Embedded Final Project: Smart Streetlight

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1 Design Overview

Smart Streetlight is a program automated by the MSP430F5529 development board that functions as a light controlling system. The design senses road vibrations and calculates an incoming car's speed based on the vibration information. In addition to the monitoring of vehicle speed, Smart Streetlight also measures the light intensity to determine if it is daytime or nighttime. The tuning for these light levels can be calibrated depending on the desired threshold for which the light considers night.

1.1 Design Features

- Power Efficient
- Ability to calibrate light intensity sensing

1.2 Featured Applications

- Power-efficient Automated Street Lights
- Automated Hall-Lights

1.3 Design Resources

- GitHub
- MSP430 Family User Guide
- MSP430F5529 Datasheet
- ADXL250 Datasheet

- OPA234 Datasheet
- OrCad Capture
- LM660CN Datasheet

1.4 Block Diagram

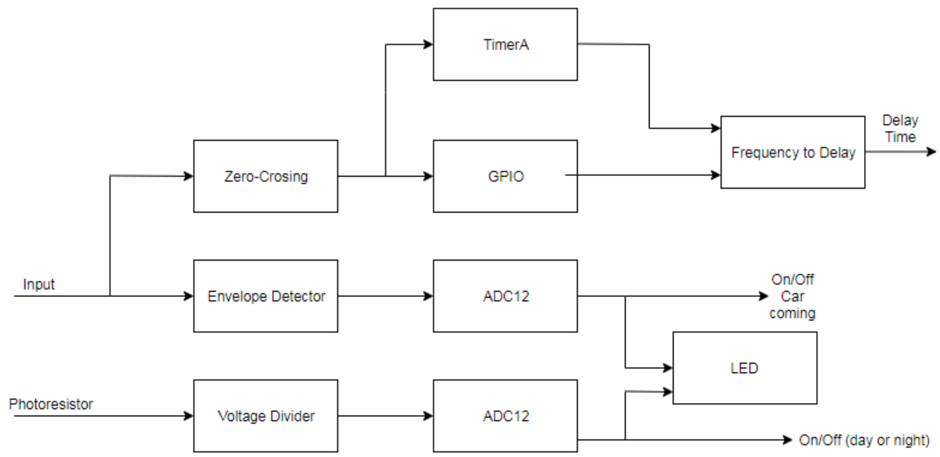

Figure 1: Block Diagram of Smart Streetlight

1.5 Board Image

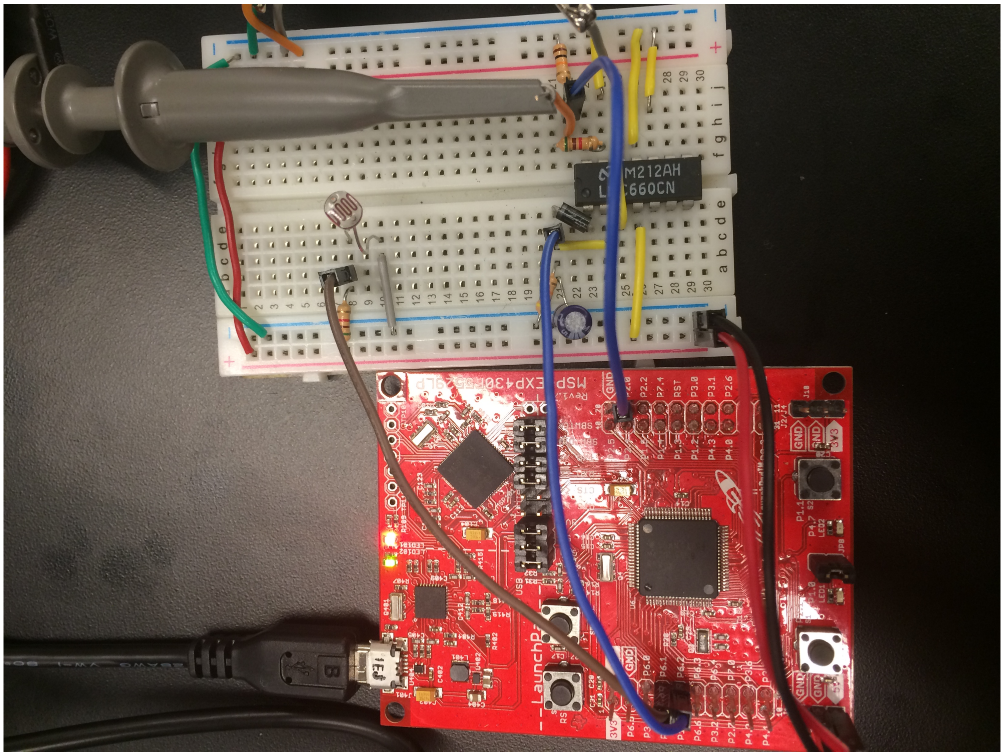

Figure 2: Circuitry for envelope detecting, zero-crossing, and light sensing

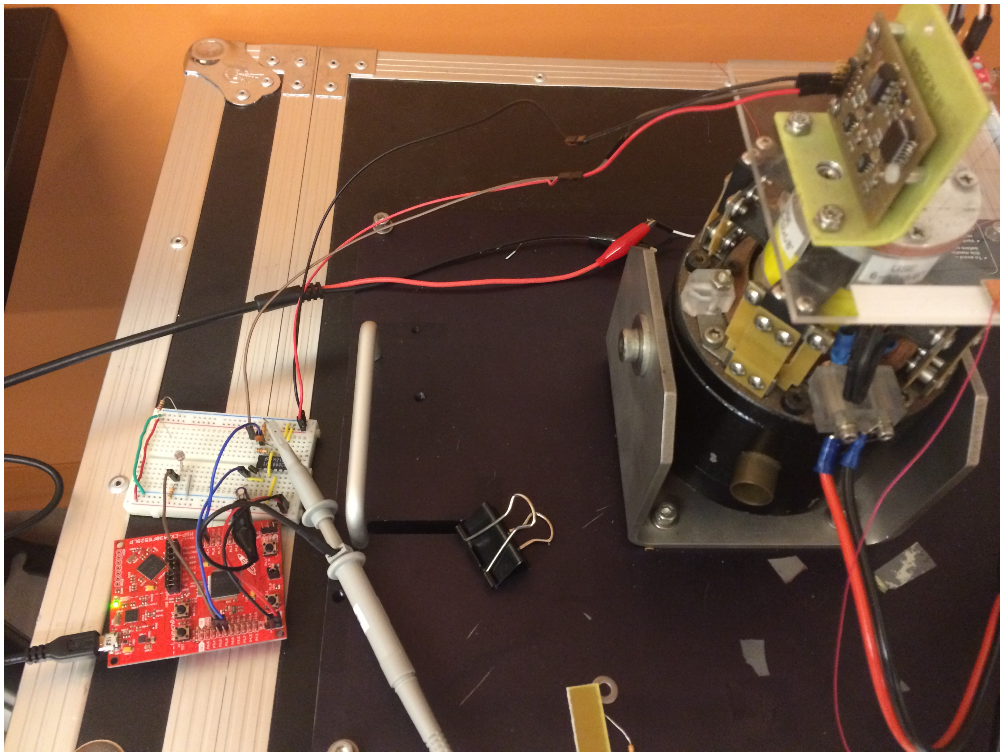

Figure 3: Circuitry for envelope detecting, zero-crossing, and light sensing connected to the accelerometer and vibration table

2 Key System Specifications

Parameter	**Specifications**	**Details**
Baud Rate	9600	Baud Rate to communicate with the MSP430F5529
Timer A0	16-bit	16-bit timer that has 5 capture compare registers
SMCLK	1 MHz	1MHz clock that is active in low power mode 0 and 1
ADC12	12-bit	Quantizes analog signal to binary values
Photoresistor	15k	Resistance changes as the intensity of light changes

Table 1: Specifications

3 System Description

The desired outcome is to be able to analyze a frequency to determine a car's speed. Depending on the car's speed, it will determine a calculated delay time before a streetlight will turn on. This streetlight will not turn on if the light level of the environment is too bright and a light sensor will be used to accomplish this design choice.

3.1 Highlighted Devices

- MSP430F5529 Microprocessor
- Labworks ET-126 Vibration Table
- ADXL250AQC Accelerometer
- 2 MΩ Photoresistor

3.2 MSP430F5529

The MSP430F5529 is a Texas Instrument microprocessor with a Timer A0 that contains five capture compare registers, six GPIO configurable 8-bit ports, and a 12-bit analog-to-digital converter (ADC12). Bit 0 of Port 2 (P2.0) and Timer A0 handled all information needed to determine the car's speed, which is used in time delay calculations. ADC12 sampled all the necessary information for determining the light intensity of the environment and if a car is present, which is used to determine whether or not to turn on the street light.

4 SYSTEM DESIGN THEORY

4.1 Design Requirement 1

The first design requirement of Smart Streetlight is to allow the MSP430F5529 to take in readings through a zero-crossing circuit. This zero-crossing circuit detects how fast the car is physically moving and a timer is set to capture the amount of time between information. The conversion for the time delay is handled in the software. The setup of the zero-crossing circuit uses an operation amplifier (op-amp) as a comparator. As shown in Figure 8, the op-amp circuit outputs 3.3 V if the sinusoidal input is positive, and 0 V if negative. GPIO pin P2.0 receives the uni-polar square-wave output of the op-amp circuit. Values read from this pin are used to configure a Timer A0 module which will count the time between positive edges, and then count how long to wait before turning on the light. A time delay is made by setting the the timer A0 capture compare register 0 (TA0CCR0) to the calculated delay time based on the speed of the vehicle. Once the value in the Timer A0 register equals the value of TA0CCR0, the street light illuminates and the timer is reset to stop mode to conserve energy. To simplify the early models of Smart Streetlight, it is assumed that the sensing module is 200 meters away from the streetlight.

4.2 Design Requirement 2

The second design requirement is for Smart Streetlight to sense whether it is daytime or nighttime. If the system senses enough light to be considered daytime, the whole control system will shut off. This is done through a photo resistor in a voltage divider circuit, as shown in 9. As the light increases, the resistance of the photoresistor decreases. This phenomenon is leveraged in our design by connecting light intensity to voltage output. Output voltage measured by the ADC is inversely proportional to the resistance. The voltage across the photo resistor is then fed into the ADC12 input channel separate from the input channel used in the zero crossing circuit. This input is compared to turn-on and turn-off thresholds. The system turn-on and turn-off thresholds are different values so the system does not oscillate between on and off if it is dusk or dawn.

4.3 Design Requirement 3

The third design requirement is for Smart Streetlight to be sensitive to the envelope of the vibration waves. Since there is expected to be ongoing ambient vibrations, the system must distinguish between ambient vibrations and vehicle-induced road vibrations. The difference will be their amplitudes - bigger amplitude signals are considered vehicles, while smaller amplitudes would be ambience. Like with the photoresistor circuit, turn-on and turn-off voltages are set so the system will only operate the amplitude rises above the turn-on threshold. To obtain this result, the sinusoid is rectified with a super-diode op-amp configuration to make the signal positive, and smoothed with a capacitor to ground in parallel with the output. The placement of the capacitor makes the signal look like 6. This way, while a car is still present, the voltage will stay above the turn-off threshold.

5 Getting Started Software/Firmware/How to use the device

To power the device, a USB-to-micro-USB must connect the MSP430F5529 loaded with the code to a USB-A type a power supply. All other connections use MSP430F5529 pins.

5.1 Device Specific Information

The positive rail on the breadboard must be connected to the 5 V pin on the MSP430F5529 and the negative rail to ground on the MSP. P6.1 must be connected to the positive leg of the photoresistor as it connects to input channel 1 of ADC12. P6.2 must be connected to the cathode of the rectifier diode as it connects to input channel 2 of ADC12. P2.0 must be connected to positive end of the 10kΩ resistor in zero-crossing circuit. This 3.3 V signal will input through GPIO. Lastly, P2.6 must be connected to the anode of the off-board LED as it represents the ultimate goal of this project: strategically turning on and off the street light.

6 Test Setup

The program requires an extensive laboratory setup. Table 2 shows all the equipment needed for the setup. Briefly, The function generator outputs a signal to the power amplifier, which drives the vibration table to vibrate at a specific frequency and amplitude. The accelerometer sits on the vibration table and outputs a voltage proportional to the acceleration it experiences. This voltage is the source for the zero-crossing and envelope detection circuitry.

Manufacturer	Model	Description	Notes
Furman	PL-8	Power Conditioner	Serves as a power strip
QSC	RMX1450	Power Amplifier	drives vibe table
Agilent	33210A	Arb. waveform Generator	Sends signal into amp
Labworks Inc.	ET-126	Vibration Table	Simulates road vibrations

Table 2: Instrument Table

6.1 Test Data

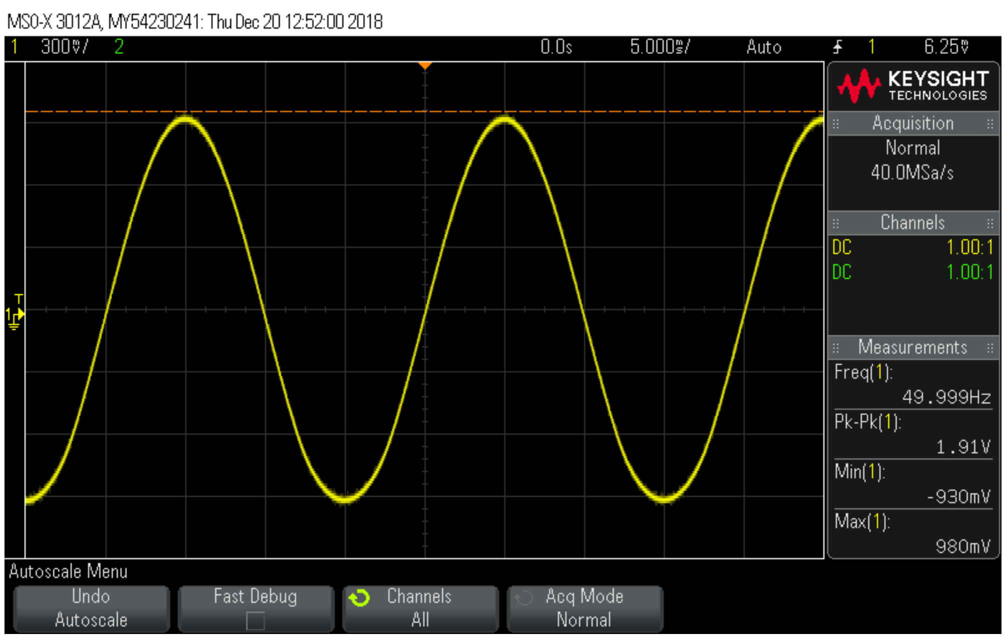

Figure 4: Input Signal from vibration table

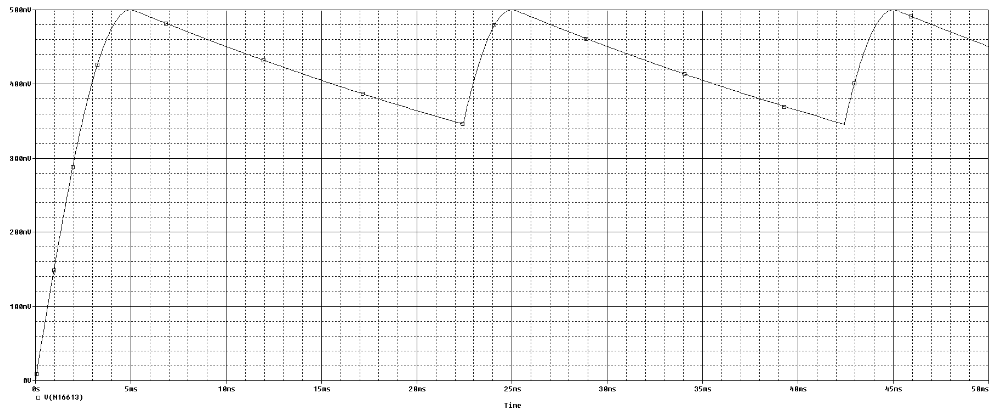

Figure 5: Simulation of envelope detector circuit.

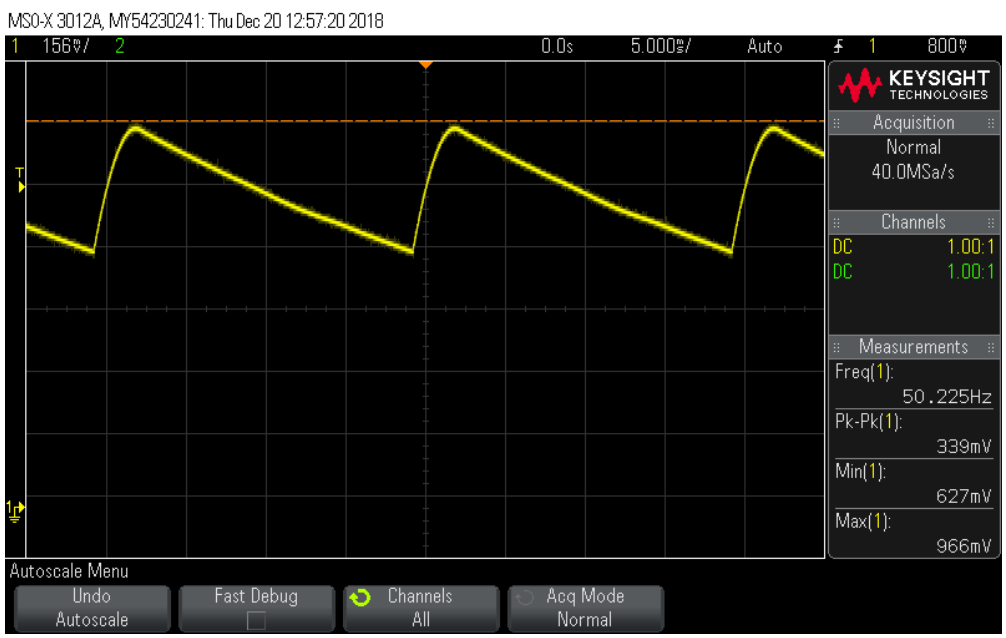

Figure 6: Oscilloscope reading envelope detector

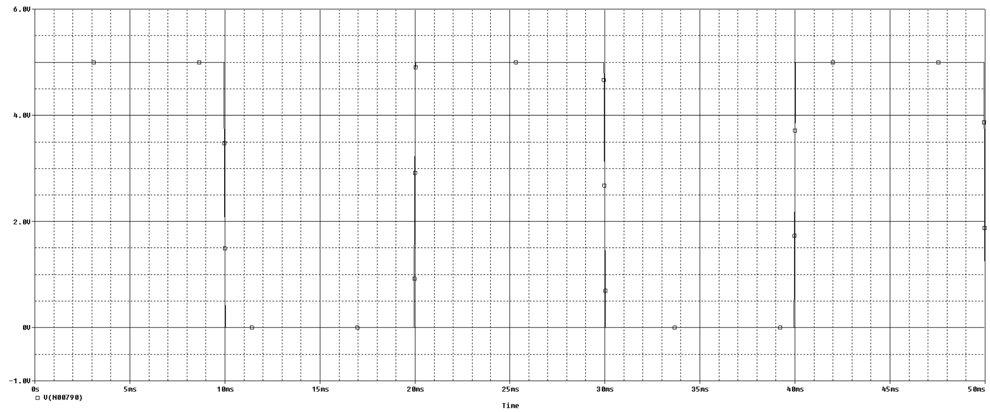

Figure 7: Zero Crossing Simulation

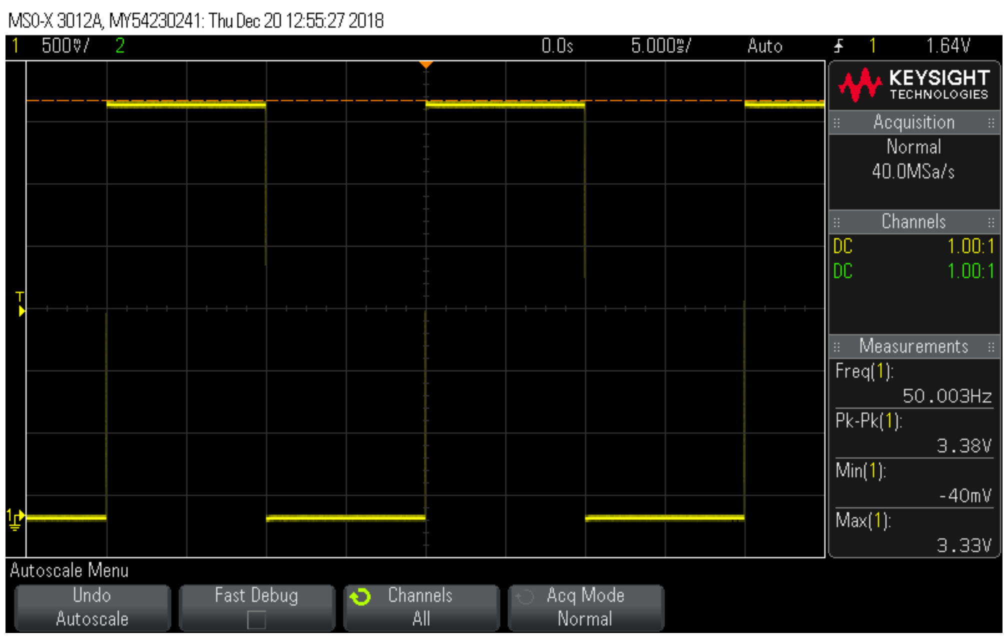

Figure 8: Oscilloscope Readings Zero Crossing

7 Design Files

7.1 Schematics

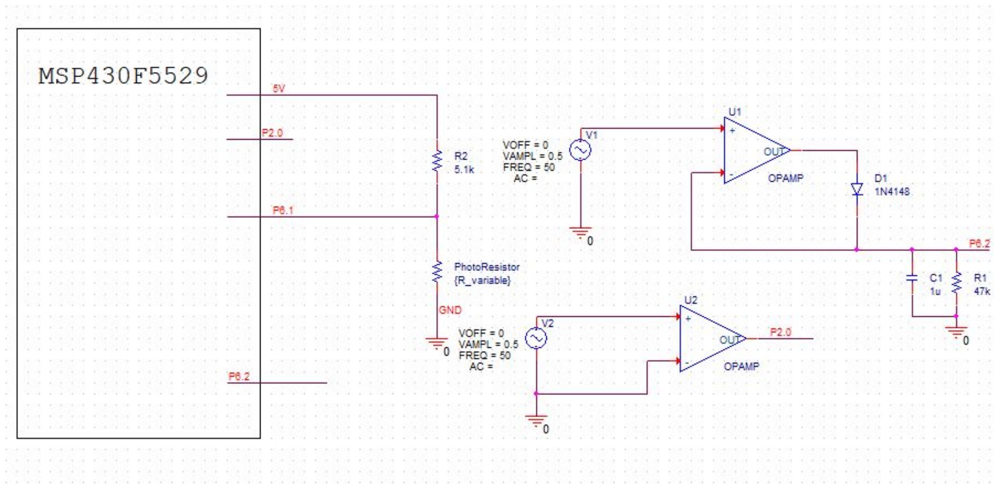

Figure 9: Voltage Divider circuit with photo resistor and envelope detector

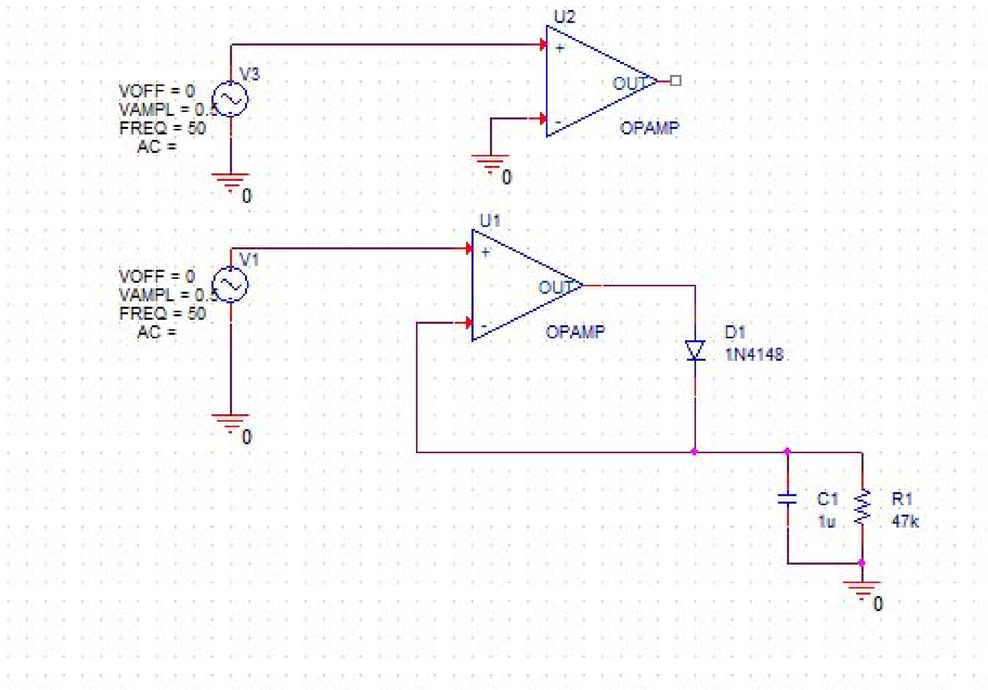

Figure 10: Envelope detector circuit

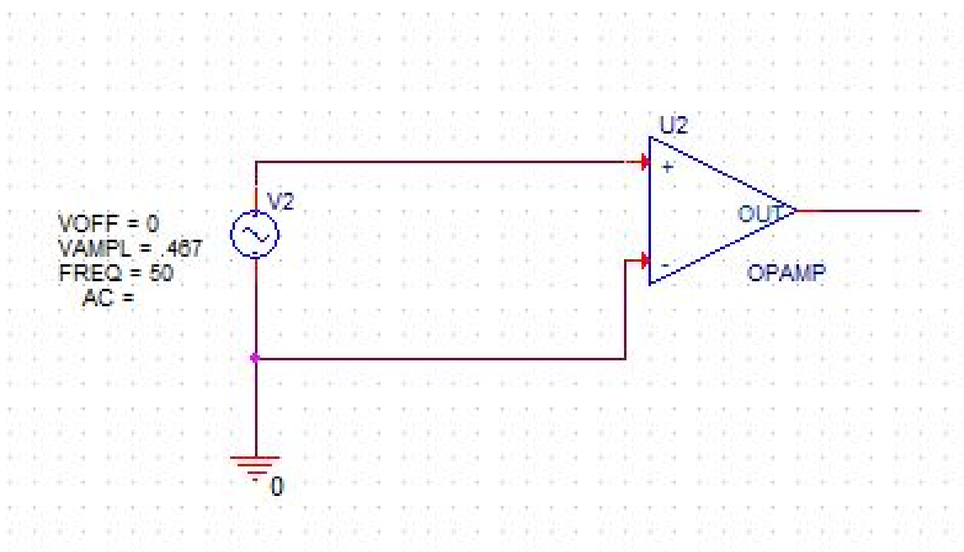

Figure 11: Zero Crossing Circuit