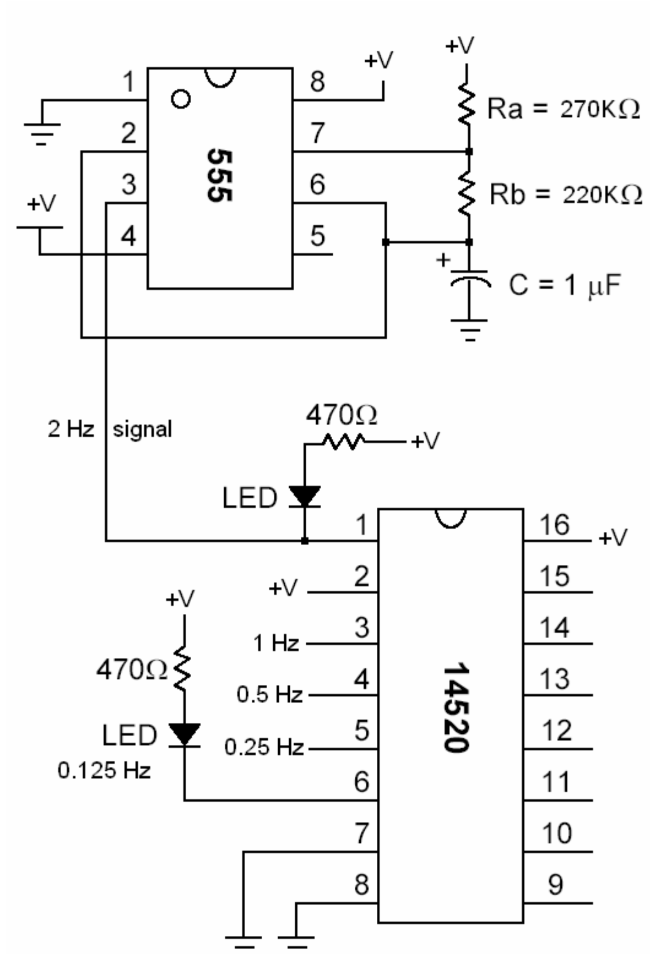
Lab 1 – Equipment Basics ELE202 FALL2007

Objectives

- Learn to assemble a simple circuit on a breadboard – this one has a clock signal (a periodic binary waveform) generated by a "555 timer" IC and a "frequency divider" IC to *slow down* the clock
- Learn to use some of the equipment on the lab bench: the digital meter to measure device characteristics and the oscilloscope to observe the clock signals to see time waveforms of typical digital signals

Procedure

1. Build and test the circuit as shown:



   - <u>With the power disconnected</u> (the battery disconnected or the power supply turned off), wire the 555 timer IC, its associated discrete components (2 resistors and 1 capacitor labeled Ra, Rb, and C, respectively), the 14520 counter IC, and the two light-emitting diodes (LEDs) with their dropping resistors (these 470Ω series resistors are needed so as to not destroy the LEDs!!). The points on the schematic marked +V correspond to positive DC power (5-9 volts), the pattern of 3 short horizontal lines (⏚) is the symbol for ground (the negative terminal of the battery), and the connecting lines represent wires. Additional information on the breadboard itself and the individual devices appears below. Also, a photo of a neatly wired circuit is shown. Dots on a pair of crossing wires (lines) indicates a connection; notice that this diagram doesn't have any. When 3 lines come together, it is a connection (for example, near pin 1 on the 14520). Normally you use wires to make all connections; however, it is sometimes convenient when connecting components such as resistors, capacitors, and LEDs to just use the component lead. For example, the 270KΩ resistor "Ra" can be connected directly from pin 7 of the 555 to power; there is no need for a wire.
   - Connect the power. Assuming that you've wired things correctly, you should see one LED blinking at about 2 Hz (twice per second) and the other LED blinking at 0.125 Hz (once every eight seconds). If the lights are not blinking, try ideas listed below in the "Troubleshooting" section. If those don't help, ask the lab assistant or instructor for help (or a classmate).
   - Demonstrate your blinking lights to your instructor.
2. Increase the clock speed and view the timing signals on the oscilloscope:
   - Replace the 555 timer's two resistors by 2.7KΩ and 2.2KΩ, respectively. Reduce the capacitor value to 0.1 µF; these changes will increase the clock frequency by a factor of 1000. If you've done things correctly the LEDs will appear dim as they are blinking faster than your eye can resolve. To "see" the signals, we use an oscilloscope to slow down repeating signals. "Dual trace" scopes (such as are available in this lab) can simultaneously display two signals of interest; particularly convenient in that you can see how they change relative to each other.

- Using the scope, observe the signals at pins 3 and 4 of the 14520 IC. You should be able to see two nicely synchronized waveforms at different clock speeds.
- Demonstrate your "timing diagrams" to your instructor.
- Other tasks for this part:
  1. Component values: your 555 timer circuit employs two resistors and one capacitor. On the lab summary sheet record the values for these components:
     a. based upon the markings on the device (or the bins you took them from)
     b. measured using the digital meter on the lab bench
  2. Oscillation frequency: The description of the 555 timer circuit below includes a formula for computing the frequency of oscillation. Since the counter provides a division in frequency by 16, what frequency square wave do you expect for the signal at pin 6? Show your result on the lab summary sheet:
     a. using the marked component values
     b. using the measured values
     c. as estimated from the oscilloscope – use the cursors
  3. Waveforms: Sketch on the lab summary sheet the following variables versus time – be sure to carefully label your axes (variable and units)
     a. the waveform appearing across the capacitor
     b. the dual trace feature of the oscilloscope allows you to view two waveforms simultaneously. Doing so in pairs, you can observe the signals at pins 3, 4, 5, and 6 of the 14520 device. Sketch all four on a single time axis (separate them vertically for clarity). Be sure to label the axes with variable, values, and units.
- Keep the circuit wired as you will use it again!!

What you've done

The 555 timer is a special IC device that can be configured to work in various ways; with the wiring as shown it generates a periodic rectangular waveform whose timing depends on the values of the two resistors and the capacitor (details appear below). For the values chosen, the result is a waveform that repeats twice per second (approximately). In other words, the 555 timer's output (at pin 3) changes between zero (ground) and one (the power supply voltage level) and back to zero two times each second. In digital systems we think of such simple repeating signals as clock signals and the 2 Hz value as the clock frequency. This "clock" signal is fed into one of the LEDs (turning it on and off) and also into the clock input of the 14520 counter IC. In this application (and we'll see counter devices again later) this counter IC acts like a frequency divider. Specifically, it reduces or divides the input clock frequency by the factors 2, 4, 8, and 16. Hence, the signals at the outputs of the counter themselves appear to be clock signals with frequencies of 1, 0.5, 0.25, and 0.125 Hz.

Troubleshooting

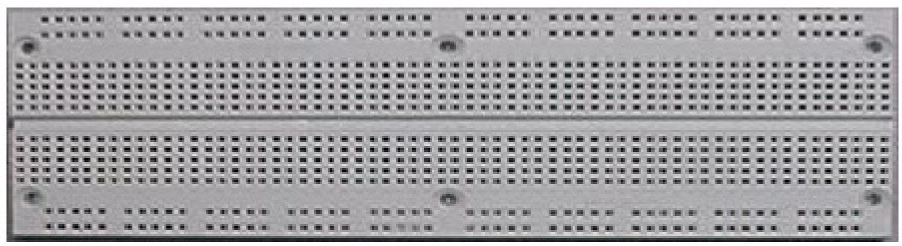
It's quite common that your circuit does not work correctly on the first try. Here are some simple ideas on what to check BEFORE you ask the TA or instructor for help:

1. Check that you have power and ground connected on each device. This can be tested using the multimeter on the bench (using the voltage setting).
2. Check that the ICs and LEDs are oriented properly (i.e. where is pin 1 on the IC? Which wire on the LED is the anode?)
3. Be sure that additional inputs to the ICs are set to the correct values (e.g. pins 2 and 7 on the 14520 must be set to specific values for the counter to operate).
4. Identify parts of the circuit that do work so as to isolate the problem. For example, is the 555 output on pin 3 alternating between high and low are the right speed? Even if the LED isn't working, you can check this with the oscilloscope. Are any of the counter's outputs changing?

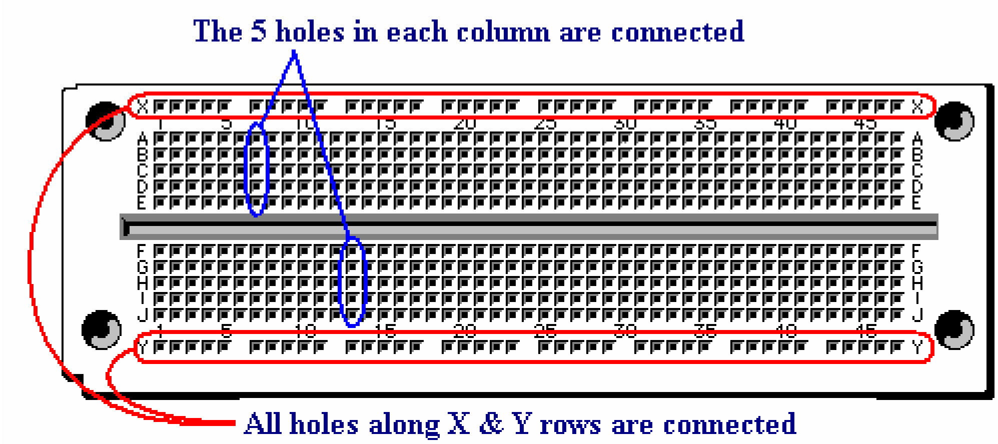
Additional Information
Lab 1 – Equipment Basics

Parts Details

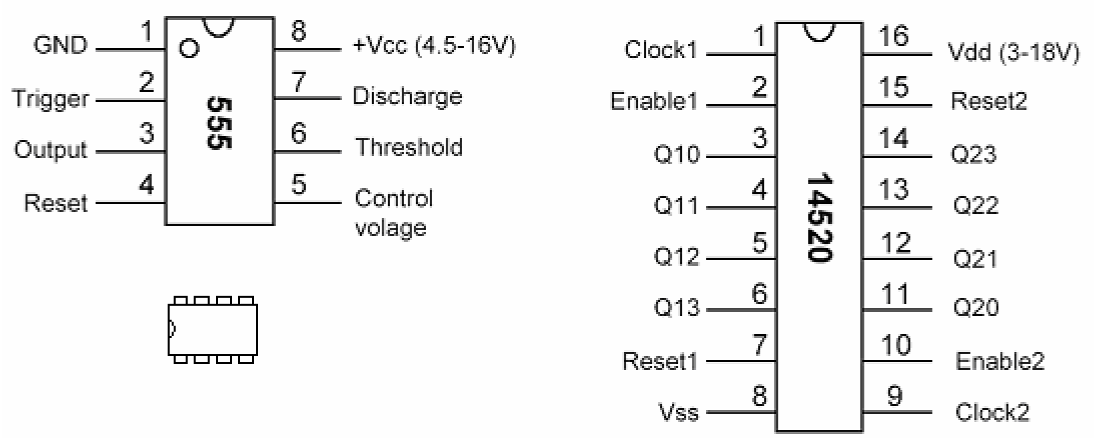
<u>Breadboard</u>: a plastic block with sets of holes, spaced 0.100" apart, on both sides of a central slot.



The holes are arranged in groups of 5 (vertically in this photo – see the diagram below) which are connected together electrically with an internal metal clip into which wires are inserted. If two components are to be connected in series, one side of each component would be inserted into the same metal strip. The longer rows of holes (along the top and bottom in this photo and diagram – there are both horizontal and vertical sets on your breadboard) are connected together and are commonly used for power and ground connections. On larger breadboards these longer lines may broken into portions (i.e. you need a jumper or small length of wire between sections). ICs are installed to straddle the central slot between sets of 5 holes (the horizontal trough in this photo and diagram); this allows for simple connection to each of the pins of the IC. Be careful when inserting the ICs to be sure that all pins actually go into the connectors (sometimes they bend underneath). Small resistors, LEDs, and other devices can also be connected to the breadboard. Additional connections between components are made using short lengths of wire. Note that we have a variety of colors of wire in the lab; try using different colors for different types of connections (e.g. red for power, black for ground, blue and yellow for signals).



<u>ICs</u> are usually shown as a rectangle with pins numbered in a counterclockwise direction starting at the top left. To mark the end containing pin 1, the plastic package sometimes shows a half circle, a dot at pin 1, or a cut off corner. In the diagram below for the 555 timer IC, two of these symbols are shown; the 14520 counter only shows the half circle. What appears on the actual device depends upon the convention of the manufacturer.



Notice that each IC has a power connection (marked Vcc or Vdd) and a ground connection GND (sometimes shown as Vss). For the devices that we will use in ELE202, a DC power supply of between 5 and 15 volts will be fine (e.g. a 9 volt battery as in your kit). The other pins on the ICs have various labels, which we shall learn describe the input and output operation of the device. Be careful when removing ICs from the breadboard so as to not break any of the pins. There is an IC puller on each bench (or you can use a screwdriver) to make this easier.

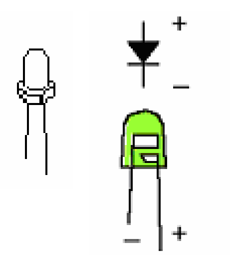
Note on CMOS: In ELE202 we will mostly use CMOS integrated circuit (IC) technologies. CMOS stands for complementary metal-oxide semiconductor and is a popular, low cost, low power technology for the manufacture of IC chips. Different ICs are identified by their product numbers; usually CMOS is coded as 14xxx where the three x's are replaced by decimal digits. For example, this exercise employs a 14520 chip, which is a dual binary counter IC (it has two 4-bit binary counters on the single chip). With CMOS devices we sometimes drop the leading 1 of the code and just call it 4xxx. For some of the later exercises you may want to consult logic data sheets for details on how to use the devices. These will be available in the lab.

555 timer: when wired as shown in the circuit above (pin 1 to ground, pin 2 connected to pin 6, pins 4 and 8 connected directly to power, a resistor Ra connecting power to pin 7, a resistor Rb connecting pin 6 to pin 7, and a capacitor C connected between pin 2 and ground) the timer runs as an oscillator (or clock) with frequency

$$f = \frac{1.44}{(Ra + 2Rb)C}$$

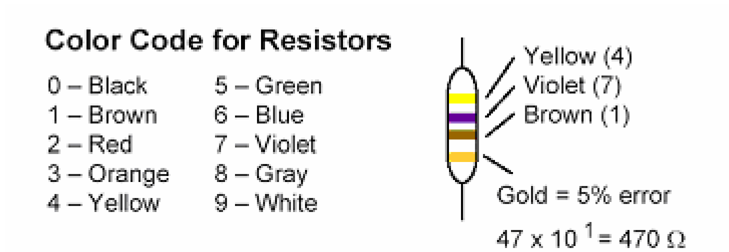
Notice that we can change the frequency by adjusting the resistors, or the capacitor, or both. Further, the relative values of Ra and Rb determine the *duty cycle*, that portion of time that the output at pin 3 is equal to a logical one.

LEDs emit light (red and green LEDs are usually in our lab) when a sufficient voltage drop appears across them *in the right direction*. Note that DC current flows from positive voltages to ground and that the LEDs light only when current is flowing in the direction of the arrow (anode to cathode). (In other words, sometimes your circuit will fail because you have the LEDs in backwards.) Some LEDs mark their anode and cathode with leads of different lengths; others have a flat spot on the package itself to mark the cathode. Note

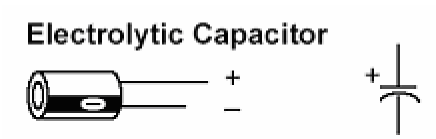


that it is imperative that you include a series resistor with an LED!!!!!!!!!!! This resistor is needed to limit the amount of DC current passing through the LED. Without it, too much current flows and destroys the device itself (unfortunately, this destruction is impossible to see on the outside of the LED; it just doesn't work anymore!)…….So, always, always, always use a series resistor.

Resistors are devices with a linear voltage/current relationship: the voltage across the device is equal to the product of the resistance value and the current (this relationship is called Ohm's Law and you'll learn about it in much more detail next semester in ELE212 and 215). Resistors are not directional, you can plug them in either way. While the bins in the back of the lab have the resistor value marked on each drawer, you can verify the value by reading the color code on the resistor (and this is important as resistors often get into the wrong bins, causing problems for the unwary student). The first two colors provide two decimal digits, the third color shows the power of 10 to multiply by, and the final color shows the precision or tolerance of the device. There is a chart on reading the color bands on the wall in the lab; below is an example. The unit of resistance is the ohm (symbol Ω, a capital omega); we use the prefix kilo for thousands (symbol KΩ) and mega for millions of ohms (symbol MΩ).



Capacitors are energy storage devices. Some are directional, some are not. If directional, there is usually a plus sign in the diagram and devices will have a plus or minus label on one wire (lead); if not, you can connect the device into your circuit either way. While resistors all seem to look alike, capacitors take a wide variety of shapes and sizes. Look in the bins in the back of the lab to acquaint yourself with these devices. The labeling of value also varies considerably between type (material used) and manufacturer. The unit of capacitance is the Farad (symbol F); as this is a large quantity, we typically use millionths of a Farad, called microfarads (symbol µF, the prefix is the Greek letter mu).



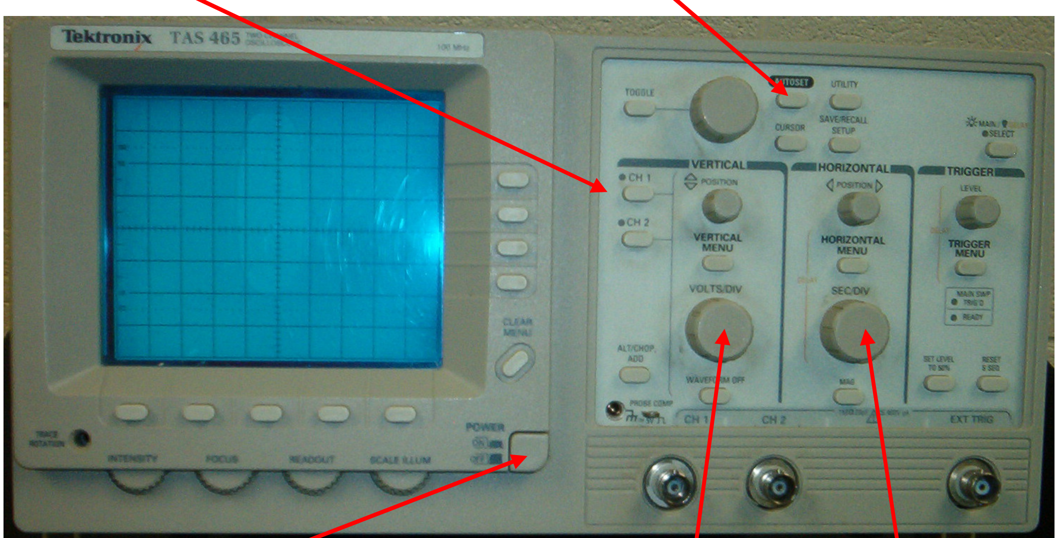
Bench Equipment (manuals describing their operation in detail are in the lab)

Power Supply: while running your circuit off of the 9-volt battery is quite convenient and portable, later labs will include devices that require more power than the battery can supply (and your battery will eventually die). To solve this, each lab bench has an adjustable DC power supply (shown below; for simplicity just use the 5 volt supply as marked). Be sure to connect both power and ground to your breadboard.

On/off button ground 5 V

Oscilloscopes allow us to see time plots of quickly varying, repeating in time voltage waveforms. By connecting the probe end to a wire in your circuit (and the ground connector, the alligator clip, on the probe to a circuit ground point!!), the oscilloscope plots a small piece of your waveform (time horizontal, voltage vertical) left to right on its screen (called a sweep) and then returns to the left side to draw another sweep. If the timing (synchronization) is well controlled (and modern scopes do a good job at this), a repeating waveform causes the same line to be drawn again and again on the screen, resulting in a constant pattern for our eyes. The scope has controls to set both the horizontal (time) and vertical scales (voltage); try changing them during part 2 of this lab as they can enhance the detail in what you observe. When you first connect the scope, press the "autoset" button to, hopefully, get a first good picture.

channel selectors autoset button probe



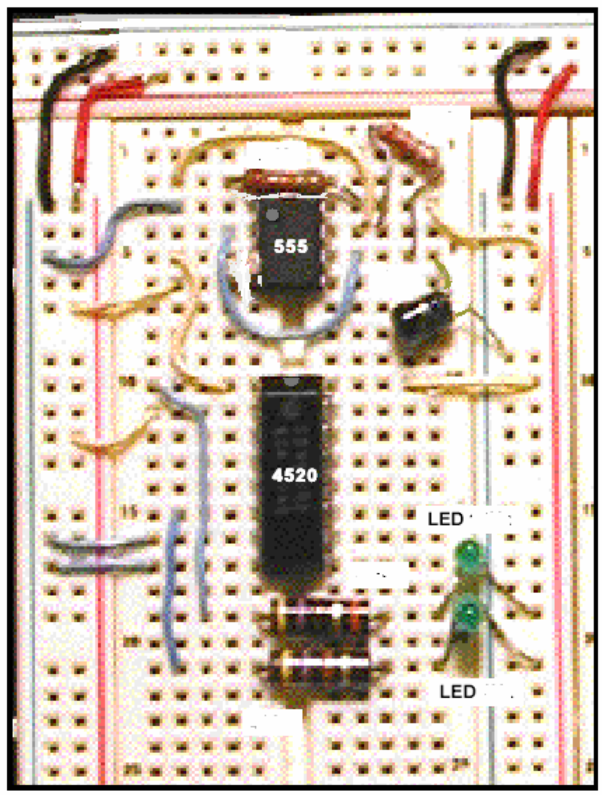
On/off vertical controls horizontal

The "scopes" in the 202 lab are all two channel or dual-trace scopes meaning that two voltage waveforms can be shown simultaneously; particularly convenient to observe the time relationships of different signals of interest. Our scopes also allow you to put cursors on the plot to accurately measure time and voltage differences.

Digital meter: this is a device that can measure voltages and currents, as well as values of resistors and capacitors.

Example of a well built circuit

Note the use of different colors of wire (e.g. black for ground, red for power, yellow and blue for signals), the logical placement of the devices (the 555's two resistors and one capacitor are next to it; the two LEDs and their resistors appear at the bottom), and the simple layout of the connecting wires (not a rat's nest!) that are easy to follow from connection to connection!



ELE202 Summary Report Form
Lab 1 – Equipment Basics

Lab day (circle one): Mon Tue Wed Thur

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NAME

Demonstrations:

Portion	Observed by	Date
Part 1: blinking LEDs		
Part 2: scope waveforms		

Component values for 555 chip during part 2:

Component	From markings (or bin)	As measured	Units
Resistor Ra			
Resistor Rb			
Capacitor C			

Oscillation characteristic of pin 6 of the 14520 during part 2:

Method	Frequency
Formula using marked values	
Formula using measured values	
Measured using cursor on scope	

Sketch of the capacitor waveform:

Sketches of the signals at pins 3, 4, 5, and 6 of the 14520:

Score: /8 pts.