EECS 371 Lab #13

µP-Based Heating Pad Control

You are to design and build a control for a heating pad. Your circuit will have a pushbutton, a TRIAC output for the heating element, a single-digit LED display for the temperature setting ("1-9"), and a "timeout" mode that shuts off the heating pad after a predetermined length of time. The control will operate open-loop. Upon timeout, a piezo disc will chirp three times.

Note:
1. In place of the resistive heating element you will drive a 120V incandescent lamp; flicker is acceptable.
2. A "real" heating pad would have a timeout period of an hour or two; for purposes of this lab your timeout mode will be about 30 seconds.
3. The input will be 120VAC +/- 15%.
4. To minimize EMI, you will use burst, integer-cycle control to guarantee symmetrical AC current drain from the line. You may assume that a real heating pad would have a time constant of many seconds. See below.

Operation:
Upon power-up, the heating element and display will be OFF. Pressing and holding the pushbutton for one second turns the control ON and the display reads "0". The operator then presses the pushbutton repeatedly (short duration) to set the desired temperature (scrolls 1-9-1,etc.). At any time the operator may turn the appliance OFF by pressing and holding the pushbutton for one second. Upon turning the appliance OFF, or upon a timeout shut- down, the setpoint will be reset to zero.

IMPORTANT

This circuit will be operating at potentially lethal voltages. In addition, energy contained in this circuit may cause components to explode with dangerous consequences. The following safety procedures are to be observed at all times:

►Under no circumstances is your circuit to be operated without isolation.

►Remember that a standard "Variac" is an *autotransformer* and does not provide isolation. We have both isolated and non-isolated variable transformers in the lab.

►The large TENMA Variable Isolated AC Power Supplies incorporate Variacs AND isolation transformers. One of these TENMA supplies is ALWAYS to be used when operating your circuit, even during demonstrations. With, **and only with**, an isolated supply may you safely connect the ground terminal of your oscilloscope, or the common terminal of other instruments, to any point in your circuit.

► Connect the programming cable to your circuit ONLY when operating the low-voltage portion of your circuit on a bench supply!!!!! (As discussed below, this lab is written for those who are using a Picaxe)

► Before applying the AC line, you MUST disconnect the programming cable and any test equipment.

COMMENTS:1. Perform as many tests as possible with your circuit operating on a low-voltage bench supply. It is likely that your circuit can be completely tested without direct connection to the 120V AC line. For example, the microprocessor section can be initially driven from a bench supply, and the triac section can be tested with the output of the "13V" transformer first used in Lab #4. In this case you would use a #194 12V incandescent lamp instead of the 120V lamp. When operating on this low-voltage AC source, the reactance of your line-dropping capacitor will be far too small. You could substitute a huge (non-polarized, non-electrolytic) capacitor in its place, but it will be much more practical to simply substitute a suitable resistor. You may also have to adjust values of your zero- cross sensing circuit.
As mentioned under "safety" above, when your circuit is deemed to be complete and ready for 120VAC operation, <u>you must only operate on an isolated AC supply such as the Tenma.</u> Remember to remove the temporary components and return the circuit to its final design.

2. Before application of the AC line, you are to prepare a clean, complete schematic which is to be approved **<u>and initialed or approved via email</u>** by the Lecturer, TA, or staff member. If available, a staff member or TA should inspect your set- up before applying the AC line.

3**. <u>YOU ARE TO USE SAFETY GLASSES WHEN OPERATING ON 120VAC;</u>** these are available in the lab.

4. When constructing your breadboard, locate the pushbutton so it can be easily accessed without touching any other components. You may prefer to depress it with a pencil or plastic pen; do not use your nose.

4. <u>You may NOT use an opto-triac</u>. Also, you cannot use a step-down power supply transformer to drive your circuitry. Think about an off-line power supply that uses an impedance to drop the line voltage. This type of circuit has limited output current, so you will have to drive the triac in a clever manner. Think *quadrants*.

5. I strongly suggest you test the off-line power supply section of your circuit independently, <u>before</u> you wire it to your microprocessor and other components. Estimate the current that the rest of your circuit will draw, and use a dummy load resistor to see if your off-line power supply will provide the necessary current (at low line, of course). Use the Tenma *isolated* (required) variable transformer. Pay strict attention to the voltage ratings of capacitors. As discussed above, **if and only if** the supply is isolated may you connect the ground of your oscilloscope to any point in the circuit.

6. Remember; remove the programming cable before you power your control on the AC line. <u>Always use a separate low-voltage DC bench supply to power the uP circuit when loading the program. After the program is loaded, remove the programming cable and then energize your circuit from the isolated AC line</u>. As an option, you may program the uP in a separate breadboard and then transfer it to your circuit.

7. You may use any microprocessor you wish. This lab is written for those who use the Pickaxe, but you can use a generic PIC, Arduino, or any processor you have available. The only requirement is that you CANNOT include the programming or development board in your circuit; just the microprocessor IC. For safety and to protect the lab equipment, if a development board is used, you MUST program the microprocessor IC then remove it from the programming board and plug it into your circuit. In the case of the Pickaxe with its on-board compiler, you can program the processor when it is installed in your circuit, but you MUST completely disconnect the programming cable before powering up your circuit.

When designing your off-line power supply, remember that you must have the TRIAC MT1 connected to one side of the line (neutral is generally best). It follows, of course, that the circuitry that drives the TRIAC gate will also have to be referenced to the same side of the line. Give some thought to the circuit that utilizes the smallest, least expensive components.

8. Please submit a Saturday Schematic. Remember that your finals schematic, before powering on the AC line, must be approved in writing by the instructor, TA, or lab staff member.

9. GRADING will be based on circuit performance as well as the estimated component cost of your circuit. The following cost of components is to be used to determine circuit cost (estimates are for production quantities):

The dropping capacitor is big and expensive, so your design should employ clever techniques to minimize its size. Try to keep its value below 2 uFd or so. Be prepared to discuss techniques for reducing overall power drain and minimizing the capacitor value.

Resistor, 1/4 W	$0.01 each	
Resistor, 1/2 W	.02 each	
Resistor, 1W	.05 each	
Resistor, 2W	.10 each	
Capacitor. Ceramic, ≤ 0.22 uFd, ≤ 16V (max allowed)	.03 each	
Capacitor, electrolytic, < 47 uFd and ≤ 16VDC	.06 each	
Capacitor, electrolytic, >47 uFd and ≤ 16VDC	.09 each	
Capacitor, electrolytic, <47 uFd and > 16VDC	.13 each	
Capacitor, electrolytic, >47 uFd and > 16VDC	.25 each	
Capacitor, film, 250 VDC	.50 per uFd.	
Heat sink, if needed	$1.00 / (^{0}C/W)	Example: A 2 ^{0}C/W sink would cost .50.
Microprocessor	.60	
Op-Amp or comparator	.20/pkg/4	
14538 one-shot	.25	
555 or any CMOS gate	.15/pkg	
Diode, transistor, or Zener	.05	
LED 7-Segment display:	.40.	

You should drive the LED display at about 5 mA per segment.

Beeper	.30	You will be provided with the beeper; style unknown.

TRIAC: Use Digikey, Arrow Electronics, or Mouser to select a TRIAC; Pay attention to triggering requirements. For production pricing, use ½ the single piece price. Have the data sheet available for recitation. For design purposes, assume that a "real" heating pad would draw 60W. The schematic that you submit for recitation should incorporate this TRIAC as well as the appropriate related components.

However, for purposes of constructing and testing your circuit for this lab, use any appropriate TRIAC from Lab stock and modify your circuit to use this TRIAC.

For components not listed, use distributor pricing at ½ the single- piece price.

For recitation, have the following available:

1. Clean, accurate schematic and code listing
2. TRIAC data sheet
3. Priced BOM with total component cost.
4. Your circuit, ready to demonstrate.

BURST INTEGER VOLTAGE CONTROL: