Assignment 2: Simulink

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# Introduction

# Variables

## Measured

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| t | ms | Time since last pulse | – |
| ATR\_SIGNAL | double | electrocardiogram measurement of atrial signal | 0 – 1 |
| VENT\_SIGNAL | double | electrocardiogram measurement of ventricular signal | 0 – 1 |
| ATR\_CMP\_DETECT | boolean | Atrial signal voltage higher than threshold | {true, false} |
| VENT\_CMP\_DETECT | boolean | Ventricular signal voltage higher than threshold | {true, false} |
| accel | double x 3 | Proper acceleration in g of pacemaker in local (x,y,z) | -4 – 4 |
| Rx | uint8 x 17 | UART in buffer | 0 – 255 |
| Status | uint8 | Indicates whether UART buffer is full | {0, 32} |

## Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| p\_mode | – | Pacemaker operational mode | {AOO,VOO,AAI,VVI, DOO, AOOR, VOOR, AAIR, VVIR, DOOR} |
| p\_lower\_rate\_limit | ppm | Lowest allowable heart rate | 30 – 175 ± 8 ms |
| p\_av\_delay | ms | Delay between paced atrial and ventricular signals | 70 – 300 ms ± 8 ms |
| p\_atr\_amplitude | V | Amplitude of pulse delivered to atrium | 0 – 5 ± 12% |
| p\_vent\_amplitude | V | Amplitude of pulse delivered to ventricle | 0 – 5 ± 12% |
| p\_atr\_sensitivity | V | Minimum voltage over which signal in atrium is classified as a pulse | 0 – 5 ± 2% |
| p\_vent\_sensitivity | V | Minimum voltage over which signal in ventricle is classified as a pulse | 0 – 5 ± 2% |
| p\_atr\_pulse\_width | ms | Pulse width of atrial pace | 1 – 30 ± 0.2 ms |
| p\_vent\_pulse\_width | ms | Pulse width of ventricular pace | 1 – 30 ± 0.2 ms |
| p\_vrp | ms | Ventricular Refractory Period | 150–500 ± 8 ms |
| p\_arp | ms | Atrial Refractory Period | 150–500 ± 8 ms |
| p\_max\_sensor\_rate | ppm | Maximum sensor rate indicated by rate adaptivity | 50 – 175 ± 4 ppm |
| p\_activity\_threshold | – | Minimum activity level for rate adaptivity | {V-Low, Low, Med-Low, Med, Med-High, High, V-high} |
| p\_reaction\_time | sec | Time required for pacing rate to rise from lower rate limit to max sensor rate | 10 – 50 ± 3 sec |
| p\_response\_factor | – | Indicates response to activity levels above threshold | {true, false} |
| p\_recovery\_time | min | Maximum allowable pacing rate decrease | 2­ – 16 ± 30 sec |

## Controlled

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| PACE\_CHARGE\_CTRL | boolean | PWM connected to primary capacitor | {true, false} |
| ATR\_PACE\_CTRL | boolean | Atrial ring connected to primary capacitor | {true, false} |
| VENT\_PACE\_CTRL | boolean | Ventricular ring connected to primary capacitor | {true, false} |
| ATR\_GND\_CTRL | boolean | Atrial ring connected to ground | {true, false} |
| VENT\_GND\_CTRL | boolean | Ventricular ring connected to ground | {true, false} |
| PACE\_GND\_CTRL | boolean | Atrial and Ventricular tip connected to blocking capacitor | {true, false} |
| Z\_ATR\_CTRL | boolean | Impedance circuit connected to atrial ring | {true, false} |
| Z\_VENT\_CTRL | boolean | Impedance circuit connected to ventricular ring | {true, false} |
| PACING\_REF\_PWM | % | Reference PWM for primary capacitor | 0–100 |
| ATR\_CMP\_REF\_PWM | % | Reference PWM for atrial signal comparator | 0–100 |
| VENT\_CMP\_REF\_PWM | % | Reference PWM for ventricular signal comparator | 0–100 |
| FRONTEND\_CTRL | boolean | Sensing circuit connected to leads | {true, false} |
| Tx | uint8 x 16 | UART out buffer | 0 – 255 |

## Internal

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| h\_atr\_pulse\_detected | boolean | Pulse detected in atrium | {true, false} |
| h\_vent\_pulse\_detected | boolean | Pulse detected in ventricle | {true, false} |
| XOO\_pace\_start | boolean | AOO or VOO indicates pace | {true, false} |
| XXI\_pace\_start | boolean | AAI or VVI indicates pace | {true, false} |
| DOO\_A\_pace\_start | boolean | DOO indicates atrial pace | {true, false} |
| DOO\_V\_pace\_start | boolean | DOO indicates ventricular pace | {true, false} |
| DOO\_AV\_select | boolean | DOO indicates which chamber will be paced next | {true, false} |
| A\_pace\_start | boolean | Signal to pace atrium | {true, false} |
| V\_pace\_start | boolean | Signal to pace ventricle | {true, false} |
| AV\_select | boolean | Selects which chamber will be paced next | {A, V} |
| sensor\_rate | ppm | Rate adaptivity indicated rate | p\_lower\_rate\_limit – p\_max\_sensor\_rate |
| increase\_rate | ppm/sec | Pace rate increase | 0 – 14.5 |
| decrease\_rate | ppm/sec | Pace rate decrease | 0 – 1.3 |
| pulse\_detected | boolean | General pulse detection | {true, false} |
| refractory\_period | ms | General refractory period | 150–500 ± 8 ms |
| current\_LRL | ppm | Current pacing rate | 30 – 175 ppm |
| activity\_amplitude |  |  |  |

# Modules

## Pacemaker Modes

### AOO/VOO/AOOR/VOOR

#### Variables

##### Measured

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| t | ms | Time since last pulse | – |

##### Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| p\_lower\_rate\_limit | ppm | Lowest allowable heart rate | 30 – 175 ± 8 ms |

##### Controlled

No controlled variables

##### Internal

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| XOO\_pace\_start | boolean | AOO or VOO indicates pace | {true, false} |
| A\_pace\_start | boolean | Signal to pace atrium | {true, false} |
| V\_pace\_start | boolean | Signal to pace ventricle | {true, false} |
| AV\_select | boolean | Selects which chamber will be paced next | {A, V} |
| sensor\_rate | ppm | Rate adaptivity indicated rate | p\_lower\_rate\_limit – p\_max\_sensor\_rate |
| increase\_rate | ppm/sec | Pace rate increase | 0 – 14.5 |
| decrease\_rate | ppm/sec | Pace rate decrease | 0 – 1.3 |
| current\_LRL | ppm | Current pacing rate | 30 – 175 ppm |

#### Requirements

### AAI/VVI/AAIR/VVIR

#### Variables

##### Measured

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| t | ms | Time since last pulse | – |

##### Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| p\_lower\_rate\_limit | ppm | Lowest allowable heart rate | 30 – 175 ± 8 ms |
| p\_vrp | ms | Ventricular Refractory Period | 150–500 ± 8 ms |
| p\_arp | ms | Atrial Refractory Period | 150–500 ± 8 ms |

##### Controlled

##### Internal

#### Requirements

### DOO/DOOR

#### Variables

##### Measured

##### Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| p\_lower\_rate\_limit | ppm | Lowest allowable heart rate | 30 – 175 ± 8 ms |
| p\_av\_delay | ms | Delay between paced atrial and ventricular signals | 70 – 300 ms ± 8 ms |

##### Controlled

##### Internal

#### Requirements

### Parameter Selection

#### Variables

##### Measured

##### Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| p\_mode | – | Pacemaker operational mode | {AOO,VOO,AAI,VVI, DOO, AOOR, VOOR, AAIR, VVIR, DOOR} |
| p\_lower\_rate\_limit | ppm | Lowest allowable heart rate | 30 – 175 ± 8 ms |
| p\_av\_delay | ms | Delay between paced atrial and ventricular signals | 70 – 300 ms ± 8 ms |
| p\_vrp | ms | Ventricular Refractory Period | 150–500 ± 8 ms |
| p\_arp | ms | Atrial Refractory Period | 150–500 ± 8 ms |

##### Controlled

##### Internal

#### Requirements

## Rate Adaptivity

### Variables

#### Measured

#### Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| p\_lower\_rate\_limit | ppm | Lowest allowable heart rate | 30 – 175 ± 8 ms |
| p\_max\_sensor\_rate | ppm | Maximum sensor rate indicated by rate adaptivity | 50 – 175 ± 4 ppm |
| p\_activity\_threshold | – | Minimum activity level for rate adaptivity | {V-Low, Low, Med-Low, Med, Med-High, High, V-high} |
| p\_reaction\_time | sec | Time required for pacing rate to rise from lower rate limit to max sensor rate | 10 – 50 ± 3 sec |
| p\_response\_factor | – | Indicates response to activity levels above threshold | {true, false} |
| p\_recovery\_time | min | Maximum allowable pacing rate decrease | 2­ – 16 ± 30 sec |

#### Controlled

#### Internal

### Requirements

## Hardware Interface

### Pacing

#### Variables

##### Measured

##### Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| p\_atr\_amplitude | V | Amplitude of pulse delivered to atrium | 0 – 5 ± 12% |
| p\_vent\_amplitude | V | Amplitude of pulse delivered to ventricle | 0 – 5 ± 12% |
| p\_atr\_pulse\_width | ms | Pulse width of atrial pace | 1 – 30 ± 0.2 ms |
| p\_vent\_pulse\_width | ms | Pulse width of ventricular pace | 1 – 30 ± 0.2 ms |

##### Controlled

##### Internal

#### Requirements

### Sensing

### Variables

##### Measured

##### Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| p\_atr\_sensitivity | V | Minimum voltage over which signal in atrium is classified as a pulse | 0 – 5 ± 2% |
| p\_vent\_sensitivity | V | Minimum voltage over which signal in ventricle is classified as a pulse | 0 – 5 ± 2% |

##### Controlled

##### Internal

#### Requirements

## DCM Communication

### Variables

#### Measured

#### Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| p\_mode | – | Pacemaker operational mode | {AOO,VOO,AAI,VVI, DOO, AOOR, VOOR, AAIR, VVIR, DOOR} |
| p\_lower\_rate\_limit | ppm | Lowest allowable heart rate | 30 – 175 ± 8 ms |
| p\_av\_delay | ms | Delay between paced atrial and ventricular signals | 70 – 300 ms ± 8 ms |
| p\_atr\_amplitude | V | Amplitude of pulse delivered to atrium | 0 – 5 ± 12% |
| p\_vent\_amplitude | V | Amplitude of pulse delivered to ventricle | 0 – 5 ± 12% |
| p\_atr\_sensitivity | V | Minimum voltage over which signal in atrium is classified as a pulse | 0 – 5 ± 2% |
| p\_vent\_sensitivity | V | Minimum voltage over which signal in ventricle is classified as a pulse | 0 – 5 ± 2% |
| p\_atr\_pulse\_width | ms | Pulse width of atrial pace | 1 – 30 ± 0.2 ms |
| p\_vent\_pulse\_width | ms | Pulse width of ventricular pace | 1 – 30 ± 0.2 ms |
| p\_vrp | ms | Ventricular Refractory Period | 150–500 ± 8 ms |
| p\_arp | ms | Atrial Refractory Period | 150–500 ± 8 ms |
| p\_max\_sensor\_rate | ppm | Maximum sensor rate indicated by rate adaptivity | 50 – 175 ± 4 ppm |
| p\_activity\_threshold | – | Minimum activity level for rate adaptivity | {V-Low, Low, Med-Low, Med, Med-High, High, V-high} |
| p\_reaction\_time | sec | Time required for pacing rate to rise from lower rate limit to max sensor rate | 10 – 50 ± 3 sec |
| p\_response\_factor | – | Indicates response to activity levels above threshold | {true, false} |
| p\_recovery\_time | min | Maximum allowable pacing rate decrease | 2­ – 16 ± 30 sec |

#### Controlled

#### Internal

### Requirements

# Design Decisions

## Pacemaker Modes

### AOO/VOO/AOOR/VOOR

### AAI/VVI/AAIR/VVIR

### DOO/DOOR

## Rate Adaptivity

## Hardware Interface

### Pacing

### Sensing

## DCM Communication

# Testing

## Pacemaker Modes

### AOO/VOO/AOOR/VOOR

### AAI/VVI/AAIR/VVIR

### DOO/DOOR

## Rate Adaptivity

## Hardware Interface

### Pacing

### Sensing

## DCM Communication