

YOUR NAME:

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Pre-Lab Score: ___/40

In-Lab Score: ___/60

Total: ___/100

RC Oscillators

LAB 4: RC Oscillators

ELECTRICAL ENGINEERING 43/100

INTRODUCTION TO DIGITAL ELECTRONICS

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Lab Objectives

In this lab we will learn to analyze and build RC oscillators that may be used as one of the modules in the final project. This oscillator primarily functions as a signal generator for a test signal. In short, you are basically building a very simple function generator.

Background

Many circuit applications that require precision timing or PWM (pulse width modulation) control need an input waveform that oscillates between two voltages. To accomplish this, we exploit the properties of capacitors to create these oscillating circuits. Often times we will have to settle for triangle or square waveforms, since sinusoidal waveforms are notoriously difficult to produce from simple RC oscillators.

These waveforms are used in mechanical applications, such as motors that require PWM control or timing circuits for synchronous digital applications. One of the advantages of PWM is that it draws less power than a DC input.

However, in our application, we will simply exploit the fact that it can function as a signal generator.

Pre-Lab Component**The Relaxation Oscillator**

Reproduced below is a schematic of the relaxation oscillator. We'll use this as a square wave generator. Notice that it is configured in a positive feedback configuration.

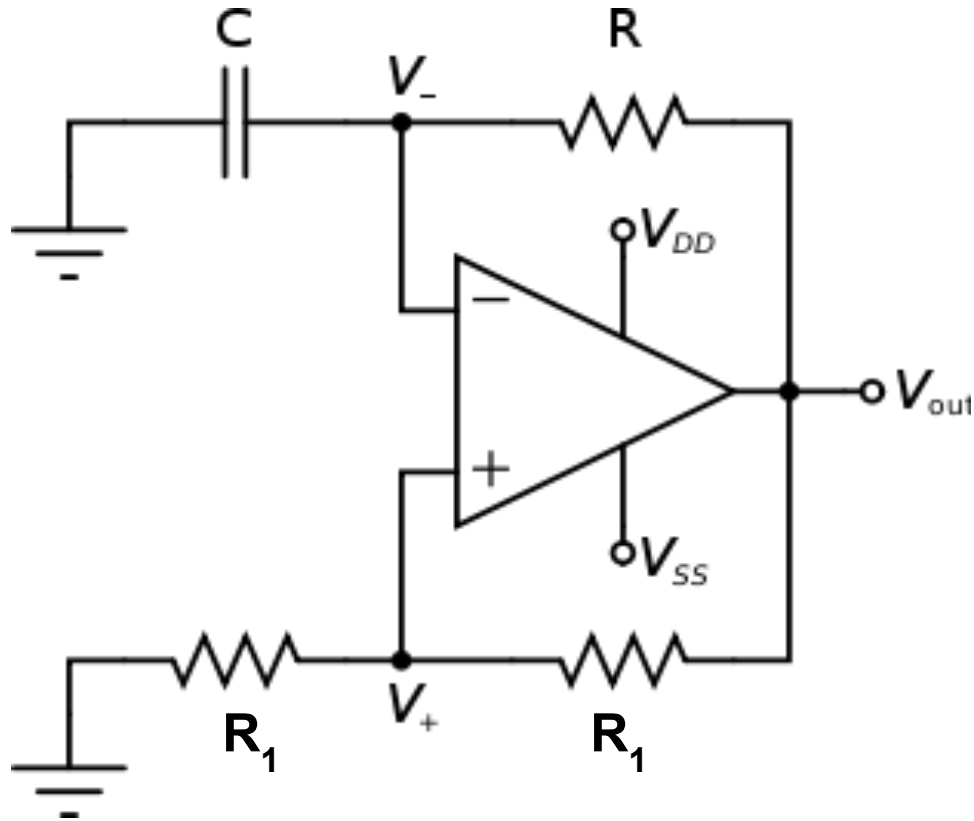


Fig 1. Relaxation Oscillator¹

Initially the relaxation oscillator will start off with zero output. But the world isn't perfect, and random fluctuations will eventually cause one input terminal to be higher than the other. Due to the positive feedback, the output will then saturate to the corresponding rail. Once this happens, the capacitor that is connected to the inverting terminal will begin to charge or discharge through the feedback loop depending on the state.

Remember, negligible current flows into the operational amplifier input terminals. Also the supplies to the operational amplifier are V_{DD} and $V_{SS} = -V_{DD}$, so the output of the operational amplifier is always either $+V_{DD}$ or $-V_{DD}$, giving us really only two states to analyze. Intuitively, the square wave comes primarily from the abrupt saturation from the positive rail to the negative rail or vice versa. But what about frequency and duty cycle? Good question...

In the space provided below, prove that the frequency f of the output signal of the relaxation oscillator is given by

$$f = \frac{1}{2 \ln(3) RC}$$

Show all relevant mathematical derivations and work.

Score: __/20

More workspace...

The Triangle Wave Generator

The triangle wave generator is actually just a simple integrator shown below.

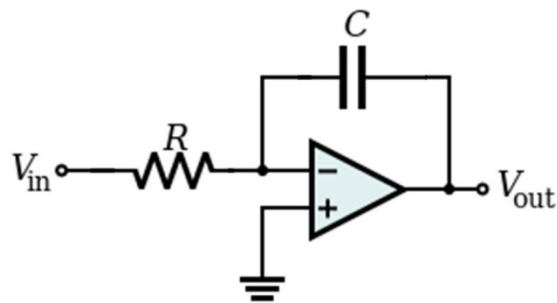


Fig 2. Inverting Integratorⁱⁱ

In the space provided below, prove that the output of the above circuit actually integrates and inverts the input signal by showing the output signal is given by the following. Assume all initial conditions are zero.

$$V_{out} = - \int_0^t \frac{V_{in}}{RC} dt$$

Then prove how this generates a triangle wave from the square waveform. What conditions for the square input waveform must be satisfied for this to actually produce a triangle wave? If V_{in} is a 10-Hz square wave with 5-V amplitude, how would you pick the value of R and C to generate a triangle waveform with 4-V amplitude?

Score: __/20

Lab Section

So why exactly do we care about an RC oscillator that produces a square and triangle wave?

Glad you asked. Square waves and triangles waves make excellent test signals, because they are periodic and predictable, unlike real world analog signals that you may be measuring.

In this lab component, you will be building the appropriate oscillator for your final project to act as you test signal source. A list of specifications as to what exactly your generator will need is explained in detail in the next section.

Your Oscillator

Obviously we can't just use any arbitrary oscillator with arbitrary specifications. Some test signals are better than others. Let's start by taking a look at the application. Suppose we need to pick up signals on a microvolt level through a pair of electrodes. In addition, the frequency that we are primarily interested in lies around 10Hz , so we want to be able to produce at least that.

However, we will be using the oscillator as a test source, so we might as well be able to sweep multiple frequencies. This will enable us to both simulate the frequency we are looking for as well as test if our circuit appropriately rejects undesired frequencies.

Thankfully, you've done all of the derivations already for both of the oscillators, so adjusting the design to fit the following parameters should be fairly simple.

In the space provided below, pick appropriate component values for the relaxation oscillator so that its minimum frequency is 10Hz . You may use one potentiometer in your design.

Score: __/10

More workspace...

Building the Oscillator

Now that you have calculated the component values, it's time to build this on your breadboard. Before we implement that microvolt-level signal generation, you will first want to test if your oscillator is working properly.

As always, some useful tips before you start breadboarding it up:

- Set current limits. Anything greater than a reasonable amount of current will destroy your circuit, and you and your chips will be very sad.
- If components are getting hot, make sure your wires are not shorting and things are connected correctly. Check supplies to make sure the high and low supplies are not swapped.
- The multimeter and oscilloscope are your friends. Use them to test if you are getting expected value on your circuit.

i) Build the relaxation oscillator (Fig 1). Pick R and C based on your previous calculation. You can use a 100-k Ω potentiometer for R. Use a 20-k Ω resistor for R1. What is the oscillation frequency? Tune the potentiometer until the frequency of the square wave is 10 Hz and show it to your GSI.

Your GSI Signs Here (15 Points)

ii) Build the triangle wave generator (Fig 2). The input comes from the square wave generated by the relaxation oscillator. Pick R, C based on your previous calculation. You can use a 100-k Ω potentiometer for R. What is the amplitude of the triangle waveform? Tune the potentiometer until the amplitude is 4 V and show it to your GSI.

Your GSI Signs Here (15 Points)

Note: you may want to put a 100 k Ω resistor across C to discharge excess charge.

iii) Once you have finished building the oscillator, it would be nice to see some indication that it works. To accomplish this, we can attach an LED to the outputs.

Add an LED to the output of your relaxation oscillator in series with an appropriate resistor. Usually resistor between 200 Ω and 1 k Ω should do the trick. You should now have a blinking LED at 10 Hz. Turn the potentiometer and show the LED blink at different frequencies. Now connect a second LED and resistor to the output of your triangular wave generator. Does the intensity of the LED change with time? Show your se up to you GSI for check off

Your GSI Signs Here (10 Points)

Lab Report Submissions

This lab is **due at the beginning** of the lab section. Make sure you have **completed all questions** and **drawn all the diagrams** for this lab. In addition, attach any loose papers specified by the lab and submit them with this document.

These labs are designed to be completed in **groups of two**. Only one person in your team is required to submit the lab report. Make sure the names and student IDs of **BOTH** team members are on this document (preferably on the front). **Image Citations**

ⁱ <http://en.wikipedia.org/wiki/File:OpAmpHystereticOscillator.svg>

ⁱⁱ http://en.wikipedia.org/wiki/File:Op-Amp_Differentiating_Amplifier.svg