McMaster University

SE 3K04 Fall 2019

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Assignment 2 Documentation Part1

Date issued: December 5th, 2019

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Changes of Requirement

Having only an accelerometer is not indicative of a person’s physical activity. It is very likely to produce false positive conditions when a person is sitting on a vehicle and the vehicle is accelerating. The person will be experiencing no physical activity but the heart would be pacing fiercely, resulting in medical emergencies. Ideally, there should be other sensors built into the heart. For example, there should be a PH meter to precisely measure the PH value of the blood. When the person starts exercising, the muscles will start releasing lactic acids, causing the blood PH to decrease. When the pacemaker receives this new programming parameter, it should increase the pacing rate correspondingly. Additionally, there could be more sensors that measure blood glucose level, blood viscosity and oxygen level in the blood.

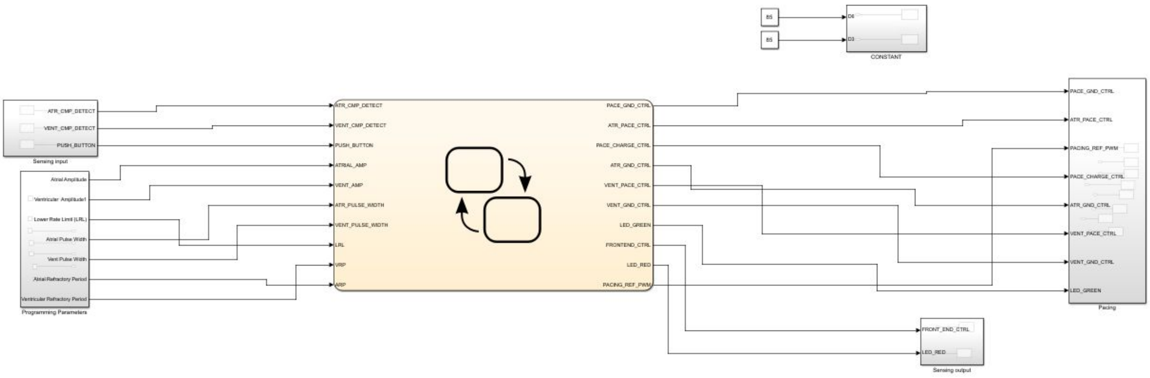
More modes might be required to implement in the future. For example, in DDDR mode, it requires dual pacing and sensing on both atriums and ventricles with rate adaptability. Then more logic states would be added into the main logic chart. Then the new protocol for serial communication needs to be designed. Correspondingly, more programming parameters would be passed through serial communication. For example, atrial sensitivity, ventricular sensitivity, and rate smoothing.

Changes of Design Decisions

In the future, a serial transmit logic chart would be added since the pacemaker needs to send Egram back to the DCM. A new protocol for serial communication needs to be developed since more programming parameters would be added. As the Simulink model grows bigger and becomes more complicated, the coupling between each module should be further decreased. The main logic chart could be broken into smaller charts with distinct functions. For example, each mode can be presented as an individual chart rather than putting all the modes in the same chart. More hardware hiding could be implemented by putting different sensors into different subsystems. For example, all the acceleration components are hidden in a subsystem and all the PH sensor components are hidden in another subsystem. The final rate transmitted into the main logic chart would be calculated as a weighted average from different sensors. Each sensor subsystem would provide a weight based on the processed sensor data respectively.

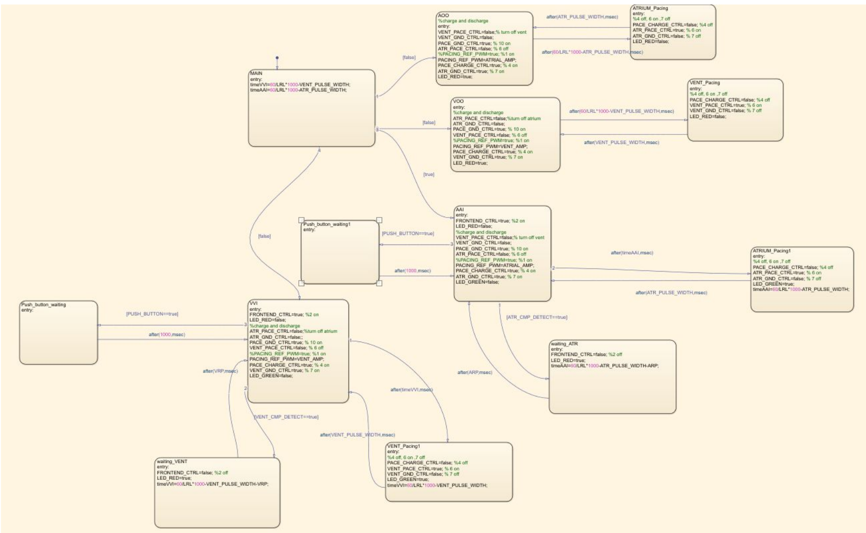
Description of Design Decisions with Simulink Diagram

Different modules are highlighted in the following section.



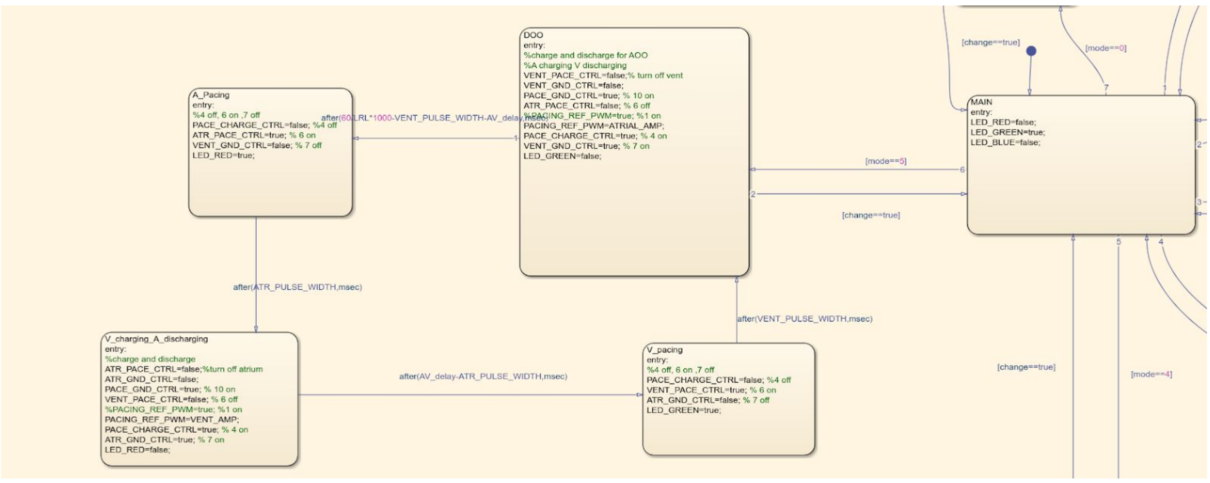
Hardware hiding was implemented to abstract the hardware components. The subsystems are namely sensing input, sensing output, pacing, constants and programming parameters. All the digital read, write blocks, pwm output and LED lights are hidden in the subsystems.

Short summary of the design decisions from Assignment 1:



The logic is implemented in the main chart. The initial state initializes two different timing variables that will be later used in AAI and VVI. In AOO, the first stage charges C22 and discharges C21. Then the next stage discharges C22 to shock the heart as well as charging C21. VOO has the same implementations except that the atrial parameters are replaced by ventricular ones. In AAI, the detect variable determines if there is a natural heart beat. If a heart beat is sensed, it will wait for a refractory period and the timing variable is changed according to the state that the program is currently in. The use of timing variable demonstrates information hiding and eliminate the use of flags which makes the program more convoluted. The pacing component of the AAI is the exact same as the AOO. For VVI, the only difference would be the atrial variables are replaced with ventricular ones. More detailed annotations are added in each states as comments.

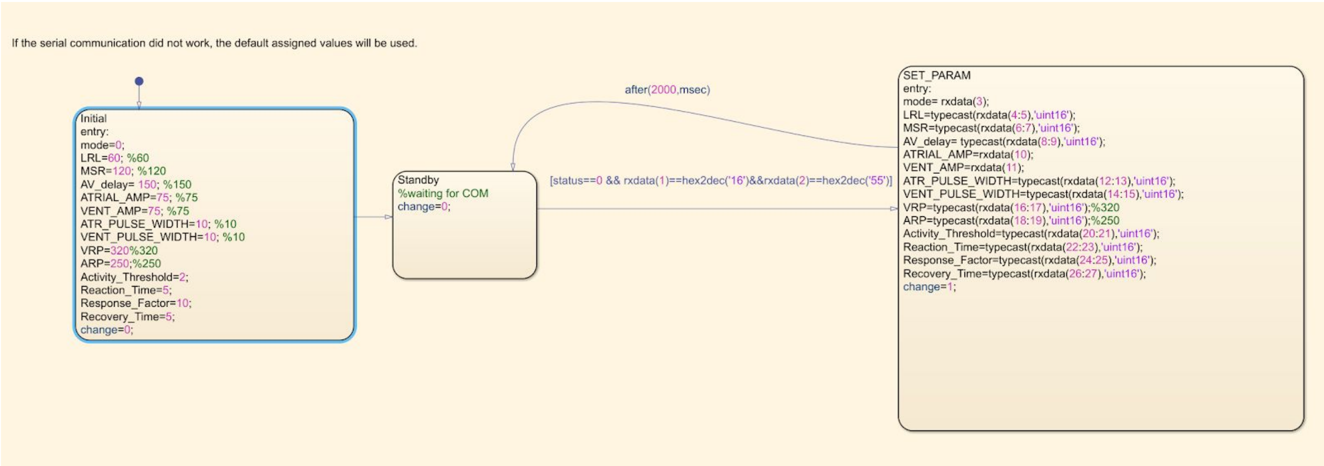
DOO



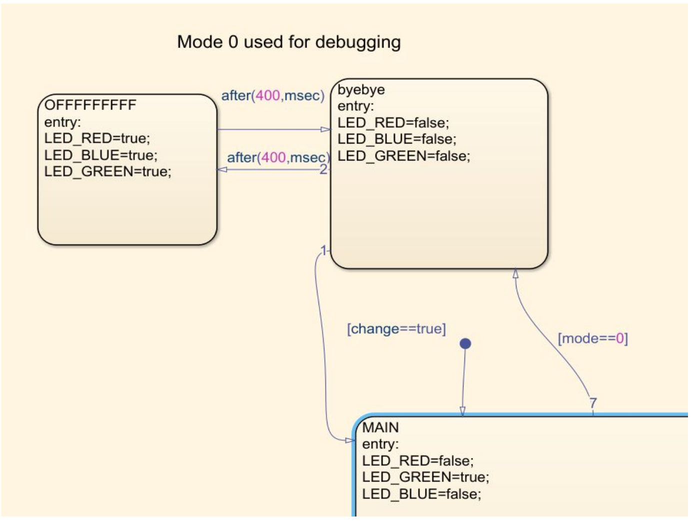
DOO means both the atrium and ventricle are paced by the pacemaker. First, the atrium is paced and discharged, then the ventricle is paced and discharged. The two states are delayed by the programming variable AV delay. The design decision is that when each mode is completely independent of other modes, which decreases the coupling between modules.

Once entering a specific mode, only the charts within the modes are repeatedly used, which ensures a high level of cohesion.

Serial Communication



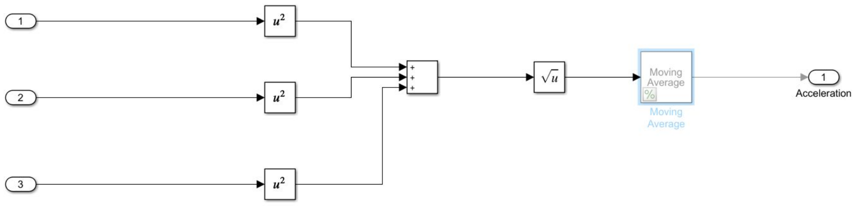
This is the chart for serial communication. The initial state sets all the variables to a default value. When the serial receive block receives data, the status would be equal to zero. All the programming parameters would then be set from the incoming byte stream. The changing variable would be modified back to zero after two seconds. During the transition period, the green light would be on for two seconds for debugging purposes.



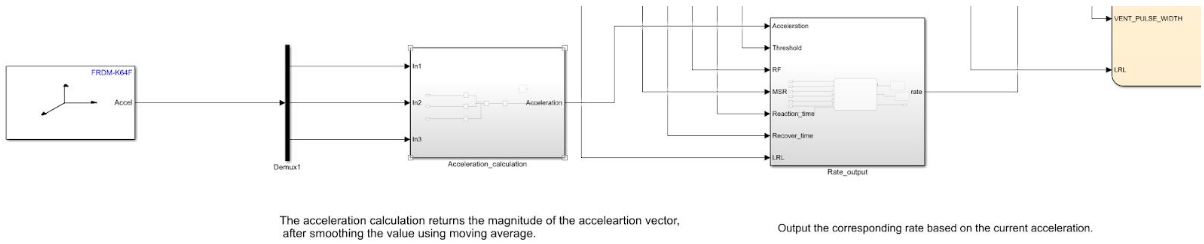
State transitioning:

Modes are changed from serial communication, the variable change is also used to transition back to the main state. The variable change is always set to false unless there are new incoming byte streams. The serial communication block would then set change to be true for two seconds and then turn it to false. The above mode 0 is only used for debugging purposes. The white light will flash every second in this mode.

Acceleration Module



Each input represents the acceleration on one of the axises. Then the square root of the sum of each value squared is calculated as the final acceleration magnitude. The moving average functions in the signal processing library take a width of 100 data and output the average of the list to output a smoother acceleration.

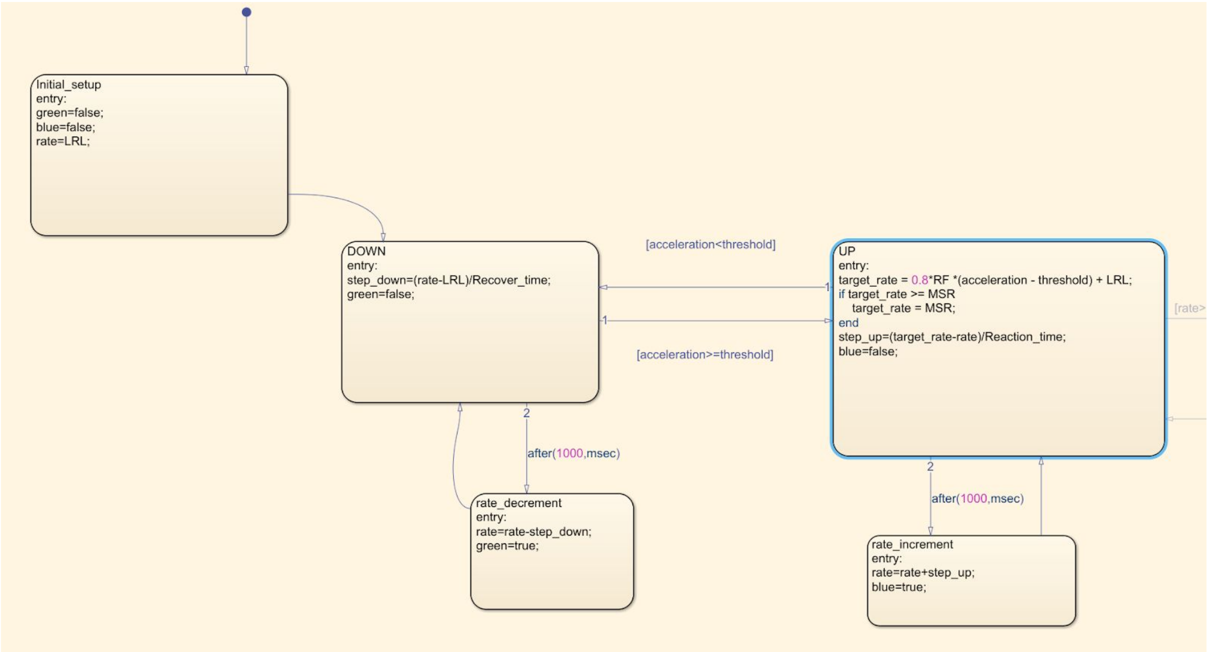


The acceleration magnitude is transmitted into the rate output chart to determine the rate at which the heart should be pacing during rate-adaptive modes.

High-Level Design:

The orange line represents the maximum sensor rate at 120 beats per minute. The pink and teal line represents the linear relationship between the acceleration and the target cardiac output rate. The steeper line (pink) indicates a higher response factor (8), whereas the teal one has a response factor of 1. The decision for choosing a linear relationship is for simplicity and ease of implementation. The acceleration value is an indication of activity level. In our design, the threshold value is set to be 2 meters per second squared, meaning that if the acceleration is lower than 2, then the pacemaker would still be pacing at the lower rate limit. Different activity level also corresponds to different acceleration values. The following table outlines the design.

Activity Level	Acceleration (meters per second squared)
Low Level	2 to 5
Mid Level	5 to 10
High Level	>10



At the initial setup, the rate is assigned as LRL. Then depending on the acceleration, if it is bigger than the threshold, it would move to the UP state. The target rate is the rate that the heart would be pacing after the reaction time. The target rate is calculated as 0.8 * Response Factor * (Acceleration - Threshold) + LRL. The design is that the rate is linearly proportional to the response factor and the difference between acceleration and threshold. The step-up variable is calculated as the difference between the target rate and the current rate over the reaction time. Then the flow chart will increase the heart rate by the value of the step-up variable per second. The same mechanism is applied when the acceleration is smaller than the threshold and the step-down variable is calculated in the same manner.

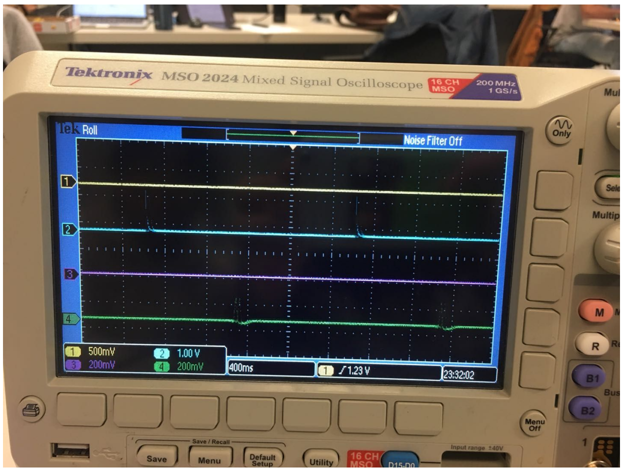
Description of Performance of Testing and Result

AOO/VOO:

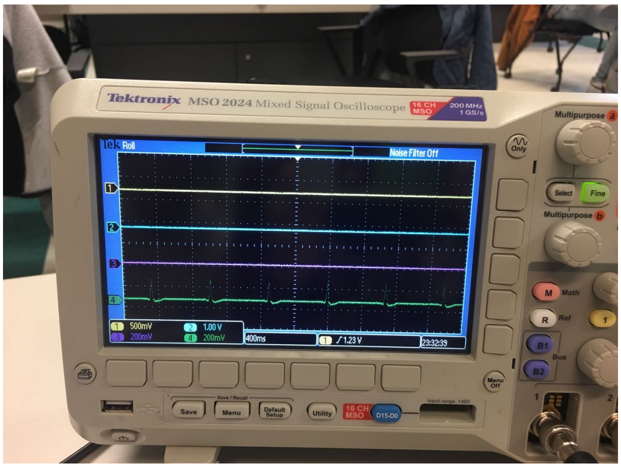
The above signals are captured from using the oscilloscope in the lab. The positive portion of the signal is pacing the heart from C22 for the length of the pulse width. The negative portion is an exponentially decaying function since it is the discharge of C21 to eliminate the charge buildup in the heart.

AAI/VVI:

The heart rate output from the computer software is set to be 30 beats per minute. It can be seen that the pacemaker makes up for the interval by pacing between the two sensed heartbeat.

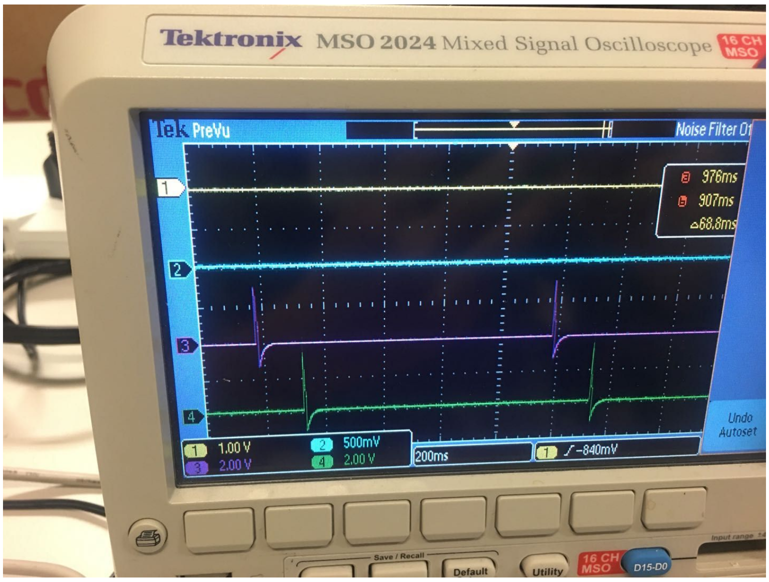


When the natural heart rate is above 60 beats per minute, the pacemaker would stop producing any pulse.

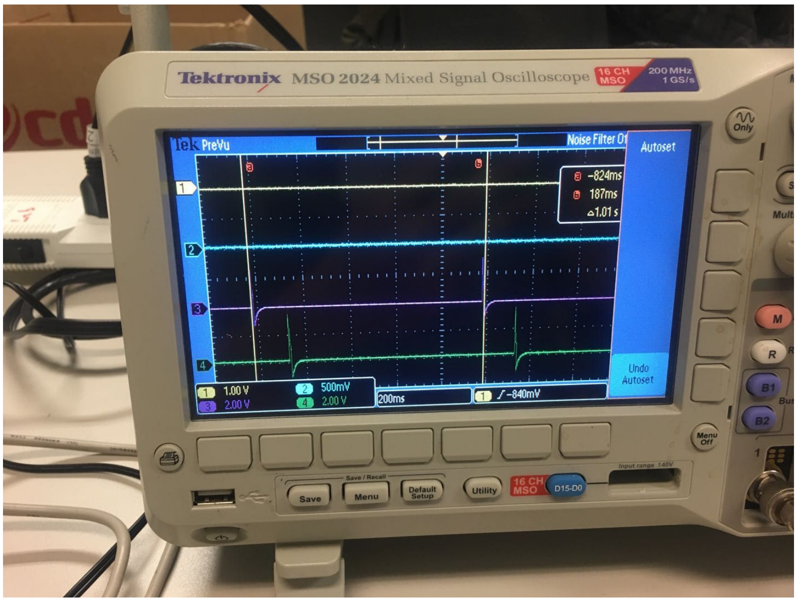


DOO:

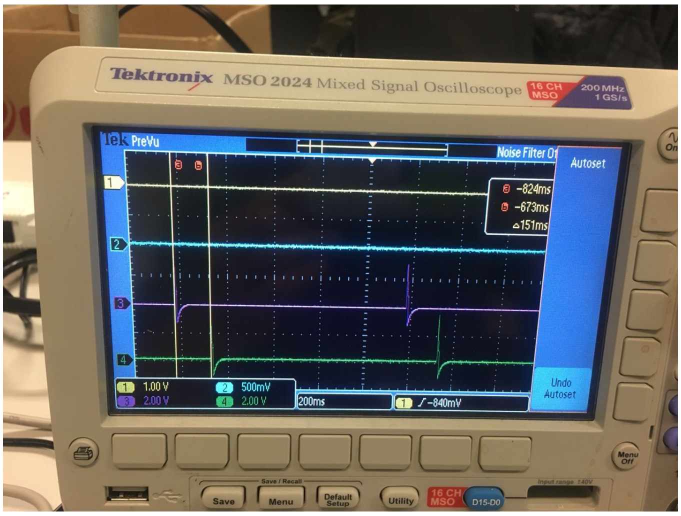
The purple curve represents atrial pacing and the green one represents ventricular pacing. It can be noted from the oscilloscope that both chambers are being paced one after another.



The cursors are used to determine the time interval between one atrial pulse to the next one. The measured internal is 1 second as expected.



The cursors are used again to determine the atrial-ventricular delay. The measured time interval is 150 ms as expected.



Rate Adaptive mode:

The mode was unfortunately not fully implemented. However, the LEDs are used to indicate the pacing of the heart. As the pacemaker was shaken, the flashing frequency of the LED increased accordingly.