Assignment 1, Part 3: Hardware Hiding

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# Introduction

# Variables

## Measured

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| t | ms | time since start of pulse | – |
| A\_pace\_start | boolean | Commence atrial pulse | {true, false} |
| V\_pace\_start | boolean | Commence ventricular pulse | {true, false} |
| ATR\_CMP\_DETECT | boolean | Atrial signal voltage higher than threshold | {true, false} |
| VENT\_CMP\_DETECT | boolean | Ventricular signal voltage higher than threshold | {true, false} |

## Constant

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Units/Type** | **Description** | **Range** |
| p\_mode | int | Pacemaker operational mode | {AOO,VOO,AAI,VVI} |
| p\_atr\_pulse\_amplitude | V | Desired amplitude of paced atrial pulses | 0.5–7.0 ± 12% |
| p\_vent\_pulse\_amplitude | V | Desired amplitude of paced ventricular pulses | 0.5–7.0 ± 12% |
| p\_atr\_pulse\_width | ms | Desired pulse width of paced atrial pulses | 0.05–1.9 ± 0.2 ms |
| p\_vent\_pulse\_width | ms | Desired pulse width of paced ventricular pulses | 0.05–1.9 ± 0.2 ms |
| p\_atr\_sensitivity | mV | Threshold voltage for sensing spontaneous atrial pulses | 0.25–10 ± 20% |
| p\_vent\_sensitivity | mV | Threshold voltage for sensing spontaneous ventricular pulses | 0.25–10 ± 20% |

## Controlled

|  |  |  |  |
| --- | --- | --- | --- |
| **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} |
| 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 | PWM | Reference PWM for primary capacitor | 0–1 |
| ATR\_CMP\_REF\_PWM | PWM | Reference PWM for atrial signal comparator | 0–1 |
| VENT\_CMP\_REF\_PWM | PWM | Reference PWM for ventricular signal comparator | 0–1 |
| FRONTEND\_CTRL | boolean | Sensing circuit connected to leads | {true, false} |

## Internal

No internal variables

# Interfaces

## **Pacing**

### Description

### Variables

#### Measured

|  |  |  |
| --- | --- | --- |
| **Name** | **Abbreviation** | **Reference** |
| t | – |  |
| A\_pace\_start | – |  |
| V\_pace\_start | – |  |

#### Constant

|  |  |  |
| --- | --- | --- |
| **Name** | **Abbreviation** | **Reference** |
| p\_mode | – |  |
| p\_atr\_pulse\_amplitude | – |  |
| p\_vent\_pulse\_amplitude | – |  |
| p\_atr\_pulse\_width | – |  |
| p\_vent\_pulse\_width | – |  |

#### Controlled

|  |  |  |
| --- | --- | --- |
| **Name** | **Abbreviation** | **Reference** |
| PACE\_CHARGE\_CTRL | – |  |
| ATR\_PACE\_CTRL | – |  |
| VENT\_PACE\_CTRL | – |  |
| ATR\_GND\_CTRL | – |  |
| VENT\_GND\_CTRL | – |  |
| PACE\_GND\_CTRL | – |  |
| Z\_ATR\_CTRL | – |  |
| Z\_VENT\_CTRL | – |  |
| PACING\_REF\_PWM | – |  |

#### Internal

No internal values

### Initial values

ATR\_PACE\_CTRL = false

VENT\_PACE\_CTRL = false

ATR\_GND\_CTRL = false

VENT\_GND\_CTRL = false

Z\_ATR\_CTRL = false

Z\_VENT\_CTRL = false

PACE\_CHARGE\_CTRL = true

PACE\_GND\_CTRL = true

### Requirements

Z\_ATR\_CTRL = false

Z\_VENT\_CTRL = false

|  |  |
| --- | --- |
| **p\_mode** | **PACING\_REF\_PWM** |
| AOO | p\_atr\_pulse\_amplitude/5 |
| VOO | p\_vent\_pulse\_amplitude/5 |
| AAI | p\_atr\_pulse\_amplitude/5 |
| VVI | p\_vent\_pulse\_amplitude/5 |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **A pace start** | **V pace start** | **A pace start-1** | **V pace start-1** | **PACE CHARGE CTRL** | **ATR PACE CTRL** | **VENT PACE CTRL** | **ATR GND CTRL** | **VENT GND CTRL** |
| false | false | false | true | true | false | false | false | true |
| true | false | true | false | false | true | false |
| true | X | X | false | false | true | false | false |
| true | false | X | X | false | true | false | false | false |
| true | X | X | ILLEGAL INPUTS | | | | |

### State Transitions

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | INITIAL | C22\_Charge | Buffer | A\_pacing | C21\_Discharge\_A | V\_pacing | C21\_Discharge\_V |
| INITIAL | – | Automatic | – | – | – | – | – |
| C22\_Charge | – | – | ~A\_pace\_start  ~V\_pace\_start | – | – | – | – |
| Buffer | – | – | – | A\_pace\_start | – | V\_pace\_start | – |
| A\_pacing | – | – | – | – | t=p\_atr\_pulse\_width | – | – |
| C21\_Discharge\_A | – | Automatic | – | – | – | – | – |
| V\_pacing | – | – | – | – | – | – | t=p\_vent\_pulse\_width |
| C21\_Discharge\_V | – | Automatic | – | – | – | – | – |

### State details

|  |  |
| --- | --- |
| **State** | **Description** |
| INITIAL | Sets initial values |
| C22\_Charge | Starts charging pacing capacitor |
| Buffer | Waits until pace start signals are low |
| A\_pacing | Paces atrium |
| C21\_Discharge\_A | Discharges blocking capacitor through atrium |
| V\_pacing | Paces ventricle |
| C21\_Discharge\_V | Discharges blocking capacitor through ventricle |

### Design details

The buffer state is necessary to make sure the pacing doesn’t loop.

### Future changes

Eventually, dual pacing modes will have to be implemented. The states will have to modified to change pacing between the atrium and ventricle.

### Testing

## **Sensing**

### Description

### Variables

#### Measured

|  |  |  |
| --- | --- | --- |
| **Name** | **Abbreviation** | **Reference** |
| ATR\_CMP\_DETECT | – |  |
| VENT\_CMP\_DETECT | – |  |

#### Constant

|  |  |  |
| --- | --- | --- |
| **Name** | **Abbreviation** | **Reference** |
| p\_mode | – |  |
| p\_atr\_sensitivity | – |  |
| p\_vent\_sensitivity | – |  |

#### Controlled

|  |  |  |
| --- | --- | --- |
| **Name** | **Abbreviation** | **Reference** |
| h\_atr\_pulse\_detected | – |  |
| h\_vent\_pulse\_detected | – |  |
| ATR\_CMP\_REF\_PWM | – |  |
| VENT\_CMP\_REF\_PWM | – |  |
| FRONT\_END\_CTRL | – |  |

#### Internal

No internal variables

### Initial Values

No initial values

### Requirements

h\_atr\_pulse\_detected = ATR\_CMP\_DETECT

h\_vent\_pulse\_detected = VENT\_CMP\_DETECT

|  |  |  |  |
| --- | --- | --- | --- |
| **p\_mode** | **ATR\_CMP\_REF\_PWM** | **VENT\_CMP\_REF\_PWM** | **FRONT\_END\_CTRL** |
| AOO | 0 | 0 | false |
| VOO | 0 | 0 | false |
| AAI | p\_atr\_sensitivity/3.3 | 0 | true |
| VVI | 0 | p\_vent\_sensitivity/3.3 | true |

### Design details

Due to the discrete clock, the PWM ON time is calculated and rounded to the nearest amount of clock cycles and then subtracted from the PWM period so that the period is not affected by rounding errors.

### Future changes

More modes will have to be implemented as they are designed. For dual sensing modes both atrial and ventricular paces will have to be monitored.

### Testing