	ECG stop after transmission and return after timeout.	ECG stop after transmission and return after 0.5 sec.	Pass

Invalid Data/Timeout

16 bytes of 0x00 were transmitted to the pacemaker, which is an invalid combination. The expected response was that the pacemaker would continue to transmit ECG data as if nothing happened.

Measurement	Spec	Observed	Pass/Fail
Pacemaker invalid response	ECG data as usual	ECG data as usual	Pass

Serial Data Processing Test

Serial Processing Test is conducted through connecting the system with a verified DCM module to confirm that all pace response behaviors are working. The DCM was configured to transmit the functionality of the default VVIR mode from an initial default mode of AOO. This ensures that all operational parameters are modified during the transmission, thereby certifying the accuracy of the entire system.

Measurement	Spec	Observed	Pass/Fail
Module successfully changes operation through communication	Behavior changes	Behavior Changes	Pass
Chamber	Ventricle	Ventricle	Pass
Response to rate changes	Responds to vibration after changes	Responds to vibration after changes	Pass
Inhibitiation behavior	Responds to natural pulses on ventricle	Responds to natural pulses on ventricle	Pass

Overall, as the system successfully transferred modes, it is ensured that the communications system is functioning correctly.

Testing Conclusions

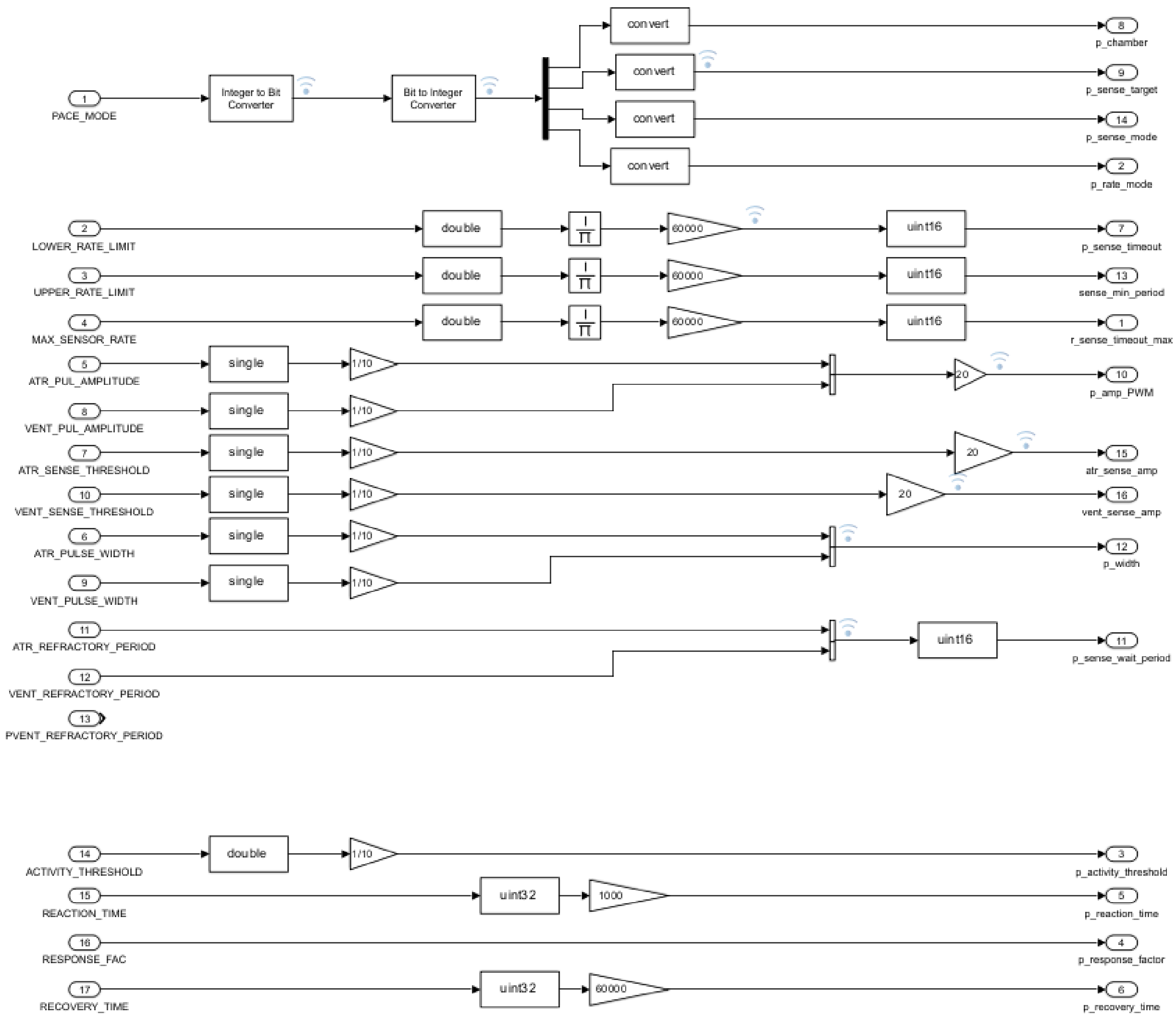
The above testing conditions provided the following conclusions for our results:

Tested Requirement	Test name	Score
Implementation of specified parameters for configuration of system	Data processing test	8/8
Generation of pacing pulses	Pulse test	2.5/3
Operation through specified pulse modes	AOO Test	5/5
	VOO Test	5/5
	AAI Test	11/11
	VVI Test	11/11
	Rate Response Test	2/2
Communication with the DCM module	ECG Test	2/2
	Data Setting/Timeout	2/2
	Invalid Data Response	2/2
	Serial Data Processing	4/4

Not all tests were perfect as expected due to errors in hardware and imperfections within simulation. We received perfect scores on Implementation of specified parameters for configuration of system and Operation through specified pulse modes tests. Generation of pacing pulses was almost perfect however there was 0.5 lost due to slight imperfections observed. Overall, most tests were able to achieve the requirements of the system.

Appendix

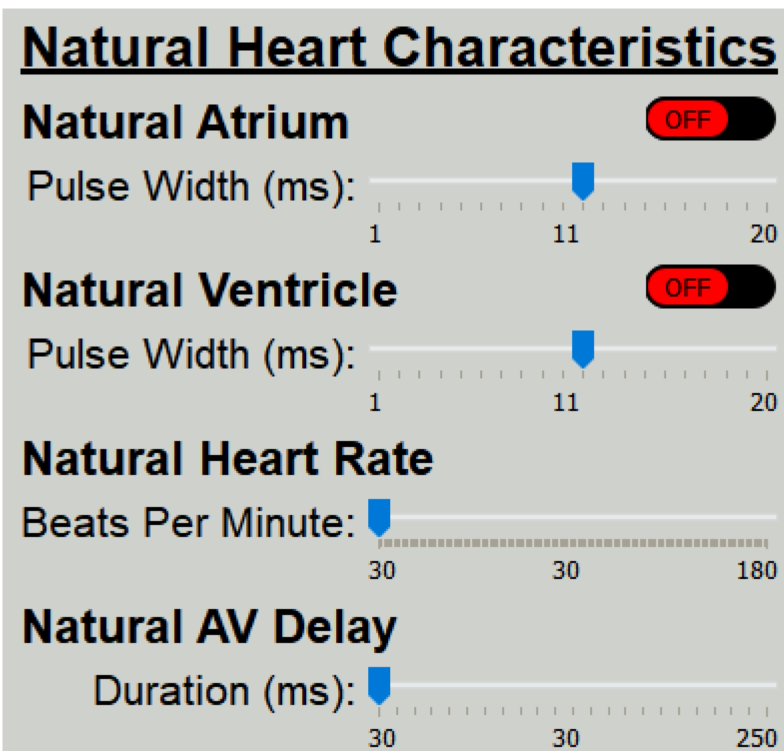
Default parameters, Simulink



Parameter	Unit	Value
PACE_MODE	8 bit int	AOOR(0b01000001)
LOWER_RATE_LIMIT	bpm	60
UPPER_RATE_LIMIT	bpm	120
MAXIMUM_SENSOR_RATE	bpm	140
ATR_PUL_AMPLITUDE VENT_PUL_AMPLITUDE	V/10	40

ATR_SENSE_THRESHOLD VENT_SENSE_THRESHOLD	V/10	35
ATR_PULSE_WIDTH VENT_PULSE_WIDTH	ms/10	50
ATR_REFRACTORY_PERIOD VENT_REFRACTORY_PERIOD	ms	150
REACTION_TIME	s	10
RESPONSE_FAC	-	1
RECOVERY_TIME	min	1

Default parameters, heartview



Parameter	Unit	Value
Natural Atrium	boolean	off
Natural Atrium - pulse width	ms	11

Natural Ventricle	boolean	off
Natural Ventricle - pulse width	ms	11
Natural Heart Rate	bpm	30
Natural AV Delay	ms	30