MODULE 14

DISCRETE COMPONENTS

PREREQUISITES: MODULE 02: INTRODUCTION. OTHER MODULES, SUCH AS THOSE COVERING OP-AMPS AND DIGITAL CIRCUITS WOULD ALSO BE USEFUL.

OUTLINE OF MODULE 14:

<u>What you will learn about in this Module:</u>

- Transistors
- Zener Diodes
- Real (non-ideal) behavior of capacitors, resistors, diodes, transistors, switches (bounce), pots (drop out) etc…
- Reverse current circuitry protection
- Optical isolation

<u>What you will build in the lab:</u>

- A switch debouncer
- A reverse current circuit protector
- Several circuits that require the use of discrete components, such as an RC oscillator

INTRODUCTION:

What do we mean by “discrete”? Well, before integrated circuits, everything was “discrete” (i.e. made up of separate, discrete components). The purpose of integration of circuits is to literally integrate many of these discrete components onto one tiny wafer, and put it inside an indestructible epoxy casket, called an Integrated Circuit. Integrated circuits are out together in such a way as to provide useful electronic functions and require a minimum of external components and electrical connections. Nonetheless, most circuits do require a number of external discrete components. These components can serve many different functions: to tune or control an IC, to filter or modify signals, or to change the output characteristics of an IC-based circuit. This Module was intentionally placed deep into the course because, with modern ICs, it is possible to build many interesting and useful circuits without too much concern about or knowledge of the details about the discrete components. By placing this information later in the course, it is hoped that you can really appreciate the importance of the details about all of these components. In particular, we will deal with discrete transistors.

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

1.06, 1.24, 1.30-1.31

Browse through all of Chapter 2, but pay close attention to sections:

- Introduction, 2.01-2.03, 2.09, 2.15-2.16, 2.20
- Appendix G (transistor saturation)

Browse through all of Chapter 3, but pay close attention to sections:

- Introduction, 3.01-3.06, 3.11-3.12

The section on “Dielectric Absorption” in capacitors, page 220.

MODULE 14

ADDITIONAL READINGS & INTERNET RESEARCH:

Go to the Texas Instruments web page and find the following two Application Reports: (you may have to search around a bit)

SLOA027: Understanding Basic Analog – Passive Devices
SLOA026A: Understanding Basic Analog – Active Devices

Then go to the Analog Devices web page and find:

AN-348: Avoiding Passive-Component Pitfalls
AN-280: Mixed Signal Circuit Techniques

Then go to the Maxim-IC web page (www.maxim-ic.com) and read:
App Note: Reverse-Current Circuitry Protection

Read these brief Reports, they are very informative. If you know everything that is in these, you will seem like some sort of genius to anyone who has a circuit that is acting strangely, because you will be able to suggest dozens of things to check out. You will also save yourself hundreds of hours of frustration by investing about 60 minutes of time reading.

Then, do an internet search to find out about optical isolation. Find a brief essay or web page describing it, what it is, and what is it good for.

MichiganEngineering

MODULE 14

SELF QUIZ

1: What is optical isolation, and when would you use it?

2: Using ExpressSCH, design a simple circuit to protect a digital IC from reverse power application. (Assume that a +5VDC power supply might, under some circumstances, be attached in the incorrect polarity).

3: Using ExpressSCH, design a circuit using an LM324 op-amp and an external transistor to switch a 12 Volt, 1 Amp solenoid valve on and off. Assume that the signal coming into the Op-Amp has been processed by some other means, and that the op-amp acts only as a voltage buffer (with gain = 1).

4: Find a circuit that will allow you to amplify the signal from a photodiode (NOT a phototransistor!). You should be able to find such a circuit in H&H or somewhere on the Internet. Draw this circuit using, you guessed it, ExpressSCH and an LF444 op-amp. Is the circuit that you found a trans-impedance or a trans-conductance amplifier (look back at the original op-amp modules or look in H&H to refresh your memory as to the definitions of these terms).

5: Look in H&H and on the Internet to find Ideas for a switch debouncer circuit that uses discrete components (resistors and capacitors). These circuits will also often use logic gates, especially logic gates with Schmidt trigger inputs. Use ExpressSCH to design at least 2 different switch debouncer circuits.

6: Make a small table showing several types of resistors and capacitors, and the available range of values (maximum & minimum available) and tolerances (± %) and (for resistors) wattage rating. Your table should include carbon film resistors, wirewound resistors, tantalum capacitors, aluminum electrolytic capacitors, ceramic chip capacitors, and several other common types of both resistors and capacitors. Also note if these components are available as "surface mount" (i.e., they have no wires attached, you solder them directly to the PCB traces…they are *very* small). An easy way to do this is to browse through a catalog online, such as digikey.com, to see what is available. Keep this list for later use.

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____

MODULE 14

LABORATORY PROJECTS

1- Build each of the circuits that you designed for the Self Quiz. You may need to scrounge for parts such as a phototransistor (the instructor keeps a supply hidden in his lab, but they are cheap and easy to find anyway). Measure the performance and modify the circuit and diagram as necessary to make the circuit work. Look at how a switch works on the o-scope by switching +5V across a 10K resistor (measure the voltage across the resistor using the o-scope). Do this both with and without the switch debouncer circuits in place. Look at a very high speed (~1µs/div).

2- Go back to Module 02 and look at the schematic for the signal generator. You can build a square wave oscillator using this basic circuit. Draw a diagram using ExpressSCH that uses two inverter gates with hysteresis (use an MC14106B Hex Schmidt Trigger IC chip, or any other CMOS hex Schmidt trigger Inverter chip in your design). Design the circuit to only use two inverters, the ones which lie between TP2 and TP7 on the circuit diagram in Module 02. You can leave out the other inverters for this exercise. Now, physically build the square wave oscillator using different resistors and capacitors for R1 and C1 in the circuit (the 10K resistor and the 0.1 µF capacitor. You use different combinations of R and C to tune the circuit to different frequencies. This is extremely common in electronics. You can start by guessing that the frequency of the oscillator will be approximately linear, and will follow the relationship:

$$F = 1/(kRC)$$

where F is frequency in Hz, R is resistance in Ohms, C is capacitance in Farads, and k is the proportionality constant. You will notice that the DVM (digital volt meter) that you used in Module 02 also has a setting for measuring frequency up to about 40 kHz. Start by assuming that the value for k ~ 1.0, then try several pairs of resistors and capacitors that should tune the circuit to 20 kHz (or about half of the maximum value that your DVM can measure). Check using the oscilloscope that the circuit is actually oscillating first, then measure the frequency using the DVM at TP7. Measure the resistance and capacitance of each component before you put it into the circuit. Then make a table:
Measured R; Measured C; Measured Frequency (Hz); Calculated "k"

Fill in this table for at least 5 different RC pairs. Is k more or less consistent? Use the smallest capacitor that you can to make this circuit oscillate at about 20 kHz. This means you will be using a correspondingly large resistor. Now, while you are watching the frequency readout on the DVM, try several things & record the results:

a) Touch your finger to the top of the small capacitor
b) Touch your finger to the back of the RC circuit, *touching* the R & C joints.
c) Heat the components up slightly (breath on them for a while).

Repeat this experiment for a different pair of R & C, but use a smaller R and larger C, each by a factor of at least 100. Is the circuit as sensitive? Does this make sense?

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