

HARDWARE

PREREQUISITES: MODULE 02: INTRODUCTION.

OUTLINE OF MODULE 15:

What you will learn about in this Module:

Printed Circuit Boards (PCB), solderless breadboards, wire wrap
Standoffs & spacers
Enclosures, Power Entry, Cables, Connectors
Switches: types, nomenclature, functional characteristics (see LabVIEW)
Potentiometers: types, linear, log, audio taper, multi-turn, trimmer
Basics of circuit assembly, layout, Printed Circuit Board (PCB) design
Ordering PCBs over the Internet

What you will build in the lab:

You will use ExpressPCB to design a double-sided PCB that you could order over the Internet.

INTRODUCTION:

Hardware is often the most overlooked aspect of an electronic circuit system. It is also frequently the most expensive. In many cases, the selection and quality of the hardware will have an impact on the circuit performance and durability. In this module we will take a close look at electronics hardware, and as an added bonus we will take a close look at the real and sometimes ugly behavior of mechanical interfaces between circuits and humans, such as switches.

READINGS FROM HOROWITZ AND HILL (H&H): *ART OF ELECTRONICS*

1.32-1.34,

6.06 (heat sinks)

Browse through Chapter 12, but pay close attention to sections:

12.05 (PCB design)

12.06 (sockets, soldering, defluxing)

12.07

12.13 (unreliable components, cold switching)

ADDITIONAL READINGS & INTERNET RESEARCH:

Locate and read:

Analog Devices, Applications Note: AN-353 (all about printed circuit boards)

Maxim-IC, Applications Note: "Switch Bounce and other Dirty Little Secrets".

Maxim, App. Note: "Interfacing Switches and Relays to the Real World in Real Time".

Maxim, App. Note: "Prototyping with Surface Mount Devices".

Do some Internet research to find out what a "Power Entry Module" is.

Do some research to find out what a "Potentiometer" is and how they function.

SELF QUIZ

- 1: Describe what “switch bounce” is and why it occurs in mechanical switches.
- 2: What is “cold switching”? Is it a good or bad design practice? Why?
- 3: What is meant by “Surface Mount” in the context of electronic components?
- 4: What are the physical dimensions of the smallest surface mount resistor that you can buy (hint: check the DigiKey catalog)
- 5: Look up an LM324 Op-Amp IC on the National Semiconductor web page, and find the technical data sheet. If you include the wire “legs” (the pins sticking out of the IC), what area (in units of square inches or square millimeters) would a DIP package of this device occupy on a PCB? What area would a surface mount version of the same Op-Amp occupy? What % area do you save on the PCB by using surface mount versus the older through-hole (DIP) package?
- 6: What is a “ground plane”? Is it a good thing to have in your circuit? Why?
- 7: What is a “potentiometer”? One other way to ask this question is, what basic purpose would a potentiometer be used for in an electrical circuit? (hint: it is just a simple type of electronic component, only its value is *variable*)

PLEASE ANSWER THE ABOVE QUESTIONS AND E-MAIL TO THE INSTRUCTOR
“I have neither given nor received aid on this examination, nor have I concealed any violation of the Honor Code”

X _____

LABORATORY PROJECTS

- 1- Go to the web page for ExpressPCB and download their circuit prototyping software (it is available on the laboratory computer if you are registered for this course). The software is free. When you load it, you will get two applications:
 - ExpressSCH – software for drawing circuit schematics
 - ExpressPCB – software for designing printed circuit boards

You used ExpressSCH to draw schematics in Modules 1 & 2 (and any subsequent module that you have done). In this Module you will use ExpressPCB to actually design a printed circuit board that, if you *want* to, you could order via the Internet (it would cost you about \$60 to do so).

Read the directions on the ExpressPCB web page for PCB layout using their software. There are plenty of other ways to design printed circuit boards, but ExpressPCB is easy to learn, free to use (until you actually order physical boards over the Internet) and quite fast and effective once you practice with it a bit.

Exercise #1:

Look at the signal generator circuit in Module-02. Design a PCB for this circuit using standard DIP ICs (ones with legs that go through holes in the printed circuit board). Be sure to include a good “ground plane” in your circuit if at all possible.

Exercise #2:

Redesign the PCB in exercise #1, except this time use surface mount ICs instead.

Exercise #3:

Sometimes you can save a lot of money and space when designing your PCBs if you put several of them on a single board and later cut the board apart to make several identical boards. With this in mind, redesign the PCB layout that you had for Exercise #2, but make it as *small* as possible. See how many of these circuits you can fit onto one of the “mini boards” (hint: check the ExpressPCB web page to determine the required dimensions for their inexpensive “mini board” service).

Exercise #4:

The frequency of the signal generator in Module-02 is set by the first resistor-capacitor (RC) pair in the upper left corner of the diagram, near TP-2. Change your PCB design from Exercise #1 to include a potentiometer to adjust the frequency of the signal generator. Look in the DigiKey catalog to find a small, 10-turn (with a small adjustment screw on top) PCB mount (not a “panel mount”) potentiometer, then use the appropriate hole pattern in your PCB to accommodate the potentiometer in your circuit.

Exercise #5:

Potentiometers are actually quite versatile components that are used for several different purposes within a circuit. They are often used to tune or adjust a circuit, by providing either a variable voltage or a variable resistance. Potentiometers typically have 3 terminals. Two of these terminals are at the ends of a “fixed” resistance element, and the third terminal slides along between these two ends. The moving terminal is often called the “wiper”. The wiper “divides” the fixed resistive element into two parts that add up to the fixed total, so a potentiometer is actually like two variable resistors in series that always add up to the same total resistance. The terminals are often numbered “1”, “2”, and “3”, where 1 and 3 are the fixed terminals, and 2 is the wiper. When you turn the adjustment knob (or screw) on a potentiometer clockwise, the wiper (terminal 2) moves toward terminal 3. Thus, for clockwise turning, the resistance between terminals 1 and 2 increases, while the resistance between terminals 2 and 3 decreases. Now, based on this description of potentiometers, you can use them to design several different circuit components:

- 1- A variable resistance that *increases* when you turn the adjustment clockwise.
- 2- A variable resistance that *decreases* when you turn the adjustment clockwise.
- 3- A voltage divider that puts out an *increasing* voltage when turned clockwise.
- 4- A voltage divider that puts out a *decreasing* voltage when turned clockwise.

Why does it matter if the potentiometer specifically increases or decreases the resistance or voltage when you turn it clockwise? Well, this turns out to be an important issue in the area of *human-machine interfaces*. People normally expect things to happen a certain way when they turn a control knob. For example, think about adjusting the volume on your stereo (assuming it is a knob). When you turn it clockwise, do you expect the volume to go up or down? Answer: *everyone* expects the volume to go up when they turn the knob clockwise. So, here is the tricky part: in your circuit you usually use a potentiometer to tune something, such as an amplifier gain or an output frequency. The thing that you are tuning may behave either proportionately (positive) or inversely to the resistance or voltage change you are making. So, using a potentiometer properly, you can always make the adjustment intuitive for the user:

- Clockwise = more gain
- Clockwise = more voltage
- Clockwise = greater current flow
- Clockwise = higher frequency
- Generally, clockwise = increased “something”

One more note: it is good practice to never leave one of the 3 terminals of a potentiometer disconnected, even if you think it is OK to do so. For example, you could make a variable resistor using only two of the three terminals (the wiper and either one of the two fixed terminals), but you should always connect the wiper to the “unused” terminal. There is a good reason for this. When turning a potentiometer, there is a moving electrical contact between the wiper and the fixed resistive element. The wiper actually skids along the surface of the resistor, briefly bouncing away and losing contact every time it encounters a microscopic imperfection on the

surface, so the resistance transiently bounces up to “infinity”, thus creating a lot of noise every time you adjust a potentiometer. If you connect the wiper to the unused terminal of the variable resistor, you limit the maximum resistance to the fixed value of the potentiometer (for example, 10 K Ω), instead of allowing it to go to “infinity”. (Note for those who are detail oriented: the resistance of course never goes to *infinity*...it is just a very high resistance due to the air gap between the wiper and the resistive element during each bounce...but you get the point).

Exercise:

Use ExpressSCH to draw a potentiometer in each of these 4 configurations:

- 1- A variable resistance that *increases* when you turn the adjustment clockwise.
- 2- A variable resistance that *decreases* when you turn the adjustment clockwise.
- 3- A voltage divider that puts out an *increasing* voltage when turned clockwise.
- 4- A voltage divider that puts out a *decreasing* voltage when turned clockwise.

For the voltage dividers, assume you are just dividing a +5V DC supply voltage. Be sure to put in numbers for each terminal of the potentiometer (1, 2, and 3).

Does this information change how you would use the potentiometer in Exercise #4 (above) to tune your circuit? (Hint: as the resistance increases in the circuit, the frequency drops)

Extra lab exercise (optional):

Set up a mechanical switch and a potentiometer with a voltage supply and an o-scope to visualize:

- switch bounce (with and without debouncing).
- potentiometer noise during adjustment.

Devise methods to reduce these sources of noise, and discuss them with the instructor. Can you find suggestions about how to do this on the Internet?

FEEDBACK

Was this Module useful and informative?

Is there a topic that should get more or better coverage?

In what way can this Module be improved:

Content: _____

Depth of Coverage: _____

Style: _____

Any additional comments that will help us to improve this course:

If you prefer, you may e-mail comments directly to Bob Dennis: yoda@umich.edu