

# Experiment 26

Please make note of the changes made to this lab to accommodate the equipment we have in our lab.

Make sure you take the screen shots indicated and post them in the form of a Reply to this week's forum.

## Time Proportioning DC Control Circuit

### Objectives

Using a schematic diagram, assemble a time proportioning circuit.

Alter the duty cycle of an amplifier to vary the average DC voltage at its output.

Given the dc voltage of a square wave and its duty cycle, calculate the average DC voltage produced by an amplifier.

### Required Materials

- (1) DC power supply 0 to +15V
- (1) Digital dual trace oscilloscope
- (1) Signal generator (sawtooth 10V p-p)
- (1) DC voltmeter
- (1) Op amp IC – LM311
- (1) 10K $\Omega$  potentiometer
- (2) 5.1V zener diodes
- (1) 2.5V zener diode
- (2) 1K $\Omega$  resistors

### Introduction

A common method of controlling a DC voltage actuator device such as a heating element or a light bulb is to vary the DC voltage of an amplifier that drives it. This method is called proportional control because the magnitude at which the actuator is driven is proportional to the amplitude of the applied voltage. For example, doubling the applied voltage produced by an amplifier doubles the temperature of the heating element.

Another way of controlling an actuator is to use an operation called *time proportioning*. Time proportioning is a method in which the amplifier output is switched alternately to fully on and fully off. Changing the ratio of signal-on to signal-off varies the average voltage produced. Figure 26-1 illustrates various time proportioning output signals which are in the form of a squarewave. When the on-time is shorter than the off-time, as shown in part (a), the average output voltage is low. When the on time and off time are the same, as shown in part (b), the average voltage is at the midrange between low and high. When the on time is greater than the off-time, as shown in part (c), the average voltage is high. The ratio of time at which the squarewave is on to the total time period of one

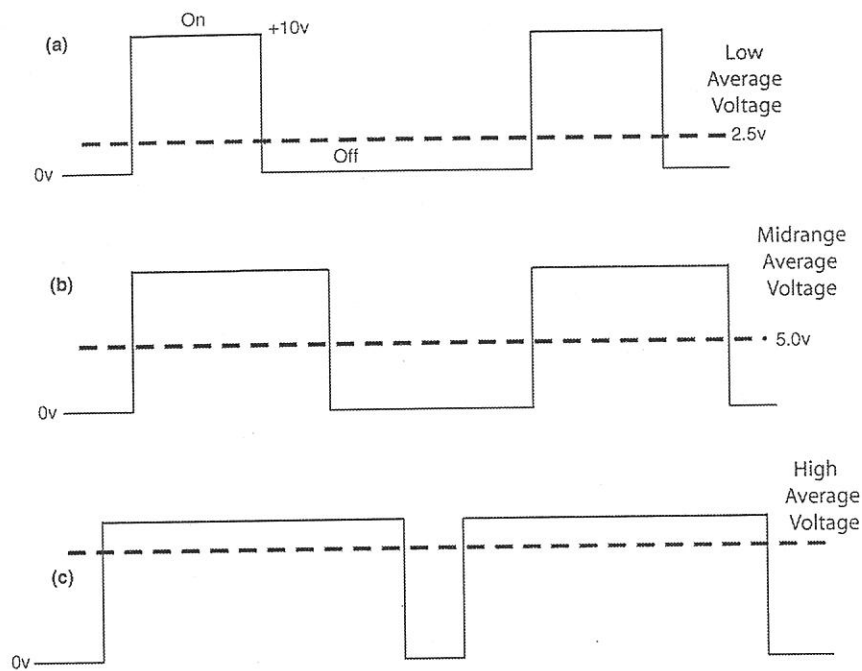


Figure 26-1 Waveforms of various duty cycles

cycle is called the duty cycle. The average DC voltage produced can be determined by multiplying the duty cycle times the on-state DC voltage of the squarewave.

Suppose the squarewave produces +10 volts when it is on, and 0 volts when it is off. If the duty cycle is 25 percent, as in Figure 26-1(a), the average voltage is 2.5 volts ( $10\text{ V} \times 25\% = 2.5\text{ V}$ ). When the duty cycle is 50 percent, as in Figure 26-1(b), the average voltage is +5 volts. If the duty cycle is zero percent, the average voltage is 0 volts.

## DC Time Proportioning Circuit

A Voltage-Level Detector Op Amp, as shown in Figure 26-2, can be used as a time proportioning circuit. The voltage level detector output is zero volts when the noninverting input is less than the inverting input. When the voltage at the noninverting input is greater than the voltage at the inverting input, the Op Amp produces a + volt saturation voltage at its output.

In Figure 26-3, a 10-volt peak-to-peak sawtooth is applied to the inverting input of the Op Amp. The wiper arm of a potentiometer is connected to the noninverting input. When the wiper arm is at the 0 volt ground position, the sawtooth at the (-) input is either equal to or greater than the (+) input. Therefore, the output of the Op Amp is at a constant 0 volt potential. When the wiper arm is in the

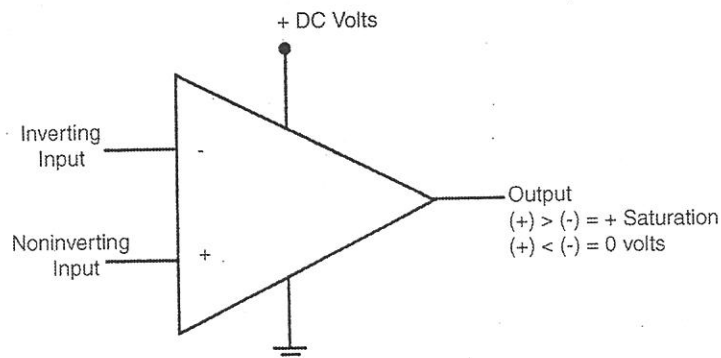


Figure 26-2 Voltage-level detector Op Amp

middle position, a +5 volt potential is applied to the (+) input. The sawtooth potential applied to the (-) input does not become greater than the (+) input until it reaches +5 volts halfway up the ascending portion of the waveform, and remains that way until it drops below +5 volts, halfway down the descending portion. The result is that the Op Amp produces a squarewave with a 50-percent duty cycle.

The resulting average DC voltage is +5 volts ( $.5 \times 10V = 5V$ ). When the wiper arm is positioned at the top, 10 volts is applied to the (+) input. The voltage applied to the (+) input is always greater than the (-) input, so the Op Amp output is always 10 volts.

## Procedure

### Step 1

Without applying power, assemble the circuit in Figure 26-3.

Ask your instructor for any needed modifications for our lab. Some are outline below on the schematic diagram.

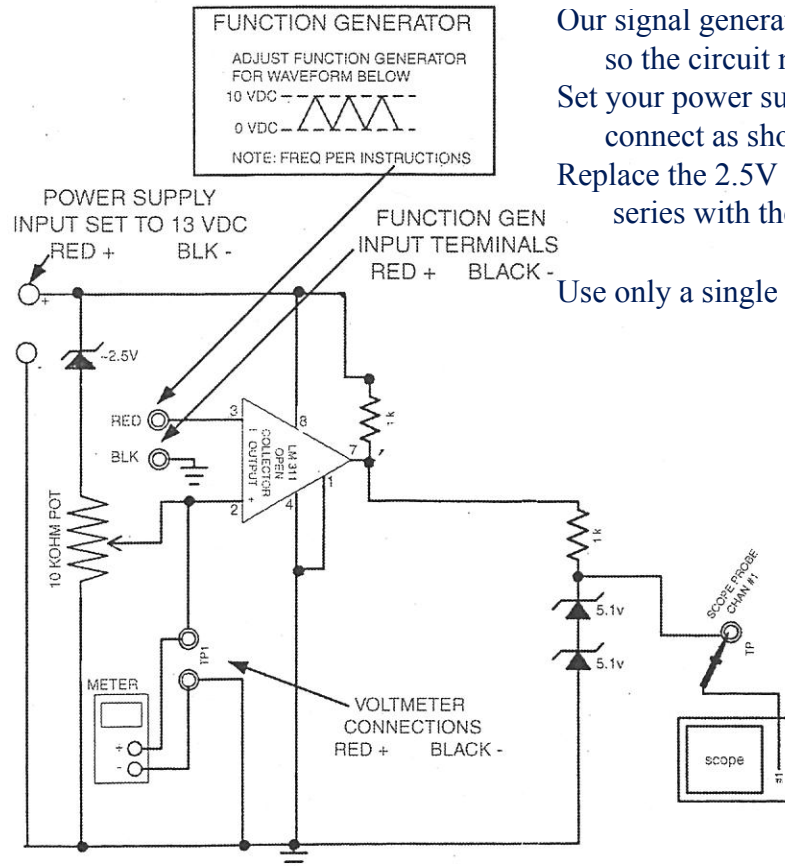
### Step 2

Connect Channel 1 of a dual trace oscilloscope between the inverting input of the Op Amp and ground with the Mode switch at the DC setting.

*Read the instructions on a digital oscilloscope if you are not familiar with the operation.*

### Step 3

Place the channel 1 Mode switch in the GND position. A straight horizontal scan line should appear to represent 0 volts. Using the vertical position control, move the scan line to a horizontal grid line at the bottom of the scope face. The line will be the 0 volt reference.



Our signal generators only put out 0V-5V so the circuit needs some mods.

Set your power supply to 0V and +10V and connect as shown.

Replace the 2.5V zener with a 10k resistor in series with the 10k pot.

Use only a single 5.1V zener on the output.

Figure 26-3 Time proportioning lab



#### Step 4

Return the Mode switch to the DC position.

#### Step 5

Apply a 250Hz sawtooth signal from a signal generator to the inverting input of the Op Amp. Using channel 1 of the oscilloscope to measure the signal, adjust the voltage of the sawtooth generator to 10 volts peak-to-peak. If the sawtooth is clipped, adjust the DC offset on the signal generator until it is unclipped. **Our signal generators can only create a 0V-5V signal.**

#### Step 6

The bottom of the sawtooth should be on the horizontal 0 volt reference line of the scope's grid. The top of the sawtooth should be 10 volts more positive in respect to the reference grid line. If it is not, make the necessary amplitude and dc offset adjustments on the generator. **The top will be at +5V.**

#### Step 7

Connect an analog DC voltmeter between the non-inverting input and ground so that it can measure 0 to 10 volts.

#### Step 8

Apply power to the circuit.

#### Step 9

Adjust the wiper arm of the potentiometer to the    volt position. **Adjust to the 2.5V position.**

#### Step 10

With the Mode switch of the scope in the DC setting, connect channel 2 of the dual trace scope across the two zener diodes located between the output of the Op Amp and ground. Adjust the Volts/division knob so that the scope clearly displays the 0 to 10 volt square wave signal that should be produced by the Op Amp.

#### Step 11

Connect a 2nd DC analog voltmeter that can read from 0 to 10 volts DC between the output of the Op Amp and ground.

#### Step 12

Fill in data in the 3 vertical columns to the right of Table 26-1 for each potentiometer setting listed in the left vertical column based on the following instructions:

Approximate Duty Cycle – View the square wave produced at the output of the Op Amp with the scope and record your estimated duty cycle.

Calculated Average DC Voltage – Based on the estimated duty cycle viewed on the scope for each potentiometer setting, multiply this value times the voltage of the on-state square wave (10 volts).

Measured Average DC Voltage – Record the average voltage measured by the DC voltmeter that is produced at the output of the Op Amp.

#### Step 13

Turn off the power supply connected to the Op Amp and return the parts and equipment to their proper storage area.

When taking screenshots, make sure to display the following information on each picture:  
+PW, Period, % Duty Cycle, Average Value, plus your name/initials.

Table 26-1

	Potentiometer Setting	Approximate Duty Cycle	Calculated Average DC Voltage (Pk On-Time Volts × Duty Cycle)	Measured Average DC Voltage
	0v			
Screenshot	1.25V			
Screenshot	2.50V			
Screenshot	3.75V			
	5.0V			

*The measured average DC voltage and the calibrated average DC voltage should be the same.*

Text

## EXPERIMENT QUESTIONS

- The term *duty cycle* refers to the amount of time a signal is \_\_\_\_\_ compared to the period of one complete cycle.
  - off
  - on
- When the voltage applied to the \_\_\_\_\_ input is greater than the \_\_\_\_\_ input, the voltage level detector Op Amp produces a + volt saturation voltage at its output.
  - inverting
  - noninverting
- A square wave that is 20 volts at its high state and 0 volts when it is off will produce an average DC voltage of \_\_\_\_\_ when its duty cycle is 75 percent.
  - 7.5V
  - 10V
  - 15V
- Referring to Figure 26-3, the duty cycle is 25 percent when the voltage at the wiper arm is \_\_\_\_\_.
  - 2.5V
  - 5V
  - 7.5V

## Week #15 Experiment

# PWM DC Motor Speed Control

The circuit schematic and the description of it's operation can be found here:

<https://howtomechatronics.com/how-it-works/electronics/how-to-make-pwm-dc-motor-speed-controller-using-555-timer-ic/>

You have a lot of flexibility for component values. To get started, you should plan on having a PWM output frequency in the range of 10Hz-50Hz. You can either calculate the component values per the link above, or try an initial value of C1 between 0.1-1.0 uF to see if that will get you somewhere near the desired output frequency.

You can use a 2N2222 NPN transistor to drive the motor and use 1N4007's for D1, D2 & D3.

