The
101 PROJECT

An electronics-based design project for Junior or Foundation Electronics Courses

Anyone can make electronics seem hard. This activity makes circuit design simple and fun.

This activity was originally developed by Paul Wytenbroek and Dan Frewing while teaching in the Vancouver school district. It is an example of what can be done with junior high school students who have had no previous exposure to the theory or practical application of electronic circuits. The pragmatic approach is excellent for young students, as is evidenced by the wide-spread adoption of this activity in many schools.

101 PROJECT - The Approach

The 101 Project is an approach which allows for the controlled progression from **problem** to **“electronic” solution.** Problem Solving has key elements that are familiar to most but difficult to describe and even more difficult to teach. The rationale is to break the process of solving problems into sections, build something that solves a real problem and do it in such a way that junior high students will enjoy the whole exercise. In this case the vehicle is electronics, however this approach could be applied to many different disciplines.

The following sequence is appropriate for a class with no electronics experience and with limited time available. The students would not breadboard their circuit and would assemble the product directly onto a pre-made universal printed circuit board.

STEPS IN THE PROCESS

1. **Define** the **PROBLEM** - This sounds easy, but students will attempt to build the solution into the Problem Statement. It is the role of the teacher to get students to re-write the Problem Statement without any pre-conceived ideas of how they are going to solve the problem.

2. The students are designing a **System** to solve a problem. Like all systems it will have an **Input**, **Processor**, **Output** and **Power supply**. In this activity the choices are limited to the available components, however there are unlimited ways in which these may be applied.

   Dissection – Look at the different **input units** available to see if any could detect when the “problem” occurs. Look at the different **output units** to see if any could be used to indicate, or solve, the problem. Decide which kind of processor would work best to solve the problem. Chose a power supply that will supply enough power at the right voltage to the circuit.

   This part of the process is most difficult as it can require ingenuity, technical aptitude, good sketching skills and perseverance. My experience is that the clearer the Problem Statement is written, the easier it is to find a solution.

   Note: It will be tempting for the teacher to solve the problem for the students – don’t do it. Remember, there are always different ways to solve a problem and the task is not to find the solution which seems best to you, the teacher, but rather the one which seems right to the student and which they own.

   The objective is to teach the art of Problem Solving in an enjoyable way which is rewarding to the student.

3. **Draw a Block diagram of the system –** indicating which input, output, processor and power supply will be used.

4. **Draw a Parts layout diagram** – On an picture of the printed circuit board, get students to draw the parts of their circuit (see Circuit Layout Sheet). You may have a problem getting students to "stick with the plan." If they see lots of other students using a buzzer as an output, they may be swayed to change. Encourage them to the hold to the original plan.

5. **Draw installation diagrams** (micro and macro) – a common problem students have is seeing what will work and what will not. Putting an ON/OFF switch in a drawer that has an Opening Sensor will cause problems. This maybe easy for you to see, but not always for students. If a student comes to you with an overall diagram of the location (macro) of their circuit and close-up views (micro), you can help the student to see any potential impracticality of their design and get them on a path that will lead to success.

6. **Collect the Parts** and stuff the board – I generally pin the sheets on the walls. Input options on one wall, Outputs, Processors and Power Supplies on other walls. On each sheet I write the price I will charge for that particular option. I have seen absolutely ingenious solutions for everyday household problems made for less than a dollar. Examples are a bathtub or laundry tub overflow alarm, a silent indicator that a drawer had been opened, rain detector and automatic night light. You name the problem, kids will find a solution.

   Part of this section is the art of parts stuffing, soldering, wiring and circuit testing. It takes time, but the motivation is great.

7. **Case construction** – many considerations must be made. Size, shape, weather-proof, water-proof and concealment are some. I insist that students make a model of the case as cardstock is cheaper than aluminum and plastic. I still find they use too much metal and plastic – part of the cost of educating. When you see these same students build their next case, you will be impressed with what they have learned. I find I give a lot of individual instruction, but it is worth the effort.

THE PROBLEM SOLVING APPROACH

Most problems can be analyzed using an organized, systematic approach. Not all problems can be solved from the standpoint of an electronic circuit, but when they can the best solutions will often be a result of following a specific sequence. In completing this activity you will do the following:

1. Analyze the problem thoroughly.

2. Word the problem statement so there are no preconceived ideas as to the solution. *This is hard to do and you may need to rewrite this statement a number of times. The more focused this problem statement, the easier it is to design the solution.*

3. Design the circuit solution to the problem without any **bells or whistles.** *Add-ons are fine and can possibly be added later, but for now, the best solution will be the one that gets the job done. A block system diagram can help at this stage.*

4. Choose an **INPUT** that best senses the "problem trigger."

5. Choose an **OUTPUT** that is the best "solution indicator".

6. Choose a **PROCESSOR** that meets the required momentary or latching function.

7. Choose a **POWER SUPPLY** that will meet the power requirements of the Input, Output and processor.

8. Draw a schematic diagram of your proposed circuit

9. Build a prototype circuit using a solderless component board to test your design.

10. Make any circuit modifications necessary to arrive at the required operation Add bells and whistles that enhance the solution at this point.

11. Design a printed circuit board for the tested circuit, bearing in mind any space restrictions. You may use the pre-designed PC board, or design your own for a higher mark.

12. Fabricate, stuff the PC board, and then test the final circuit.

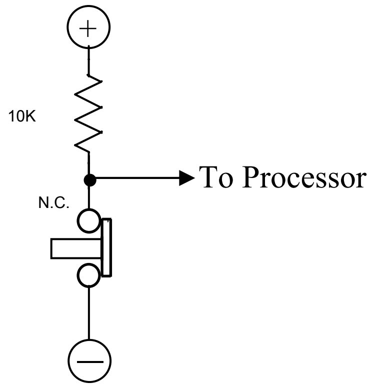
13. Design and build a case which will suit the application, including any special concerns relating to the intended operating environment.

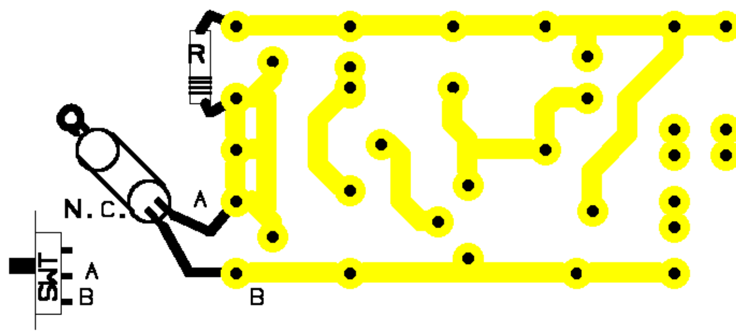
14. Assemble and test the completed product.

Inputs

The following inputs, or variations on these concepts, may be used for the 101 project. A schematic diagram and printed circuit board component positioning are shown for each.

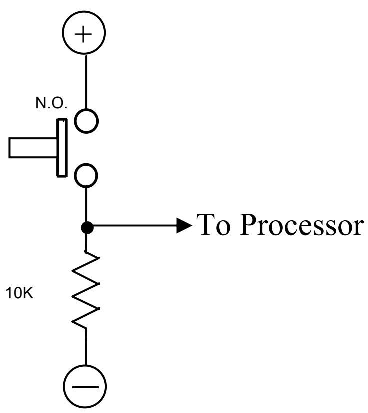
INPUT – OPENING / CLOSING DETECTOR 1

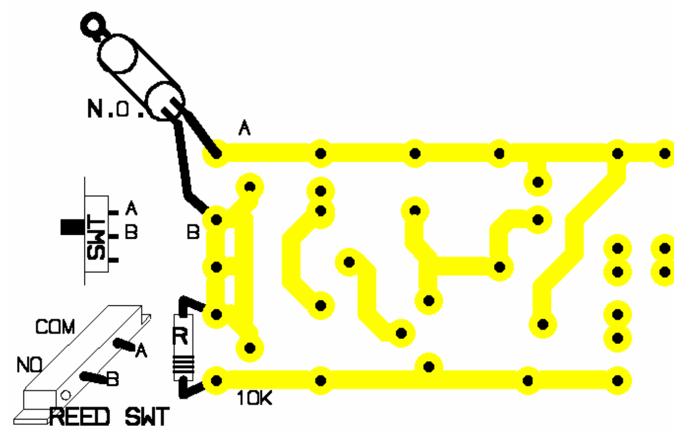




DESCRIPTION: When the push button is released a negative voltage is presented to the processor. When the pushbutton is depressed the connection to the processor is positive. A N.O. push button will function in the reverse manner. Other switch types may be substituted for the push button.

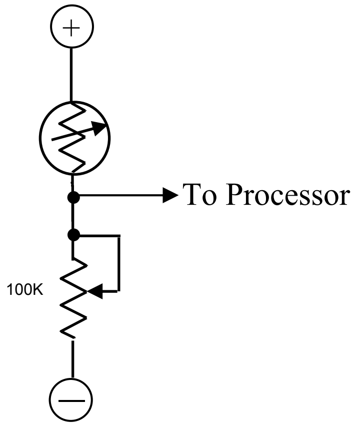
INPUT – OPENING / CLOSING DETECTOR 2

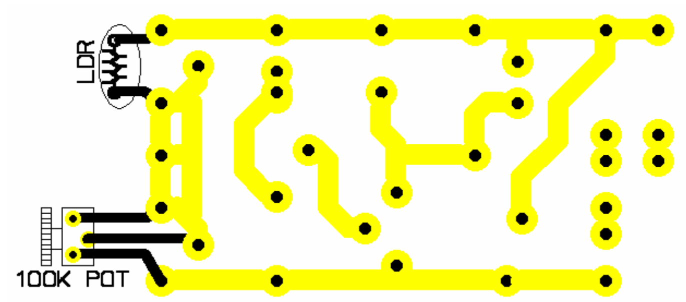




DESCRIPTION: When the push button is released a negative voltage is presented to the processor. When the pushbutton is depressed the connection to the processor is positive. A N.O. push button will function in the reverse manner. Other switch types may be substituted for the push button

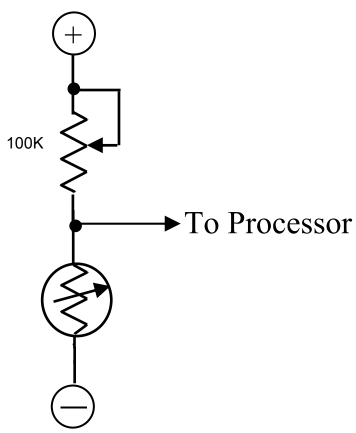
INPUT – LIGHT DETECTOR

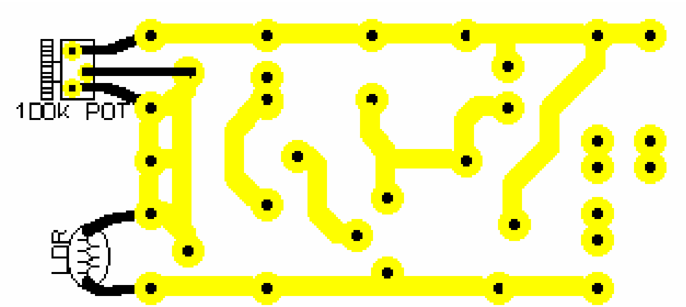




DESCRIPTION: When the LDR (light dependant resistor) is in the dark, it's resistance is very high and a negative voltage level will be presented to the processor. As more and more light shines on the LRD it's resistance decreases and the voltage level to the processor becomes more positive. At some point, depending on the setting of the 100k trim pot, a voltage level positive enough to activate the processor will be reached. The trim pot acts as a sensitivity adjustment for the LDR. (Note that the 100k Pot should never be adjusted to minimum resistance as the LDR could be damaged due to excess current in high light conditions. As a safety precaution a 1k resistor may be placed in series with the LDR.)

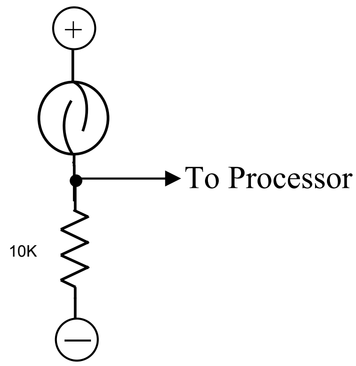
INPUT – DARKNESS DETECTOR

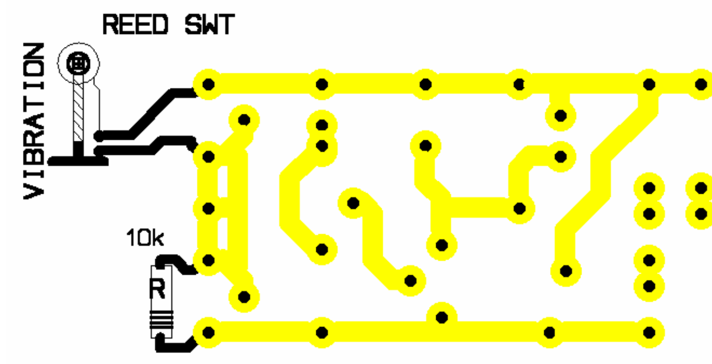




DESCRIPTION: When the LDR (light dependant resistor) is in the light, it's resistance is very low and a negative voltage level will be presented to the processor. As the LDR receives less light it's resistance increases and the voltage level to the processor becomes more positive. At some point, depending on the setting of the 100k trim pot, a voltage level positive enough to activate the processor will be reached. The trim pot acts as a sensitivity adjustment for the LDR. (Note that the 100k Pot should never be adjusted to minimum resistance as the LDR could be damaged due to excess current in high light conditions. As a safety precaution a 1k resistor may be placed in series with the LDR.).

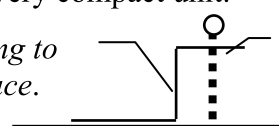
INPUT – VIBRATION DETECTOR





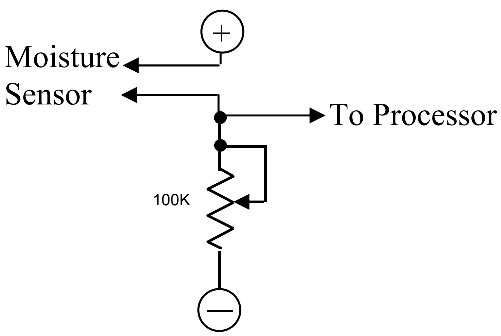
DESCRIPTION: When a vibration moves the sensor it completes the circuit, resulting in a positive voltage presented to the processor. It is possible to make the vibration detector in many ways - don't be afraid to design your own. One possible mechanism incorporates a spring or hanging electrode and brass shim-stock "ring" which attaches directly to the printed circuit board, resulting in a very compact unit.

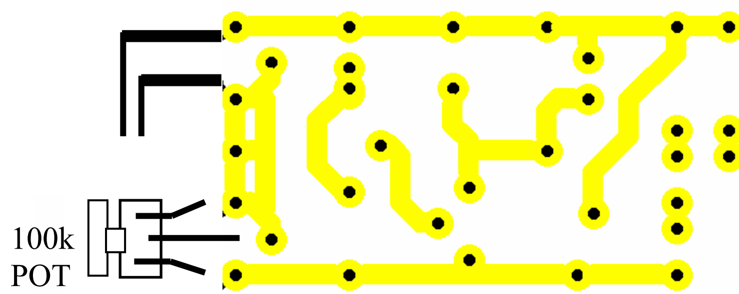
Shim-stock bracket with hole for spring to pass through is soldered to a PCB trace. Hole diameter controls sensitivity.



Spring with solder ball as a weight is soldered to a PCB trace. Passes through a hole in the bracket. Alternately a swinging electrode could hang from above.

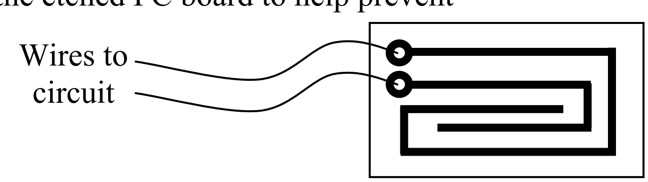
INPUT – MOISTURE / TOUCH DETECTOR





DESCRIPTION: When moisture is present between the sensor probes a lower resistance path is created to positive, presenting a positive voltage to the processor. Some experimentation is necessary to arrive at the best sensor design for your situation*. Where possible use probe materials which don't rust. The 100k potentiometer is adjusted to change the sensitivity of the circuit: the lower the value the less sensitive it becomes. If the 100k pot and probes are swapped the function is reversed so that the processor will remain OFF as long as there is moisture between the probes.

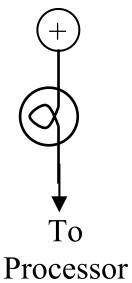
*A sensitive yet compact probe may be made on a printed circuit board (≈1" x 2") as shown below. Carefully draw a similar pattern on the copper using a resist pen. More lines, closer together are more sensitive. Tin the etched PC board to help prevent corrosion. Also works as a "touch" sensor.

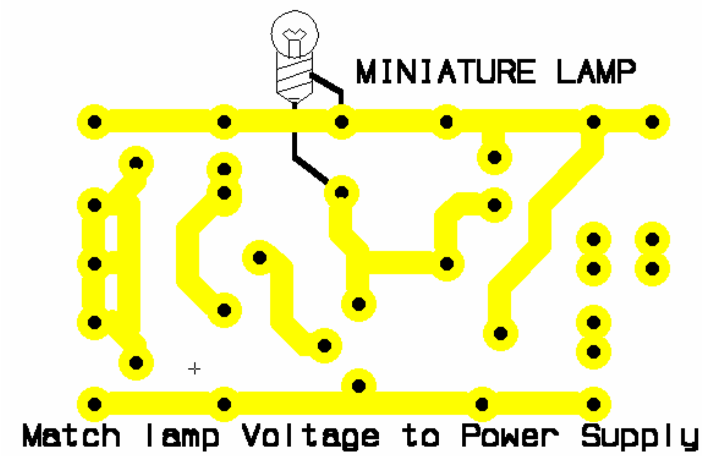


Outputs (Loads)

The following outputs may be used for the 101 project. A schematic diagram and printed circuit board component positioning are shown for each.

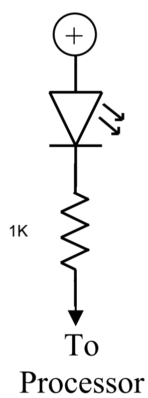
OUTPUT - LAMP

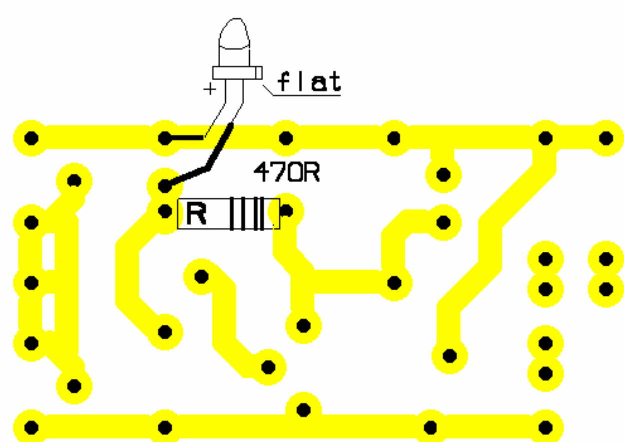




DESCRIPTION: The size (current requirement) of the lamp will determine the size of the Power Supply. Both Voltage and Current will have to be accounted for.

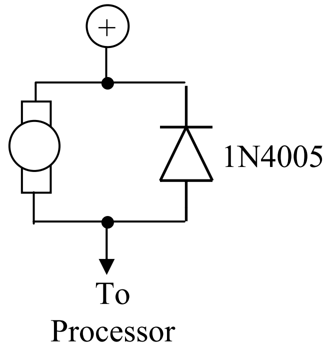
OUTPUT - LED

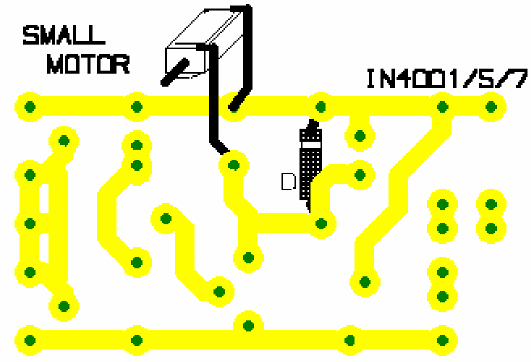




DESCRIPTION: The LED must be in series with a resistor or it will be destroyed. If the LED is connected backwards (reverse biased) it won't work.

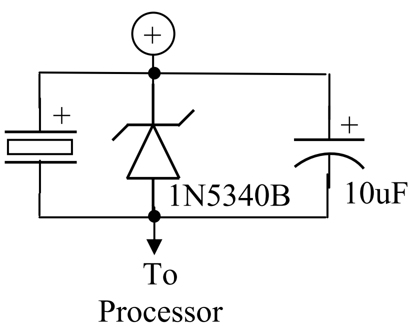
OUTPUT - MOTOR

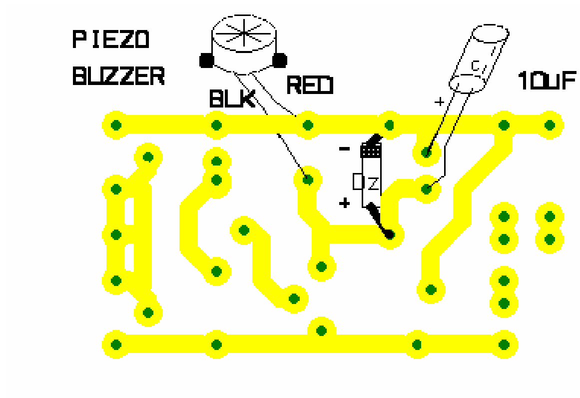




DESCRIPTION: Small motors require low voltage but greater current to operate. It is suggested that C or D cells be used for the power supply. Arrange the cells in series and add a cell for each 1.5volts required. Bigger motors may require a large processor. The diode will stop most voltage noise generated by the motor.

OUTPUT – PIEZO BUZZER



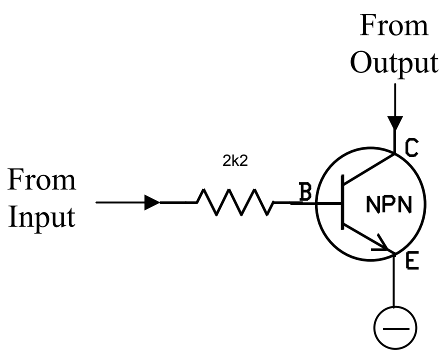


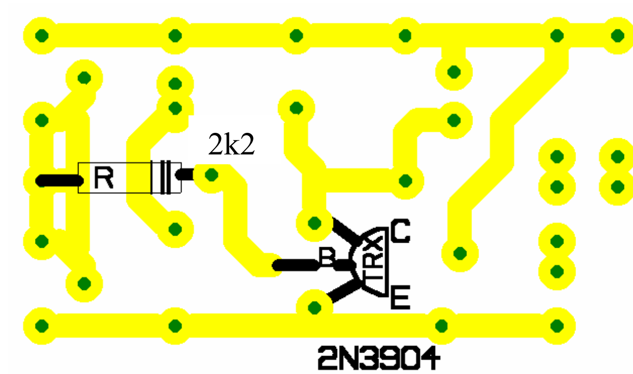
DESCRIPTION: Piezo buzzers give a piercing sound but only require a 9V battery for a supply. An 11volt Zener diode and a 10uF capacitor are required to control the voltage noise generated by the buzzer.

Processors

The following processors may be used for the 101 project. A schematic diagram, package outline, and printed circuit board component positioning are shown for each.

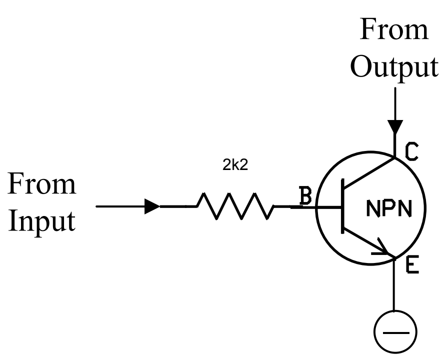
PROCESSOR - MOMENTARY

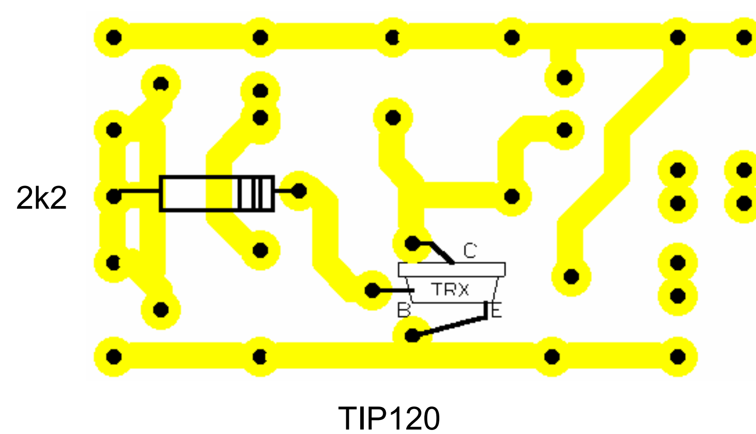




DESCRIPTION: The small momentary processor uses an NPN transistor and a 2k2 Ω to limit the current through it's base-emitter junction. A positive voltage signal from the INPUT will turn on the transistor and power the output.

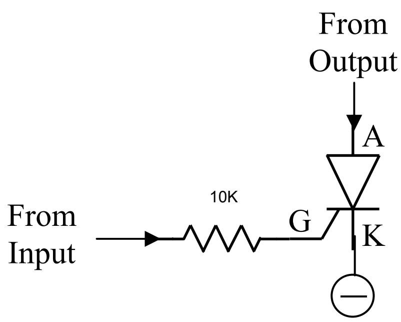
BIG PROCESSOR - MOMENTARY

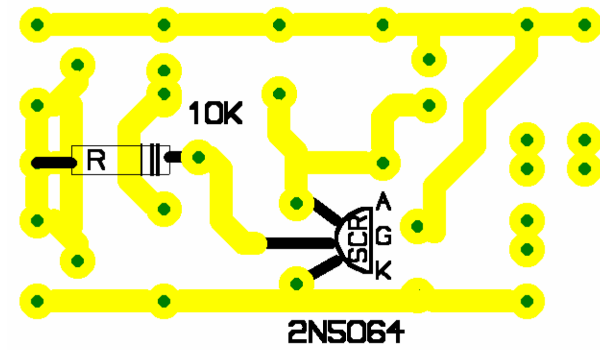




DESCRIPTION: Carefully bend the pins of the NPN transistor to fit the hole spacing. Keep the thermal tab of the transistor towards the LOAD. Use a 2k2Ω resistor to limit the current through the base of the transistor. Loads with current usage up to 3 amps can be used. The transistor requires a heat sink beyond 1 amp of current.

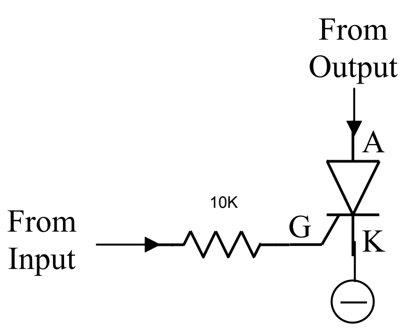
PROCESSOR - LATCHING

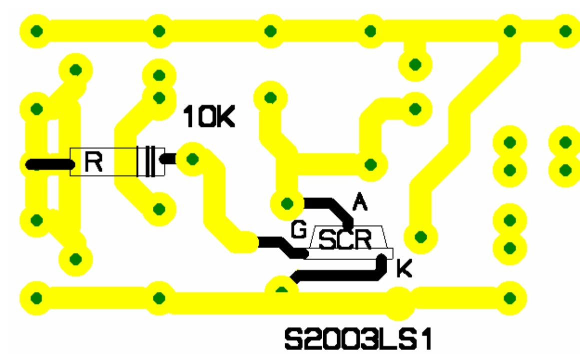




DESCRIPTION: The small latching processor uses an SCR (silicon controlled rectifier) to turn on the LOAD and keep it on (latch). The gate current is limited by a 10KΩ resistor. Output currents up to 0.8 amps can be handled by this SCR.

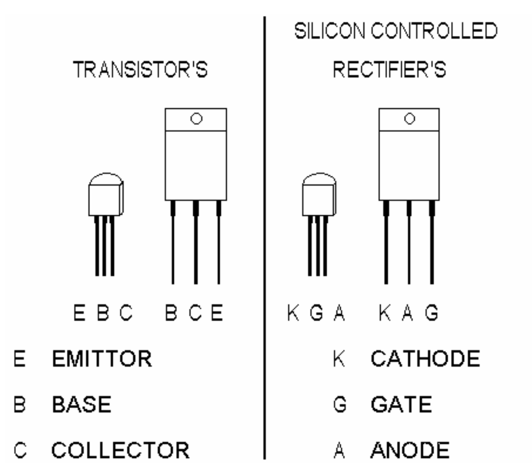
BIG PROCESSOR - LATCHING





DESCRIPTION: Carefully bend the pins of the SCR to fit the hole spacing. Keep the thermal tab of the SCR facing the negative side of the circuit board. Use a 10KΩ resistor to limit the current through the gate of the SCR. Loads with a current usage up to 5amps can be handled, but more than 1 ampere and the SCR requires a heat sink.

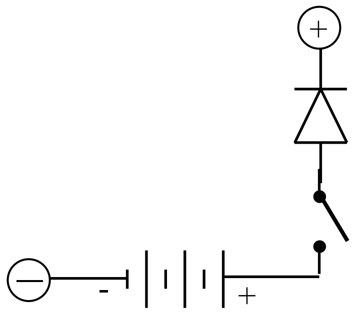
PROCESSOR CONFIGURATIONS

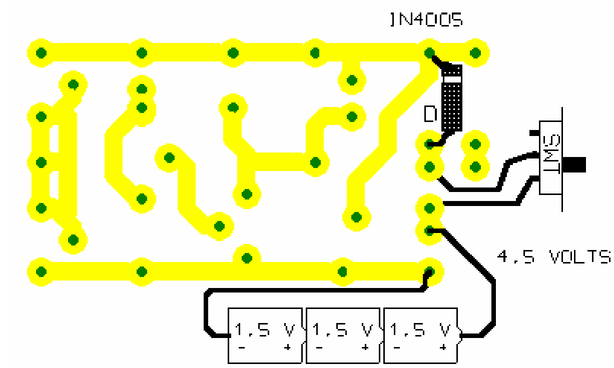


Power Supplies

The following power supplies may be used for the 101 project. A schematic diagram, package outline, and printed circuit board component positioning are shown for each.

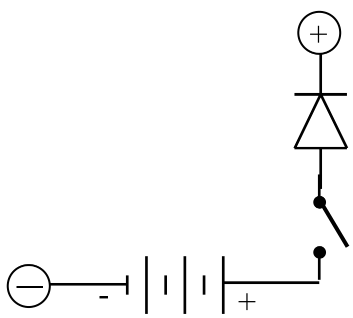
POWER SUPPLY – C or D CELLS



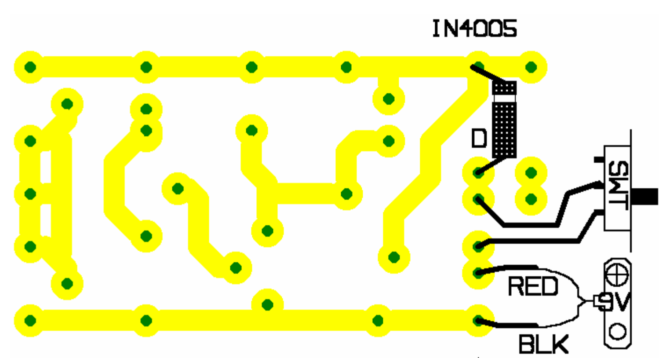


DESCRIPTION: Wire the cells together in series. Every cell added raises the total voltage by 1.5volts. The cells must be connected with each positive terminal pointing towards the switch on the circuit board. The diode protects the circuit if the cells are connected backwards. The switch turns the circuit ON/OFF and is also a reset for latching processor units . The battery holder is provided, but not the cells.

POWER SUPPLY – 9 VOLT BATTERY

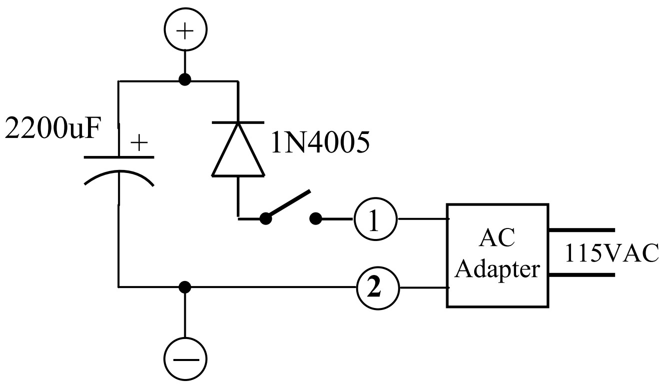


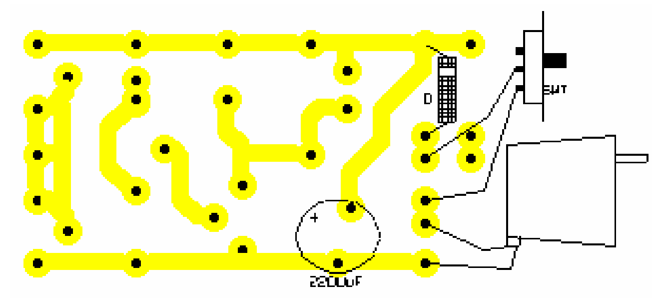
9V Battery



DESCRIPTION: The battery clip is polarized so watch the colour orientation. The slide switch acts as a power switch and also a reset for latching processor units. The diode protects the circuit if the battery is placed against the battery clip backwards.

POWER SUPPLY – WALL ADAPTER: 5V & 9V





2200uF

DESCRIPTION: We will provide the power connector but not the adapter. These cost $5 to $10, but you may already have one which will do as they come with many household devices. An acceptable wall adapter would have an output of 5 to 9 VDC* or 9 to 12VAC*. Wall adapters come in a range of current outputs. Make sure the adapter is capable of providing sufficient current for the LOAD.

The power supply circuit includes a switch for on/off control and to act as a reset for latching processor units. The 2200uF capacitor will filter (smooth out) the pulsing DC before it reaches the circuit. The capacitor must be installed in the circuit the right way around or it can be destroyed.

The diode will protect the circuit against reverse connection of a DC adapter if it's installed correctly. Reversing it may result in your circuit not working and/or damaged parts – be careful.

Connect a DC adapter so that terminal 1 is positive, terminal 2 negative. If your adapter is AC it doesn't matter which wires are connected to terminals 1 and 2. The 1N4005 diode will act as the rectifier diode to convert the AC from the adapter into the DC required.

*DC is *Direct Current* as provided by a battery or power supply. AC is *Alternating Current* as delivered by hydro. Virtually all electronic circuits require direct current, so AC must be rectified, or converted from AC to DC. A single diode is placed inside the DC adapter to rectify (change) AC into DC.

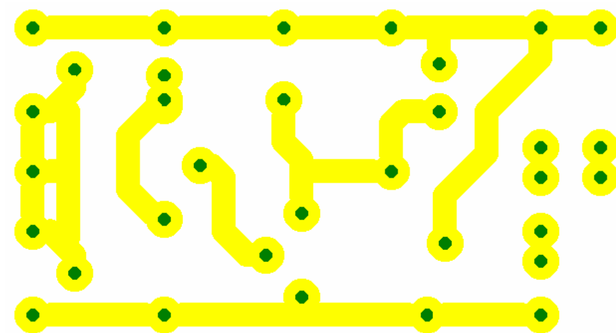
PRINTED CIRCUIT BOARD

Pre-designed PC board - Shown from the top (component) side.

Note: Students who design and make their own PC board will receive higher grades (10% allocated to PC board design).

Output Area

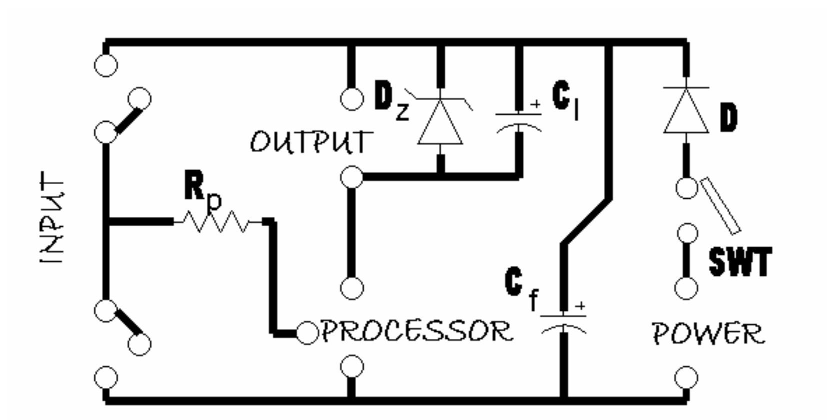
Input area



Power Supply Area

Processor Area

THE SCHEMATIC DIAGRAM - showing the basic 101 circuit components:



Basic Parts List:

D Diode		1N4001 or 1N4005 or 1N4007 silicon diode
D_Z	Zener Diode	1N5240B 10volt, 1/2Watt Breakdown Point Diode
C_L	Load Capacitor	10µF / 16volt$_{min.}$ electrolytic radial Capacitor
C_F	Filter Capacitor	2200µF / 25volt$_{min.}$ electrolytic radial Capacitor
SWT	Switch	Any economical SPST (or better) device such as a DPDT slide switch from Mode
9V Clip		any economical 9V battery snap clip will do
R_P	Resistors	All resistors are ½ watt

CIRCUIT LAYOUT SHEET

Draw schematic symbols in pencil for the components for *your circuit* on this parts layout diagram. You will then know which traces are required and which may be left out for your product.

Fill in the table indicating the components you require. The costs are included so you will have an idea of what it would cost to produce this circuit in a classroom situation.

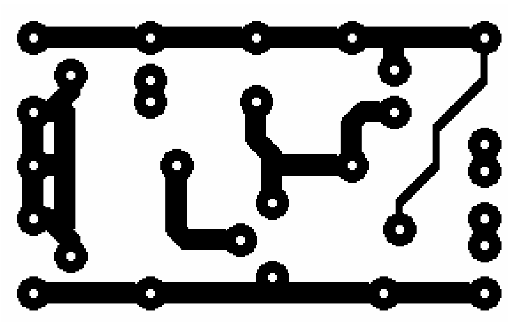
	Description	***Cost***
Input		
Output		
Processor		
Power		
Diode(s)		
Capacitor(s)		
Resistor(s)		
Switch		
Miscellaneous		
TOTAL COST		

These costs are estimates only but are appropriate to cost your circuit for this assignment.

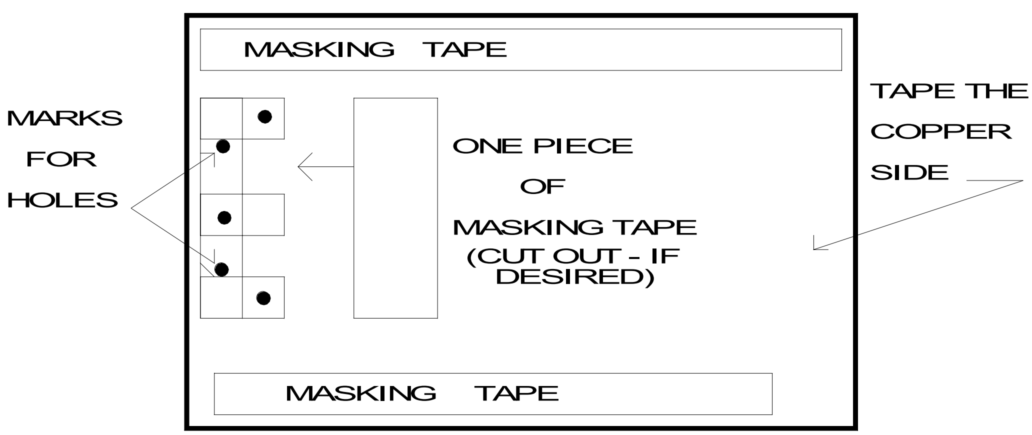
Description	Approximate Cost (per unit)
Push button (N.O. & N.C.)	.75
Slide switch (DPDT)	.50
Magnetic reed switch	1.75
Light dependant resistor (LDR)	.75
Vibration sensor parts	.25
Potentiometer	.55
Miniature incandescent lamp	2.25
Light emitting diode (red LED)	.20
Small motor	1.00
Piezo buzzer	1.25
2N3904 (transistor - small momentary)	.15
TIP120 (transistor - small momentary)	1.25
2N5064 (SCR – small latch)	.45
S2003LS1 (SCR – large latch)	.75
Battery holder – 2 C- cells	1.00
Battery holder – 4 C- cells	1.50
9V battery clip	.25
AC Adapter jack	.75
1N4005 diode	.10
1N5340B 10V Zener diode	.30
10 microfarad 16V electrolytic capacitor	.20
2200 microfarad 25V electrolytic capacitor	1.50
Resistor ¼ watt, all values	.05

Making your Printed Circuit Board:

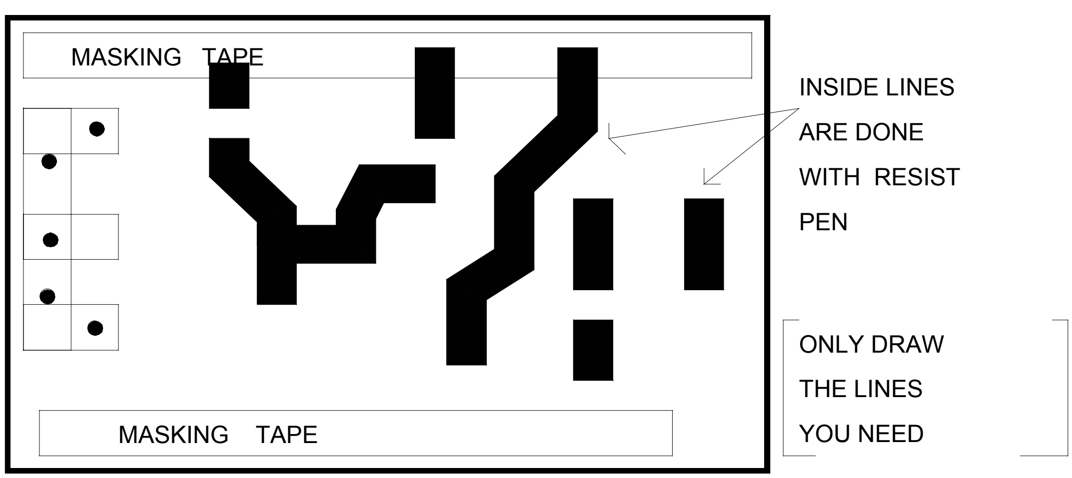
The bare 101 board can accommodate all circuit variations. You may not need all of the traces shown.



First Step – Decide which traces are necessary, then plant masking tape around the outside where traces are desired.



Second Step – Use a resist pen to draw the inside traces. You can include all of them, but some may not be used for your circuit. Lightly mark hole locations with a centre punch.



Etching, Drilling, Tinning and Soldering

Etching – getting rid of unwanted copper

- Safety is critical   Cleanliness is very important
- Eye protection MUST be worn by ALL people in the etching tank area
- Neoprene (light green) or rubber gloves should be worn to protect your skin
- Place circuit boards in tank (copper side up) and set timer for 8 – 10 min's
- DO NOT lift the lid of the tank until pump motors have stopped
- Ferric Chloride should not end up going down the drain, so rinse circuit boards in the rinse bucket before drying with a paper towel.
- Cleanup all drips and spills with paper towels, rinse gloves and hang both goggles and gloves on proper racks.
- All Etchant contact with skin and clothing should be rinsed off immediately
- Should Etchant get in eyes, wash in the Eye Wash Station for an extended time. Failure to get Ferric Chloride out of your eyes can cause permanent damage to tear ducts and glands in your eye. Inform your instructor.

Tinning – tinning keeps the copper from oxidizing

- Smear a small amount of plumber's flux on copper side of circuit board
- Turn adjustable solder stations to maximum temperature
- Flood the copper traces and solid areas with solder and spread with the heated pencil. You can actually build the thickness of the copper traces
- Wash the flux off the board with warm water. The flux is environmentally safe.
- Buff the tinned surfaces with a dry paper towel

Drilling – holes for components to attach to board

- Wear eye protection whenever using machines with powered moving parts.
- Wear ear protection with the small Dremel drills as the noise can damage hearing.
- Both drilling booths are set-up with a small drill bit (#60) and a large drill bit (1.5mm)
- Most components require a #60 hole. If larger holes are needed use the #60 as a pilot hole then drill with 1.5mm or go to the drill press and drill with a larger size bit
- NO drill bits larger than 1.5mm should ever be placed in the Dremel drills and don't use these drills for any plastics and the speed is 20,000 to 30,000 RPM and will melt a hole rather than cut it. The result is a ruined bit and a lousy hole.

Stuffing & Soldering Components – attaching components to the circuit board

- Solder can splatter and cause eye injury. Glasses should be worn while soldering. Plastic lenses could be pitted by hot solder but this is unlikely. Your choice, safety glasses or regular seeing glasses. BUT, WEAR GLASSES!!!
- Start soldering the smallest components to the board first. It is very difficult to get the small pieces on the board when big components are in the way.
- Many components should lay flat on the board. Most resistors, diodes and capacitors should lay flat. LED’s and transistors should be raised up off the board.
- Use solid and stranded wire in appropriate places, depending on the use. Always use stranded wire where the lead must flex in normal use.

Case

- *Note: A plastic case is available from your instructor, however if you design and fabricate your own case you will earn a higher grade (10% allocated).*
- To be realistic the case must be such that it may be fabricated entirely in the electronics shop. In the school environment students are not free to wander between shops.
- Sheet aluminum (16 and 20 gauge) and 1/8 ABS plastic sheet are available.
- The shop has typical tools, including a shear, box & pan brake, and strip heater.
- The case should allow easy access to the circuit for battery replacement, repairs, etc., and be appropriate for the proposed environment.

101 Project Submission

The following list indicates the various aspects of the 101 Project which will be graded. Be sure *all parts* are clearly marked with your name.

Submit paperwork stapled together and in the sequence listed below. This submission is expected to conform to program standards as described in the orientation package you received in September.

- Title page
- Your problem statement, as approved by the instructor
- A block diagram of your circuit
- The Circuit Layout Sheet (a separate sheet is provided) showing your:
  - components on the standard circuit board (do this even if you design your own PC board)
  - parts and costs (see page 16)
- A schematic diagram of your circuit
- Installation diagrams (micro & macro as required)
- The final product, in an appropriate case
  - Assemble using your own PCB design or use the provided board
    - There will be higher marks for a PCB of your own design
  - Design & make your case, or use the provided plastic box
    - There will be higher marks for a case of your own manufacture
  - Leave the cover off the case so I can easily inspect your work
    - Keep screws so I don't lose them!
  - Include the power source for testing purposes

This assignment is due at the end of your final lab class for this course.

101 Project Evaluation

Name: ____ **/105**

Documentation:

Submission stapled & in sequence specified ..../2
Problem Statement: ..../5

Circuit Block diagram
Neatly drawn to illustrate solution ..../5

Circuit Layout Sheet
Shows components in correct locations...................../5
Part list & costs complete ..../5

Schematic Diagram
Uses correct symbols ..../5
Neatly drawn to standards../5

Micro/Macro Diagram(s)
Provide all required information ..../5
Neatly drawn to standards ..../5

Printed Circuit Board

Soldering ..../5
Orientation, height of components ..../5

Student's own design & fabrication (PC board)
PC board layout../5
Quality of manufacture ..../5

Case

Fitting of components to case ..../5
Access for servicing ..../5
Unique features ..../3
Quality of work ..../5

Student's own design & fabrication (Case)
Quality ..../5
Design ..../5

Function

Power source included for testing ..../5
Circuit functions as intended ..../10