**Introduction**

This circuit measures the speed of a motor. The motor is powered by a separate 0 - 16 v supply, with an ammeter in series for measuring the motor current. The motor turns a chopper wheel separating an infrared LED and a phototransistor. This provides the pulses needed to count revolutions per second. At an interval specified by a 555 timer, two decade counters are zeroed and then count pulses for one second. That is, the 555 timer should be high for exactly one second, during which time counting occurs, and then low for about 2 seconds so that the count can be read. The diode in the 555 timer circuit allows one to independently adjust the duration of "high" and "low" periods.
The circuit

The counters are either 74LS90’s or 74LS196’s. Either of these may be cleared (set to zero) asynchronously, that is, independent of the clocks. (Certain other counters, such as the 74LS162, are cleared synchronously: the “synchronous reset” input must be held low while the counters are cleared on a clock rising edge.)

You will need to fill in some of the details of this circuit. You should have some details clear in your mind, such as: Is the sign of the “clear” pulse correct? Does the counter clock on a positive-going or negative-going pulse? What will be the approximate resistances needed for the 555 timer? If necessary, you may modify the circuit, using inverters or other logic where appropriate. The resistor and capacitor values shown are only suggestions — modify them if necessary to make the circuit work properly.

Note: you will want the “clear” pulse from the 'LS122 to occur on the rising edge of the 555 timer output; i.e. at the beginning of the “count up” period. The ‘A’ inputs of the 'LS122’s seem to work fine for triggering on a falling edge, but the ‘B’ inputs, used for triggering on a rising edge, do not trigger reliably on the rising edge of a 555 timer. It could be that the rising edge is not sharp enough on a 555. (Remember, the 555 timer is not TTL or LS TTL technology.) You may need to route the 555 output through an inverter and use the ‘A’ input of the 'LS122.

A high level from the 555 allows the pulses from the Schmidt trigger to clock the counter through an AND gate. Adjust the 555 for a 1.0 second (high) pulse length, using an oscilloscope. (We have made the AND from two NAND’s since the NAND’s were already on the chip.) To sharpen up the signal from the phototransistor, we employ another 555 chip as a Schmidt trigger. (This has proven to work better than a 74LS14 Schmidt trigger in this particular application.) The counters are used in a ripple configuration. The 74LS47’s or 74LS347’s are used as in a previous lab.

If you use the 'LS196 counter, be sure the Load input and Clear input are held high, not just left open. You use these chips as ripple counters in a manner similar to 'LS90’s, except the pin labels are a little different. (Clock 1 and Clock 2 instead of Input A and Input B.) As with all low-power Schottky chips, despiking capacitors are a necessity.

The readout will be a double 7-segment LED in an 18-pin case. The pinout is given here. You will need 14 330-Ω or 220-Ω resistors.

You need two power supplies: one for the motor and one for your digital circuit. Keep them separate!
Measurements

With the motor running fairly slowly, use a dual-trace scope to simultaneously observe the phototransistor output and the output of the Schmidt trigger. Draw these signals in your notebook. Do you notice any “jitter” in the triggering? (That is, does it trigger at the same level of phototransistor signal every time?) Once your circuit is working, record some data on motor speed versus motor current. Record about 10 readings, for currents up to 250 mA. Do not exceed 250 mA, for obvious reasons.

The write-up

Draw your circuit in detail.

Describe the behavior of the LED readouts during operation of your circuit. Now, describe how you could modify the circuit, using a latch, so that there would be no “counting up” observed. The readout would continuously display the last count while the counters were counting up for the next reading. Draw the portion of the circuit you would modify. Specify chip numbers and show the hookup. Careful with timing here. (Note: you don’t have to actually build the circuit.)

Make a graph of current (x-axis) versus motor speed.

Additional notes

- The pinout diagram for the 74LS347 given in the National Semiconductor LS/S/TTL Logic Databook (page 2-348) is wrong! Here is the correct pinout:

![74LS347 Pinout Diagram]

- **DIP resistors.** Instead of using separate 330-Ω resistors, it is handy to use duel-inline-package (DIP) resistors. We have some, in yellow plastic, labeled “MDP1603 331G”. The resistors go straight across: pins 1-16, 2-15, …8-9.

- **Circuit drawings:** you should not usually draw “pictures” of the chips, pin-for-pin. Draw a box to represent the IC, with wires coming out as is convenient. Then label the connections with pin numbers. Pin numbers are usually outside the box, next to the wires, while functional descriptions (QA, LOAD, CLK, etc.) are inside the box, next to the pins.
• **Wiring:** the random wire or rat’s nest technique will lead to hair-pulling in this lab. Organize your IC’s logically and run wires in $x$ and $y$ directions on the prototype board; do not criss-cross them diagonally. Establish power and ground busses right away. I strongly suggest using only red wires for +5 volts.

• **Debugging.** The turn-it-on-and-wait-for-smoke approach will result in extra hours of lab time. You cannot just hook up the whole circuit and expect it to work. *First* design and debug your 555 oscillator, *then* make sure your 74LS122 is providing a pulse at the proper place, *then* make sure pulses are getting to the counter clocks when the 555 is high, etc. Nail down a section at a time.

Use the oscilloscope to make sure the signal from the tachometer is good. A pulse detector is often useful for finding narrow pulses that do not show up well on the 'scope. (For instance, narrow pulses from the 'LS122 one shot.) There is one of these on the prototyping units.

To debug the counters, you may want pulses getting through to the counters all the time (i.e. not just for one second at a time.) This can be done by simply removing the wire from pin 3 of the 555 oscillator, allowing the AND gate input to float high.

The bottom line: make sure each component is working individually before putting them all together.