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University of Utah
Electrical & Computer Engineering Department
ECE 1250 Lab 3
Electronic Speed Control and Pulse Width Modulation

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A. Stolp, 12/31/12
Rev.

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Objectives

1   Introduce the Oscilloscope and learn some uses.
2   Disconnect motor, connect light bulb
3   Make measurements of the Electronic Speed Control (ESC) output.
4   Determine frequency duty cycle, etc. Examine reverse
5   Look at actual waveforms with motor connected
6   Make a simple PWM with the signal generator and a transistor.

Parts to be supplied by the student:

● Breadboard and wires
● IRLZ34N N-channel enhancement-mode power MOSFET transistor

Check out from window:

● Remote-Control (R/C) car
● HP 54654A Self-Paced Training Kit for HP 54600-Series Oscilloscopes
   Check that it contains a battery and Training Guide
● 1157 Light bulb with leads

Also pick up 2 scope probes, a BNC-to-clip cable and 3 jumpers from the leads hanging in the lab.

Oscilloscope

In class we've moved beyond simple DC and have been talking about voltages and currents that are functions of time. These waveforms are AC or at least have an AC component. Simple multimeters are adequate to measure DC voltages and currents but can only give some average or effective (RMS) values for AC. Some will also measure frequency and/or peak values but to *see* the waveform as a function of time you need to use an oscilloscope. Today you will learn to make some basic measurements using the Agilent 54622D 'scope, but first, familiarize yourself with the scope and its control groups:

1.   The screen should be obvious.
2.   Right beneath the screen are 6 unlabeled keys. They are "softkeys" and their functions will be shown on the bottom of the screen and will depend on what state the scope is in.
3.   Under the softkeys is a floppy drive, flanked by the "intensity" (brightness) knob and the power key.
4.   The knobs and keys on the right side of the scope are grouped according to function. You will be using controls in the "Analog", "Horizontal", and"Trigger" areas as well as some of the others to the left of the Trigger area. You will not be using the "Digital" area.
5.   The inputs to the scope are the BNC connectors at the bottom of the Analog area.

Step by step:

Turn on the training board and oscilloscope

☐ Open the Training kit to reveal the Training board and verify that it has a battery. If not, ask for one from the window and insert it.

☐ Press the pushbutton near the battery holder next to the red LED. Push once to turn on. The LED will light.

☐ Turn on the oscilloscope with the power button under the screen (right side). The scope should "wake up" in its default state.

☐ Connect the scope probe to BNC input "1". Push it in and twist it clockwise to lock it in place.

☐ Find the "1x 10x" switch on the business-end of the probe and switch it to the 1x position.

☐ Connect, the probe ground (short clip lead) to a ground test point on the training signal board.

☐ Pull back on the sleeve covering the probe tip to reveal the hook at the end and then connect the probe tip to the number 1 test point on the board.

☐ Find and press the "Autoscale" key on the scope. You should now have a display of the test, point 1 waveform. If not review the instructions above and ask your TA for help if you still can't get a trace.

☐ Press the "1" key in the analog area to activate the channel 1 softkeys. Hit the 6th softkey and rotate the ↻ knob as needed to let the scope "know" that you're using a 1x probe. Unfortunately this is not automatic for the scope probe we use. You will have to do this every time you connect a new probe or change the 1x-10x switch position on the probe. If you don't, your vertical scope readings may be off by a factor of 10 or 100.

☐ Write a line or two in your notebook about how to turn on the scope, use the "Autoscale" and set the scope for the probe..

☐ From here on you will be referring to the Training Guide. You have just performed the "View a signal on the training signal board" in Chapter 1 of the guide. This guide assumes some basic knowledge of oscilloscope controls, functions and terms. I will try to fill you in on those before you do each section.

Set up the vertical

☐ Turn to page 2-4 in the Training Guide. The "Volts/Div" knob is the knob just above the "1" key in the Analog area. The "channel 1 position" knob is the knob just below the "1" key with the ▲and ▼ symbols next to it. The "status line" is the top line of text information on the screen. Follow the directions in the guide on pages 2-4 and 2-5.

☐ After you've finished this section, write a line or two in your notebook about what you learned. You should repeat that and all that sections that follow.

Set up the main time base

☐ Turn to page 2-6 in the Training Guide. The "Time/Div" knob is the big knob in the Horizontal area. (Time is the horizontal axis on the scope screen.) This section refers to "triggering" but doesn't explain this very important concept. The scope shows you volts as a function of time, but at what time? When should the trace start? When should it start a new trace? These are the questions answered by the triggering function of the scope. Triggering refers to starting a new trace. Before starting a new

sweep from the left side to the right side of the screen, the scope waits to be "triggered". If the input signal is periodic and the scope triggers on the same point of the waveform each time, then the beam will draw a similar part of the waveform each time and the trace will appear stable. Look at the figures below. The first shows a continuous periodic waveform.
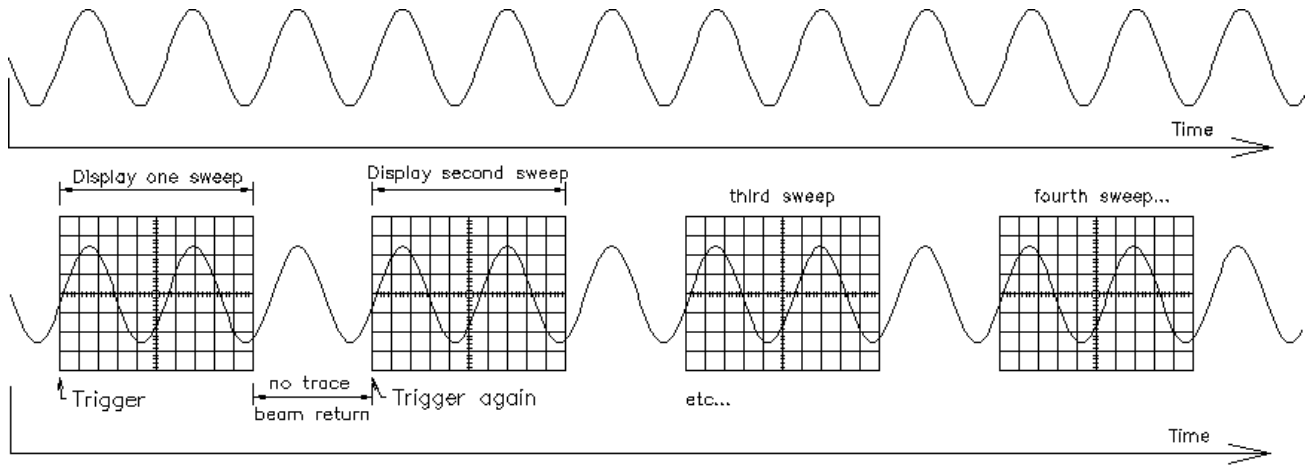
The second shows the pieces that will be seen on the scope screen. In this example the scope is triggering at 0V and a + slope. Why does it need to differentiate between + and - slope to get a stable trace? Explain triggering in you notebook in you own words.

OK, that's how an old-fashioned analog scope works– it quite literally waits for the correct trigger before starting a new trace. But this scope is digital. It's constantly sampling, digitizing and memorizing the input, which means that it can do something no analog scope can do, it can show what the waveform was *before* the trigger. The trigger event is not at the left side of the screen on a this scope. Instead it is either at the first vertical division (about 1 cm in from the left) or at the center of the screen, depending on how you set it.

Now that you understand triggering this section may make some sense. Follow the directions in the guide on pages 2-6 and 2-7.

Use the delayed time base
☐ Turn to page 2-8 in the Training Guide. The delayed time base allows you to look at a smaller portion of the main trace in greater detail. Do this section.

Set up the normal trigger
☐ Turn to page 2-9 in the Training Guide. In step 4, use the "Edge" key and try the different softkey options to see what they do.

Use time and voltage cursors
☐ Do the next two sections. Note that the "Cursors" key gives you X1 an X2 softkeys instead of t1 and t2. For voltage cursors, hit the "X Y" softkey and use Y1 and Y2 instead of V1 an V2.

Make voltage and time measurements
- ☐ Notice the status line at the top of the screen. It shows the volts per division setting for both channels. Use these values and the division lines on the scope screen to determine the peak-to-peak voltage of each waveform. The status line also shows the time per division setting. Use that to determine the period of either waveform and from that the frequency.
- ☐ Now turn to page 2-13 in the Training Guide. Follow the directions there to see how you can let the scope make these measurements for you. Note: your scope has just one "Quick Meas" key instead of individual "Voltage" and "Time " keys.

Using Trigger Holdoff
- ☐ Trigger holdoff isn't a separate knob on this scope. Use the "Mode/Coupling" key the softkeys and the ↻ knob as needed to get the trigger holdoff.
- ☐ Turning to page 2-15 and doing the next two sections will give you a much better idea of what triggering is all about and why it is needed to get stable trace.

Observe the phase differences between signals
- ☐ Turn to page 2-33 and do that section. Note: use the "Edge" key and the softkeys to change the trigger source.

- ☐ Make sure that you've made some comments in your notebook for each section.

Ok, that's enough for now, let's actually measure something with the scope. But first, turn off the training board and disconnect the scope probes from the board.

The R/C Car Electronic Speed Control (ESC)

Disconnect the motor from the speed control (just one lead is enough). DON'T just yank the wires fer cryn'-out-load! Try to grab the actual connector through the clear plastic covers or try to move the covers back out of the way first. Use the jumpers and possibly a wire slipped under the connecter cover to connect the light bulb in place of the motor. Connect the scope probe to the same leads– black to ground, red to probe tip. **MAKE SURE** the wires **CANNOT SHORT**.

Turn on the transmitter and car. Notice that the steering still works but that the throttle now just controls the light bulb brightness. Comment in your notebook. With the trigger pulled, hit "Autoscale" on the scope. Observe the waveform over a range of "speeds". What kind of waveform is this and how does it control the speed of the motor?

Measure the peak-to-peak voltage of the waveform and find its frequency.

Observe reverse as well. How can the pulses be negative if the car has only a single positive supply?. Think about how you would design the ESC. Consider looking at section 13.3 (p.811) in your textbook. Measure the peak-to-peak voltage of the waveform and find its frequency.

Disconnect the light bulb and reconnect the motor. Use the jumpers and possibly wire slipped under the connecter covers to connect the scope probe to the motor leads. **MAKE**

SURE the wires **CANNOT SHORT** even under vibration conditions. Lift the rear wheels of the car off the bench without touching and parts that can rotate with the drive motor. Pull the throttle trigger again and observe the waveform now. It is not so clean now because the DC motor is not as simple a load as the bulb. Also note that you can hear the motor's response to the pulse frequency, unlike the bulb. Comment in your notebook.
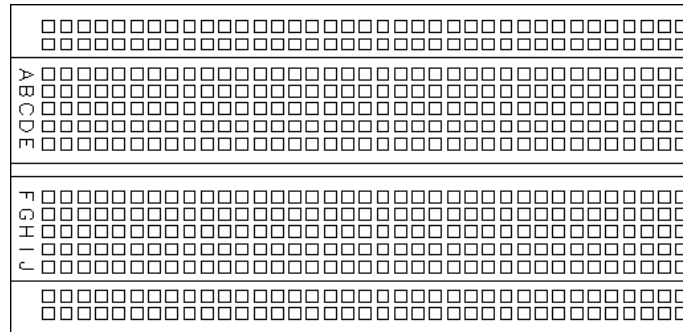
Make a simple PWM

Find the signal generator on your bench. Connect the BNC-to-clip lead to the SYNC output and connect the scope probe to these leads. Turn it on and observe the waveform with the scope. Hit the Square-wave, the Shift and the %Duty keys and then turn the knob to see the effect.
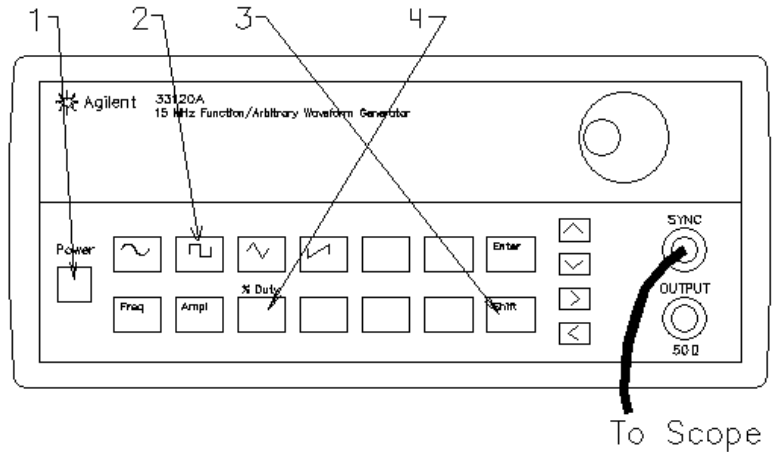

The breadboard wiring is shown at right. It's an easy way to make prototype and experimental circuits because you can just push wires and part leads into the holes and each holes is connected to at least 4 other holes that you can use to make connections to other wires and parts.
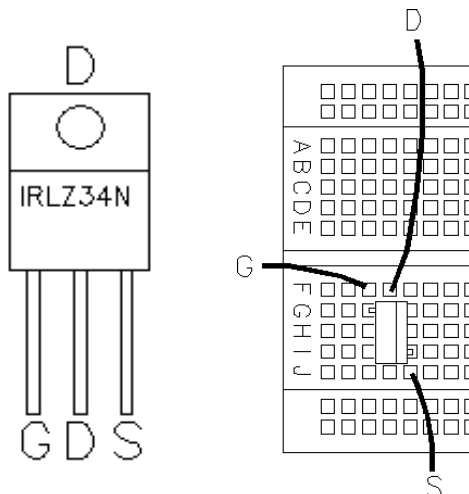

Breadboard

The next drawing shows one way to put the power MOSFET in t he breadboard. Because of the shpe of the leads, you have to bend one lead forward and one lead backward in order to put the into the board.
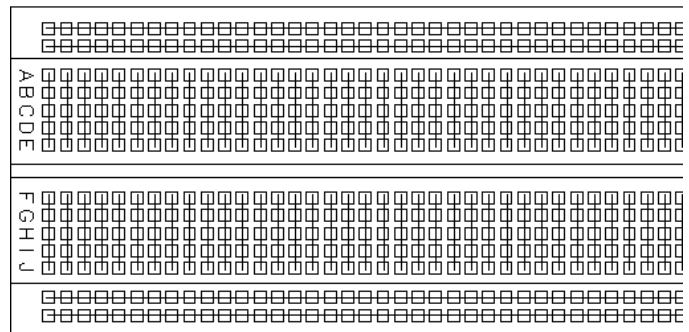
Breadboard with internal connections shown

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Now you are ready to make the circuit shown. The part with the leads D, G, and S leads is the power MOSFET. Vs is the Agilent power supply that you used in lab 1 to power the bulb and resistor and again in lab 2 to charge the battery. Set it to 12V. Leave the signal generator set as it was.

Hit Shift and %duty again on the signal generator and see how changing the duty cycle affects the bulb brightness. Use the scope to observe the waveform at the D lead of the MOSFET with ground hooked to the common ground of signal generator. Is there something unexpected or different from the PWM signal that you observed earlier? What is different and why is it different in this circuit?

Net lab you will make the controlling pulses on the breadboard some op amps, so you may want to leave the MOSFET in place for that lab.
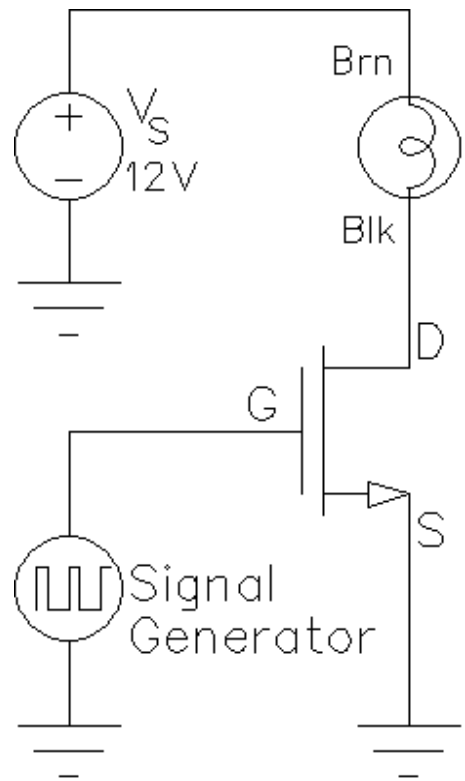
Conclude

Call your lab instructor over to check you off. Be prepared to discuss your measurements, calculations, and conclusions and to show off your notebook.

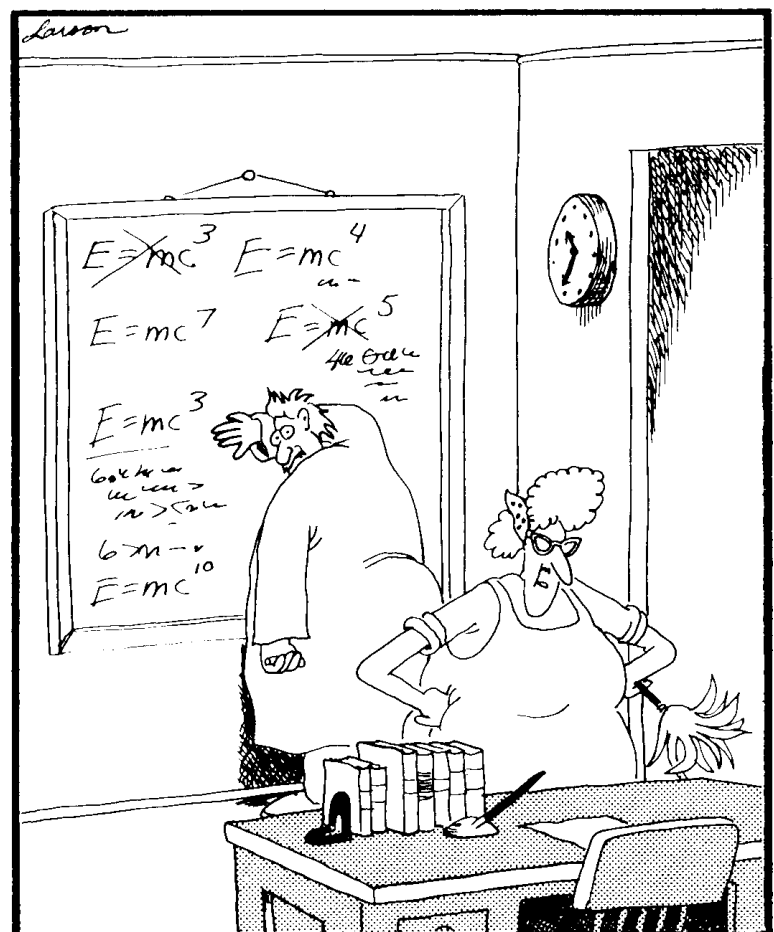Write a conclusion in your notebook like you've done before.

If you have any time left over, you may want to play with the car some more. Before leaving, make sure everything is turned off and return the stuff you checked out.

TURN OFF the **CAR**

TURN OFF the **TRANSMITTER**

TURN OFF the **TRAINER BOARD**

A small word of Thanks

"*Now* that desk looks better. Everything's squared away, yessir, squaaaaaared away."