DIGITAL VOLTMETER

OBJECTIVE

To combine analog and digital circuits to perform digital measurements of voltages in the 0 to 5 volt dc range.

PROCEDURE

1) Use a potentiometer in Fig. 1 to obtain a dc voltage that can be varied from 0 to 5 volts. There are many ways in which this voltage may be measured digitally. In this experiment, the first step is to change the dc voltage into a low frequency square wave, whose amplitude is approximately equal to the original voltage. *How well does the circuit in Fig. 1 do this?* For simplicity, use a 0-3 volt square wave output at 20 Hz from a function generator - however, note that a 555 multivibrator oscillator, as used later on in this experiment, would work equally well.

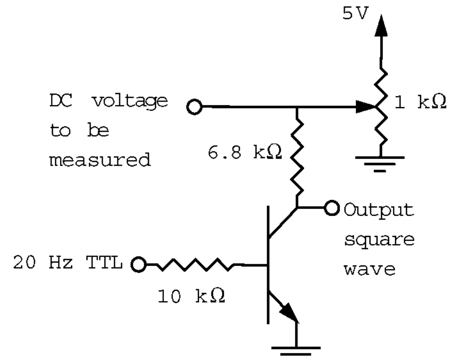

Figure 1

2) The next step is to generate pulses whose length is proportional to the amplitude of the square wave. Connect the circuit in Fig. 2 to the output of the circuit in Fig. 1. *What is the waveform on the base of the npn transistor in Fig. 2? How does it change with the amplitude of the square wave coming from Fig. 1?* Note that the bigger the amplitude of the square wave, the greater the negative voltage to which the base is driven, and hence the longer the time for the base to return to 0.7 volts. *How does the waveform on the collector of this transistor change with the input amplitude?*

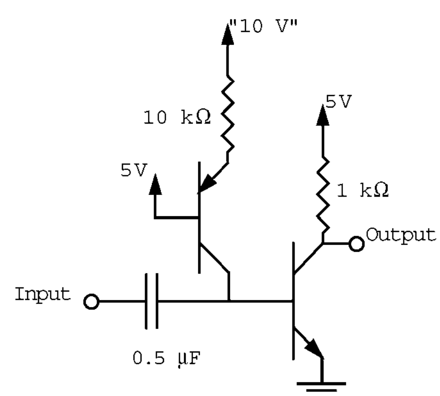

Figure 2

To make the length of the output pulse at the collector strictly proportional to the input amplitude, it is important for the voltage on the base to rise linearly. To do this, the 0.5 μF coupling capacitor is charged by a constant current source. This is obtained from the pnp transistor in Fig. 2. Note that you can also adjust the length of the output pulse by varying the "10 volt" supply voltage. This will be important later for scale calibration.

3) Connect the 555 timer chip as a free running oscillator, as shown in Fig. 3. Its operation is similar to the multivibrator oscillator in Experiment 19 - look at the waveform on pins 2 and 6 - but it's simpler to use the prewired chip. Note that the oscillation can be gated; that is, the oscillator will run only when pin 4 is high. Connect pin 4 to the output of Fig. 2. The 555 now produces trains of pulses. The number of pulses in each train is proportional to the amplitude of the square wave generated in Fig. 1, and hence to the amplitude of the input dc voltage. Check that with the capacitor and resistors you used there are approximately 50 pulses in each train for 5 volts dc on the input in Fig. 1.

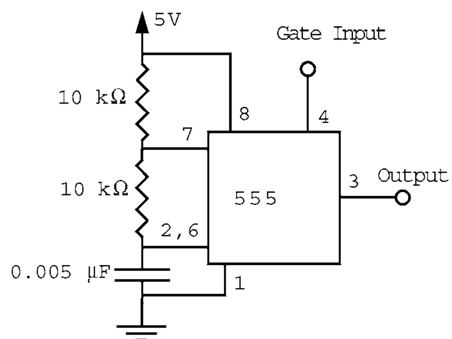

Figure 3

4) The pulses in each train are counted by the TTL level dual decade scaler chip shown in Fig. 4. There is only one input, from the 555 chip, and some internal connections. However, there are 8 outputs - four from each decade scaler. Connect these outputs to a digital display. (It's very important to locate the TTL chip as near as possible to the display. The 1kW series resistor between the 555 and the dual decade scaler is very desirable. Its purpose is to slow down the signal so that if it contains any nanosecond long spikes the scaler will not count them. However, the local **capacitor by-passing the power supply is essential** and its leads should be as short as possible.)

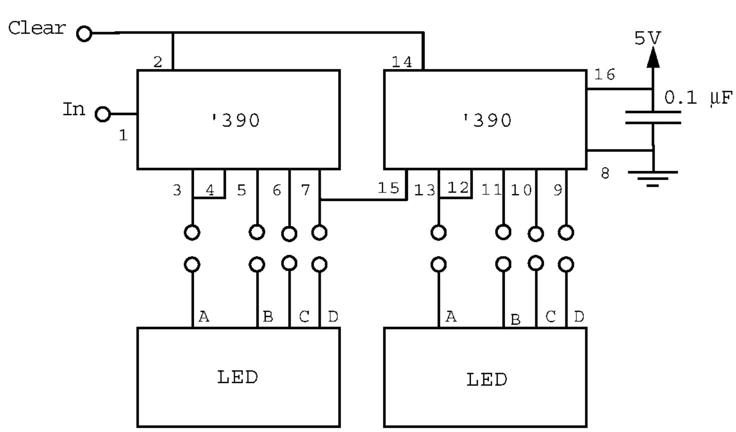

Figure 4

5) There is one remaining logical problem to be solved: every train of pulses adds additional counts and the number in the display keeps growing and becomes meaningless. What is required is to reset the decade scalers before each pulse train. This is done with the 0.1 µF capacitor to the clear inputs, as shown in Fig. 5. It’s very important that the 270 W resistor go to a ground point next to the TTL chip.

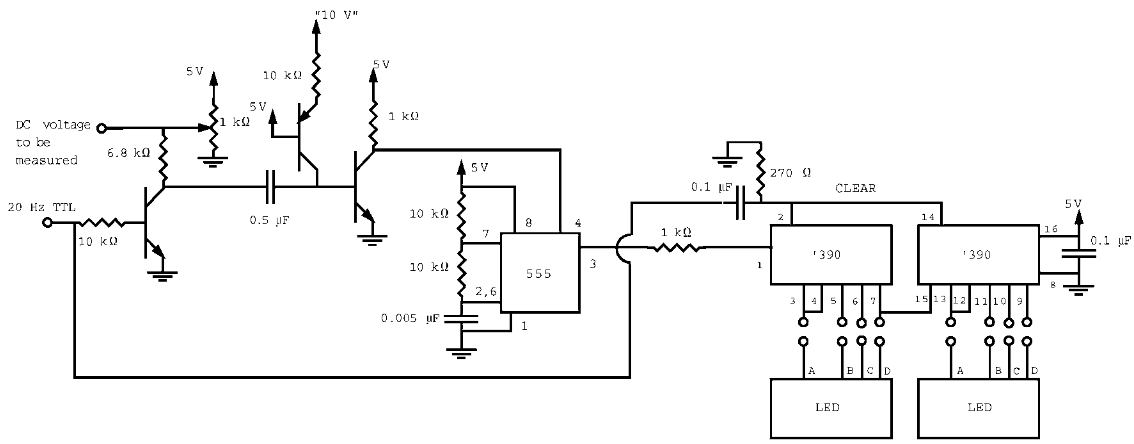

Figure 5

Set the voltage on the adjustable input to 5 volts , and adjust the "10 volt" supply so that the display reads 5.0. (Alternatively, an adjustable emitter resister could be used with a fixed supply.) Now make a plot of the displayed voltage as a function of the input voltage as measured on a "good" digital voltmeter. *How accurate is the device you built?*

PSPICE ASSIGNMENT

Use PSPICE to evaluate the performance of the transistor circuits in Figs. 1 and 2. Choose 4 or 5 equally spaced settings of the 1 kW potentiometer, and determine the amplitude of the square wave in Fig. 1 and the length of the output pulse in Fig. 2 for each setting. *How linear is the circuit? What is the major source of nonlinearity?* Redesign the circuit to improve the linearity, and sketch your proposed design. *How much better is it than the original design?*

QUESTIONS

1. *How would you measure 0-50 volts with this circuit?*
2. *How would you measure 0-1 volt with this circuit?*
3. *How would you measure an ac voltage?*
4. *What is the input impedance of your voltmeter? How would you make it "infinite"?*
5. *What does the display read while the pulses in each train are being counted? What is the effect of this?*