

Table 2.5: Given a Shaft Speed of 4,980 RPM

Cycles per Revolution	Counts	Scaler	RPM
1	83	60	4,980
2	166	30	4,980
4	312	20	4,980
6	498	_____	4,980
360	_____	_____	_____

**Challenge #3: Monitor and Control Motor Speed.**

Varying the voltage applied to the small brushless motor varies its speed. The BASIC Stamp does not have a continuous analog output. The pulse-width modulation (PWM) command allows the BASIC Stamp to generate a controllable average analog voltage.

The syntax of PWM is shown below.

**PBASIC Command Quick Reference: PWM**

*PWM Pin, Duty, Cycles.*

- *Pin:* specifies the output pin which is driven.
- *Duty:* is a value between 0 and 255 that expresses the average analog output between 0 and 5 volts.
- *Cycles:* is a value between 0 and 255 that specifies the duration of the PWM signal in milliseconds.

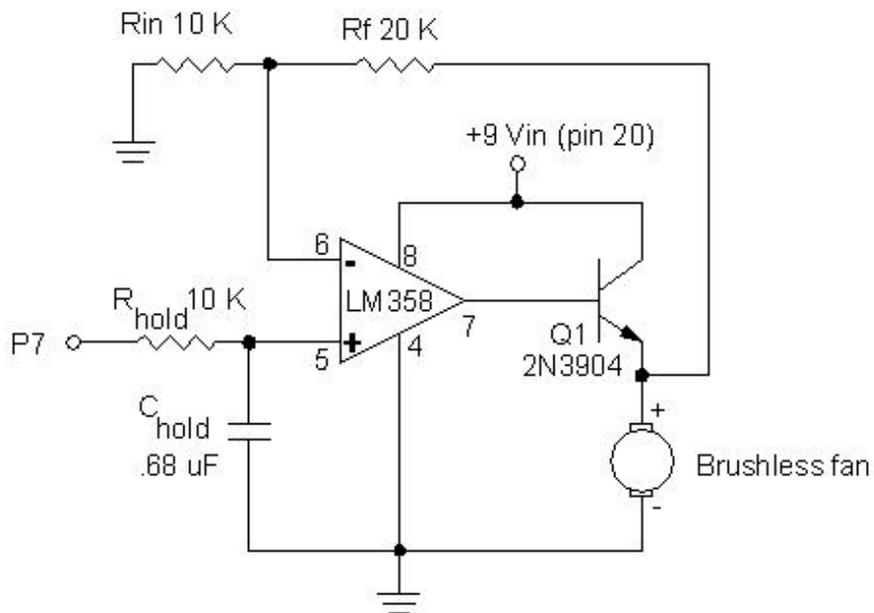
The command PWM 7,190,30 will produce at output pin 7 a series of pulses whose average high time is .75 (190/255) for a duration of 30 milliseconds. For this time, the average voltage at the pin is .75 \* 5 or 3.5 volts. To deliver this average voltage throughout the duration of a program loop, a sample and hold circuit must be developed. Figure 2.17 is a sample and hold circuit that will work well for the brushless fan. Capacitor C<sub>hold</sub> charges during the PWM command to the average voltage. At the end of the Cycle time, PWM changes the direction of the output pin to an input. This places the pin in a high impedance condition and the charge on the capacitor is held due to the high impedance of pin 7, the dielectric of the capacitor, and the input to the op amp. The op amp is set to a gain of 3 by the Rf/Rin network ( $A_v = R_f/R_{in} + 1$ ). The output of this amplifier drives transistor Q1. It provides current boost for the majority of the load current. Ideally, a charge could be held indefinitely. Small capacitor leakage currents and op amp bias currents result in slight variations in

## Experiment #2: Digital Input Signal Conditioning

voltage between PWM commands. Usually the bias currents dominate and result in a slight rise in voltage during this time.

Figure 2.17 is designed around the second op amp in your LM358 package. Carefully add this circuit to your tachometer circuit on the Board of Education. Note that the supply voltage to the op amp is changed to the 9 volt unregulated supply. This allows this circuit to have a voltage output that will approach 14 volts. Your tachometer op amp comparator will also have a higher output. Note: It is imperative that the zener diode in Figure 2.11 is in place to clamp the input to P3 at 5 Volts. Your BASIC Stamp is at risk if voltages exceed 5V.

**Figure 2.17: Brushless fan with sample and hold PWM drive.**



### Testing the Sample and Hold

The fan's electronics requires 4 to 5 volts to operate. The voltage applied to the fan will be approximately equal to:  $(5V * Duty/255)^3$ . According to this equation, voltages from 4 to 12 will be produced by Duty values of 70 to 210. Replace "Duty" with values from this range in the following program. Use a voltmeter and Table 2.6 to record the voltage applied to the fan for the values of "Duty" listed.

```
'Program 2.8 Sample and Hold Test
Loop:

PWM 7, (Duty), 60

PAUSE 500

GOTO Loop
```

Duty	Voltage	Duty	Voltage
60			160
80			180
100			200
120			220
140			254

Next, the tachometer Program 2.7 will be modified to include your PWM with the Sample and Hold circuit. Recall that this program reported motor RPM by accumulating pulse counts from the encoder wheel over a period of 1 second. Without Sample and Hold, the motor would come to a stop during this one-second off period. Program 2.9 includes these modifications in bold print. The program will operate the motor at Duty Cycle increments between 70 and 210. Each increment will be tested for approximately 5 seconds. StampPlot will report the steps in the status box and plot the RPM continually. The formula for calculating the expected voltage assumes that the circuit is following the transfer function discussed earlier. You may modify this formula to better fit your circuit based on the tests performed in Program 2.8.

Modify program 2.7 as indicated below (additions are shown in bold). Run the program and record the speed voltage characteristics in Table 2.6.

```
'Program 2.9 (Modified Program 2.7 Tachometer Test - with the StampPlot Interface)

' Initialize plotting interface parameters.
' (Can also be set or changed on the interface)
DEBUG "!AMAX 8000",CR          ' Full Scale RPM
DEBUG "!AMIN 0",CR           ' Minimum scaled RPM
DEBUG "!TMAX 150",CR         ' Maximum time axis
DEBUG "!TMIN 0",CR          ' Minimum time axis
DEBUG "!AMUL 1",CR           ' Analog scale multiplier
DEBUG "!PNTS 600",CR        ' Plot 600 data points
DEBUG "!PLOT ON",CR         ' Turn plotter on
DEBUG "!RSET",CR            ' Reset screen

Counts VAR word                ' Variable for results of count
```