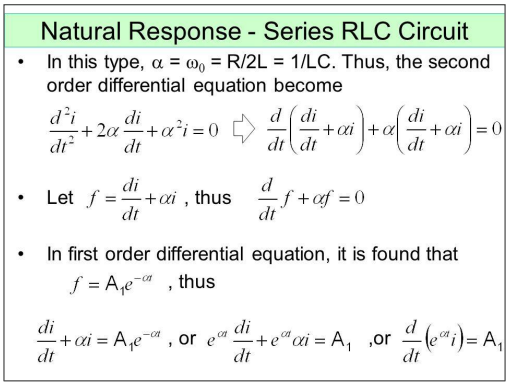
Electronics Merit Badge Workshop

The 6 Requirements will be covered in the following discussions:

- Introduction
- Current, Voltage & Resistance
- Components
- Skills
- Project (*Let's a Vampire Bristlebot!*)



***** Make sure you have an attendance sheet!!! *****
https://drive.google.com/open?id=1Sy-B1WsKe1qBZATdRXoVe8ncnnYb26q6cbZtgk9WPxU

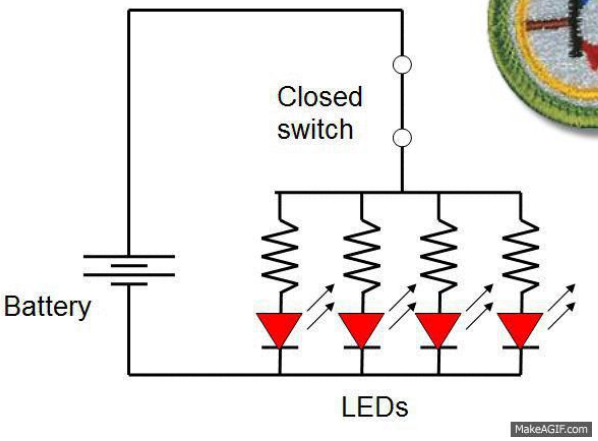
Welcome to this Electronics Merit Badge workshop! The workshop consists of a single four hour session.

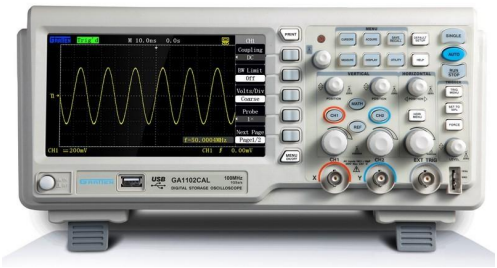
There are 6 requirements (https://filestore.scouting.org/filestore/Merit_Badge_ReqandRes/Electronics.pdf) broken down into 4 major sections as can be seen in the following spreadsheet used for planning the workshop: https://docs.google.com/spreadsheets/d/1sJKB-XExJ83dYyZA2nrO-pyCz0yvK97BmHFsZOHRwyM/edit?usp=sharing. Each sections corresponds to a slide. There will be supporting slides for each section but the goal for this workshop is to focus less on lecturing and maximize hands-on project time. A lot of the requirements will be satisfied while designing and building the actual project.

The Project itself can be any suitable electronics project that satisfies Requirement 4c. In this case I have chosen to solve a problem using a control device. There are other examples in the pamphlet that can be used instead.

Also Note: The Bristlebot project I have chosen is not easy. Not all the Scouts might be able to finish it in the time allotted. It is important to make it clear up front that as long as they can demonstrate they can fulfil the requirements covered in that section (see the slide for more details) they will still earn the merit badge. Having a completed and working Bristlebot is not a requirement and they can take it home and finish it if they want.

FEEL THE POWER!





***** Take a group Photo with the screen in the background showing the merit badge patch *****

Ground Rules

1. This is a Scouting Event - ALL the associated rules apply. Including 2 deep leadership and taking a Buddy if you leave the area.
2. Can not help yourself to snacks or drinks - we need to respect allergies.
3. Class B Uniforms required
4. Recite Pledge of Allegiance to the Flag
5. Recite Scout Oath
6. Recite Scout Law

Initial Introduction

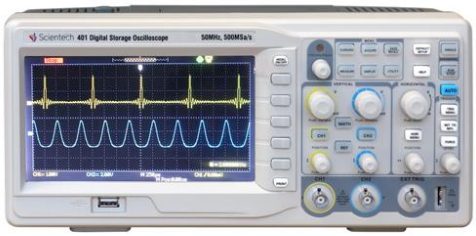
- Do an introduction geared to spark their interest at the very beginning of the Workshop.

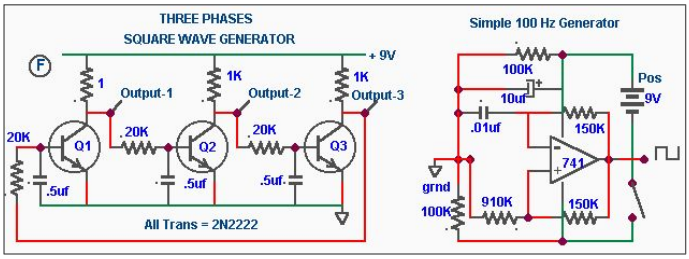
- Have the Scouts gather around a table that has the following on top (or similar): Soldering iron, prototype breadboard, oscilloscope, multimeter, printed circuit board, completed or prototyped Vampire Bristlebot (or any other project you selected) and the individual components that make it up:

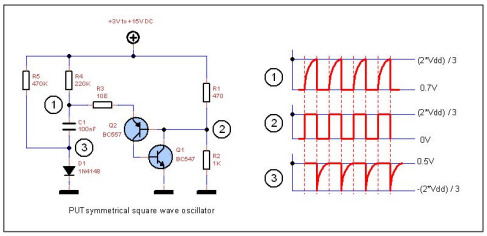
    - Briefly explain each item and component (*this will be revisited in depth*)
    - Demonstrate the Vampire Bristlebot or prototype.
    - Emphasize the need for Math & Physics in Electronics and Engineering
    - Talk about the History of Electronics as per the Pamphlet.
    - Then have the Scouts sit down and proceed.

Introduction

- Safety
- Test Equipment
- Careers







Cover the safety section in the pamphlet (page 8):

1) Googles
2) **BE CAREFUL FOR SHOCKS - SOME ELECTRONIC COMPONENTS STORE CHARGE**
3) Electrostatic discharge
4) Never force a component into place
5) Wires are delicate
6) Never force plugs into sockets
7) Be careful when using tools not to cut yourself or break solder connections
8) Don't bend component leads too close to the body component. It may break.

Explain the Test Equipment placed on the table previously discussed in the prior slide.

Talk about Careers in Electronics:

- Manufacturing/Assembly
- Merchandising/Sales
- Service/Repair
- Quality Assurance
- Electrical Engineering (Microwave/Radar, Control Systems, Robotics, Consumer Electronics, etc..)

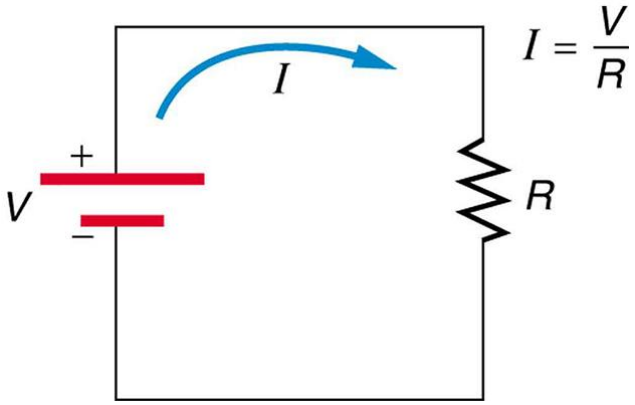
BREAK OUT: Requirements

Let's work on the following requirements:

- 1. Describe the safety precautions you must exercise when using, building, altering, or repairing electronic devices.
- 5b. Tell about the need for and the use of test equipment in electronics. Name 3 types of test equipment. Tell how they operate.
- 6. Find out about 3 career opportunities in electronics that interest you. Discuss with and explain to your counselor what training and education are needed for each position.

Current, Voltage & Resistance

- Power Sources
- Circuits & Closed Loops
- Resistance
- Ohm's Law
- AC/DC (*Not the band*)



Discuss the basics. Current, Voltage, Resistance and Ohm's Law as listed in the bullet points of the slide.

Talk about Batteries and how electrons flow through a closed loop.

Point out the important Laws of Physics when working with Electronics:

- **Ohm's Law**
  - I = V/R
  - Have them try solving a simple problem using Ohm's Law:

    *If **V=100** volts And **R=25** Ohms… What is the current in Amps?*

- **Kirchhoff Current Law** (KCL)
  - The sum of all currents leaving a node in any electrical network is always equal to zero.

- **Kirchhoff Voltage Law** (KVL)
  - The sum of the voltage rises and voltage drops over all elements in a closed loop is equal to zero.

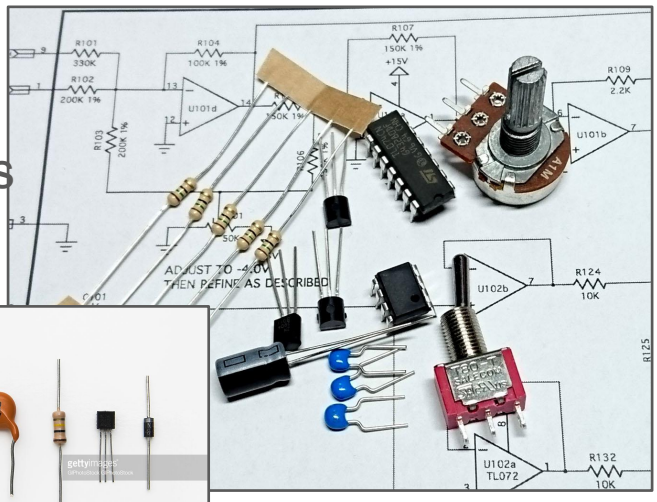
BREAK OUT: Requirements

Let's work on the following requirements:

- 5a. Show how to solve a simple problem involving current, voltage, and resistance using Ohm's law.

Components

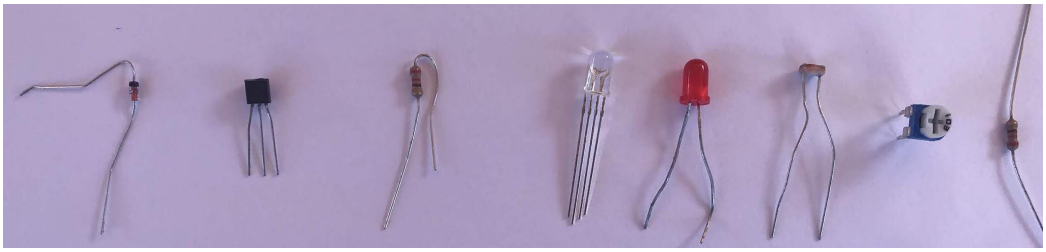
- Analog vs Digital
- Binary Numbers
- Electronic Components
- Audio Applications



Refer to the supporting slides that follow for each section.

Analog Components

- Voltage & Current values can vary over time.
- Basic building blocks for digital components.
- They are used to make Digital Components which have “discrete” values - “0” or “1”.
- Active vs Passive Components



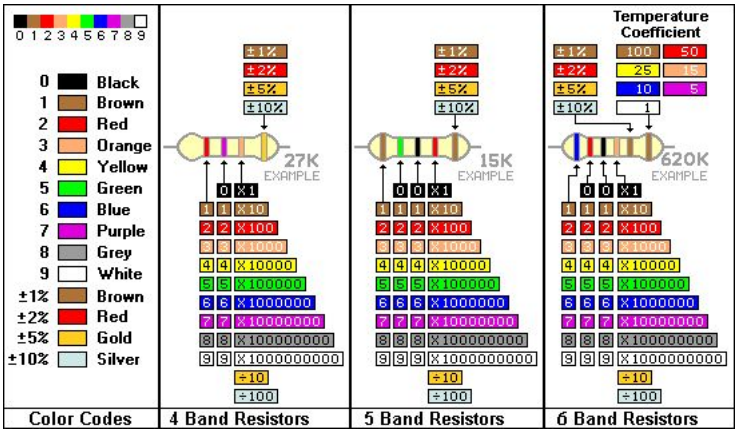
Talk about each of the basic analog components, their electrical characteristics and practical uses for a our project
(Use the slides that follow to demonstrate each one as you talk it out):

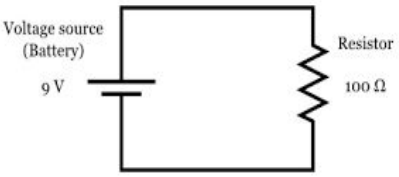
- Resistor
- Capacitor
- Inductor/Coil
- Diode
- Transistor

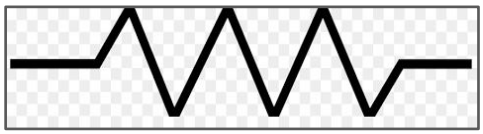
Explain the difference between **Active and Passive Components**. Active components require external power to work like a transistor or an IC Chip and do not consume power from the circuit. Passive components like a resistor or capacitor dissipate, store, and/or release power.

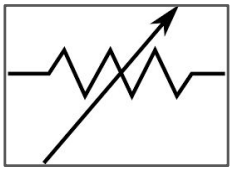
Explain how analog components are used to make digital components. It’s not magic inside those computer chips - its really small analog components.

Resistors

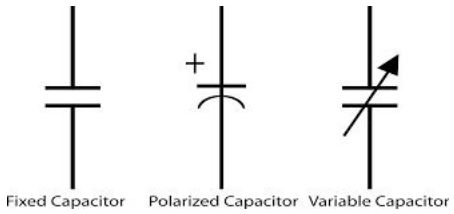

0 1 2 3 4 5 6 7 8 9
0 Black
1 Brown
2 Red
3 Orange
4 Yellow
5 Green
6 Blue
7 Purple
8 Grey
9 White
±1% Brown
±2% Red
±5% Gold
±10% Silver
Temperature Coefficient
27K EXAMPLE
15K EXAMPLE
620K EXAMPLE
Color Codes
4 Band Resistors
5 Band Resistors
6 Band Resistors


Voltage source
(Battery)
9 V
Resistor
100 Ω



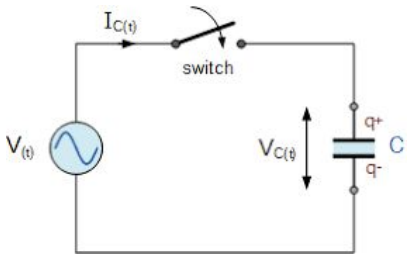


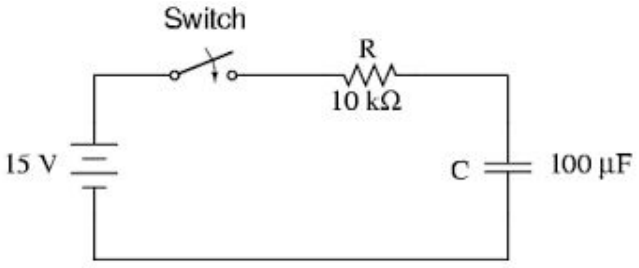
Capacitors


Fixed Capacitor
Polarized Capacitor
Variable Capacitor

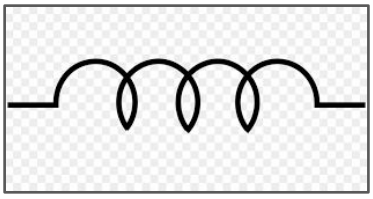

E
202M
12KV
EG
103

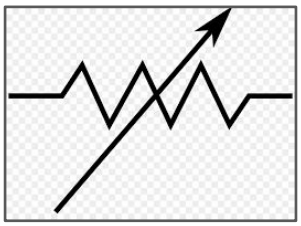

CAPEX
35V3300uF

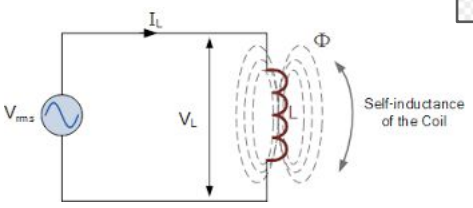

$I_{C(t)}$
switch
$V_{(t)}$
$V_{C(t)}$
q+
C
q-

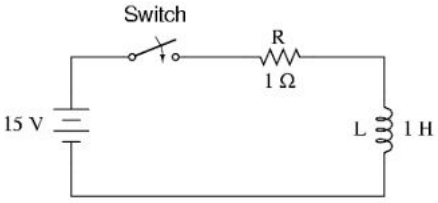

Switch
R
10 kΩ
15 V
C
100 µF

Inductors (Coils)

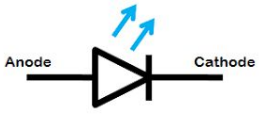




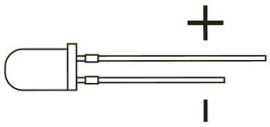


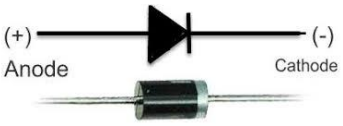


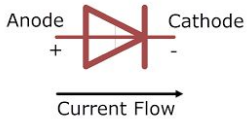
Diodes

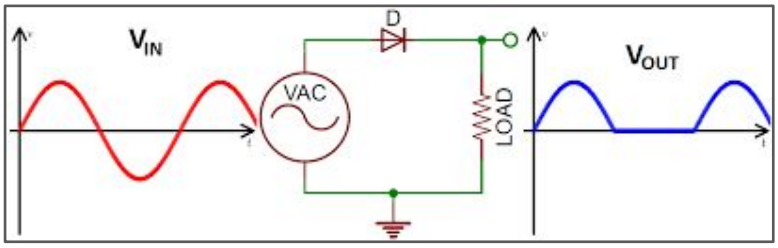


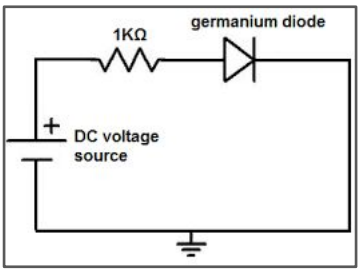
LED symbol



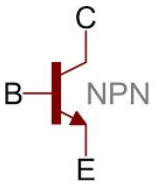


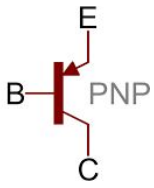


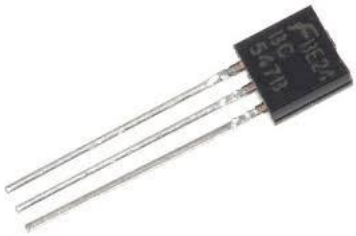


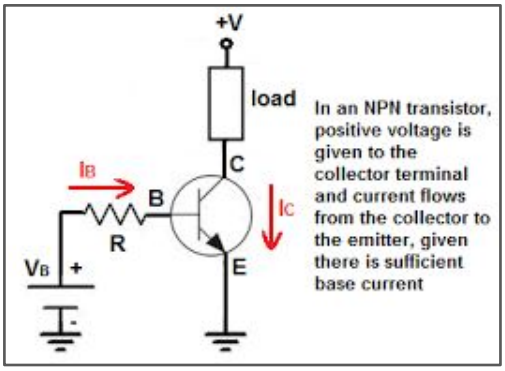


Transistors

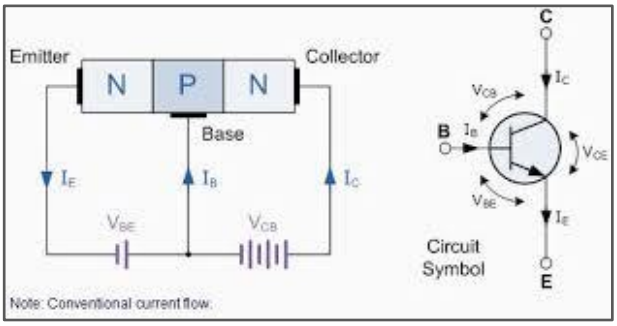




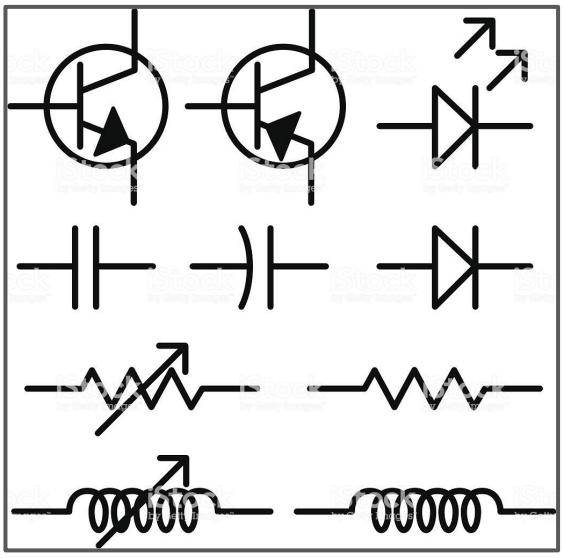




In an NPN transistor, positive voltage is given to the collector terminal and current flows from the collector to the emitter, given there is sufficient base current



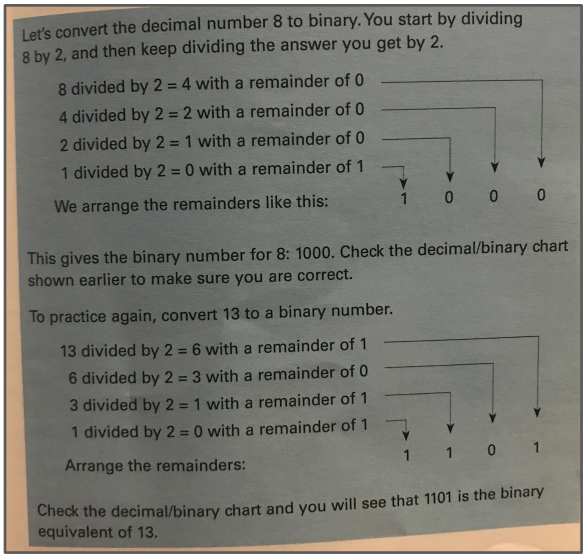
Circuit Symbols



Explain the different types of circuit symbols and how they are used to make circuit (schematic) diagrams.

Binary Numbers

- Changing Decimal to Binary



Let's convert the decimal number 8 to binary. You start by dividing 8 by 2, and then keep dividing the answer you get by 2.

8 divided by 2 = 4 with a remainder of 0
4 divided by 2 = 2 with a remainder of 0
2 divided by 2 = 1 with a remainder of 0
1 divided by 2 = 0 with a remainder of 1

We arrange the remainders like this: 1 0 0 0

This gives the binary number for 8: 1000. Check the decimal/binary chart shown earlier to make sure you are correct.

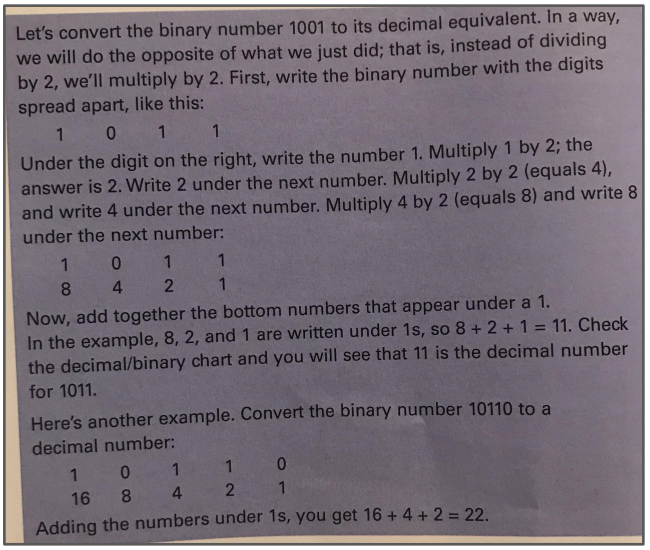
To practice again, convert 13 to a binary number.

13 divided by 2 = 6 with a remainder of 1
6 divided by 2 = 3 with a remainder of 0
3 divided by 2 = 1 with a remainder of 1
1 divided by 2 = 0 with a remainder of 1

Arrange the remainders: 1 1 0 1

Check the decimal/binary chart and you will see that 1101 is the binary equivalent of 13.

- Changing Binary to Decimal



Let's convert the binary number 1001 to its decimal equivalent. In a way, we will do the opposite of what we just did; that is, instead of dividing by 2, we'll multiply by 2. First, write the binary number with the digits spread apart, like this:

1 0 1 1

Under the digit on the right, write the number 1. Multiply 1 by 2; the answer is 2. Write 2 under the next number. Multiply 2 by 2 (equals 4), and write 4 under the next number. Multiply 4 by 2 (equals 8) and write 8 under the next number:

1 0 1 1
8 4 2 1

Now, add together the bottom numbers that appear under a 1. In the example, 8, 2, and 1 are written under 1s, so 8 + 2 + 1 = 11. Check the decimal/binary chart and you will see that 11 is the decimal number for 1011.

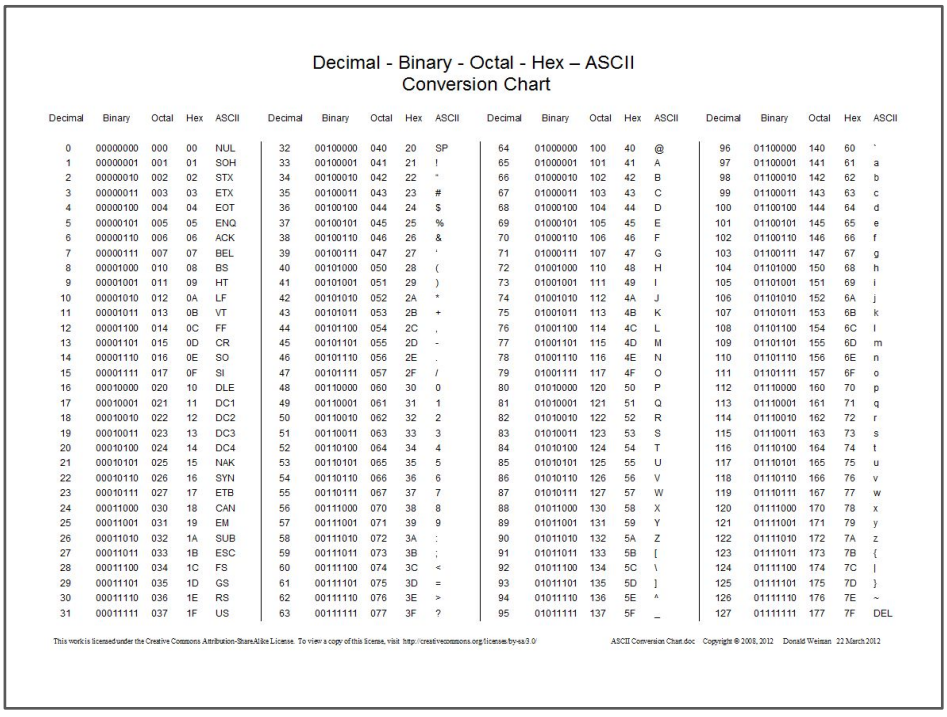
Here's another example. Convert the binary number 10110 to a decimal number:

1 0 1 1 0
16 8 4 2 1

Adding the numbers under 1s, you get 16 + 4 + 2 = 22.

Explain the importance of binary numbers in digital electronics and computers.

Go over how to convert decimal numbers to binary and binary numbers to decimal as per the pamphlet (page 61-62).



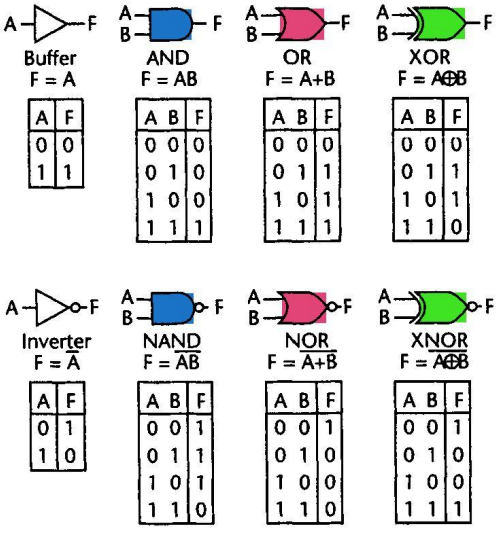
Decimal - Binary - Octal - Hex – ASCII Conversion Chart

Decimal	Binary	Octal	Hex	ASCII	Decimal	Binary	Octal	Hex	ASCII	Decimal	Binary	Octal	Hex	ASCII	Decimal	Binary	Octal	Hex	ASCII
0	00000000	000	00	NUL	32	00100000	040	20	SP	64	01000000	100	40	@	96	01100000	140	60	`
1	00000001	001	01	SOH	33	00100001	041	21	!	65	01000001	101	41	A	97	01100001	141	61	a
2	00000010	002	02	STX	34	00100010	042	22	"	66	01000010	102	42	B	98	01100010	142	62	b
3	00000011	003	03	ETX	35	00100011	043	23	#	67	01000011	103	43	C	99	01100011	143	63	c
4	00000100	004	04	EOT	36	00100100	044	24	$	68	01000100	104	44	D	100	01100100	144	64	d
5	00000101	005	05	ENQ	37	00100101	045	25	%	69	01000101	105	45	E	101	01100101	145	65	e
6	00000110	006	06	ACK	38	00100110	046	26	&	70	01000110	106	46	F	102	01100110	146	66	f
7	00000111	007	07	BEL	39	00100111	047	27	'	71	01000111	107	47	G	103	01100111	147	67	g
8	00001000	010	08	BS	40	00101000	050	28	(	72	01001000	110	48	H	104	01101000	150	68	h
9	00001001	011	09	HT	41	00101001	051	29	)	73	01001001	111	49	I	105	01101001	151	69	i
10	00001010	012	0A	LF	42	00101010	052	2A	*	74	01001010	112	4A	J	106	01101010	152	6A	j
11	00001011	013	0B	VT	43	00101011	053	2B	+	75	01001011	113	4B	K	107	01101011	153	6B	k
12	00001100	014	0C	FF	44	00101100	054	2C	,	76	01001100	114	4C	L	108	01101100	154	6C	l
13	00001101	015	0D	CR	45	00101101	055	2D	-	77	01001101	115	4D	M	109	01101101	155	6D	m
14	00001110	016	0E	SO	46	00101110	056	2E	.	78	01001110	116	4E	N	110	01101110	156	6E	n
15	00001111	017	0F	SI	47	00101111	057	2F	/	79	01001111	117	4F	O	111	01101111	157	6F	o
16	00010000	020	10	DLE	48	00110000	060	30	0	80	01010000	120	50	P	112	01110000	160	70	p
17	00010001	021	11	DC1	49	00110001	061	31	1	81	01010001	121	51	Q	113	01110001	161	71	q
18	00010010	022	12	DC2	50	00110010	062	32	2	82	01010010	122	52	R	114	01110010	162	72	r
19	00010011	023	13	DC3	51	00110011	063	33	3	83	01010011	123	53	S	115	01110011	163	73	s
20	00010100	024	14	DC4	52	00110100	064	34	4	84	01010100	124	54	T	116	01110100	164	74	t
21	00010101	025	15	NAK	53	00110101	065	35	5	85	01010101	125	55	U	117	01110101	165	75	u
22	00010110	026	16	SYN	54	00110110	066	36	6	86	01010110	126	56	V	118	01110110	166	76	v
23	00010111	027	17	ETB	55	00110111	067	37	7	87	01010111	127	57	W	119	01110111	167	77	w
24	00011000	030	18	CAN	56	00111000	070	38	8	88	01011000	130	58	X	120	01111000	170	78	x
25	00011001	031	19	EM	57	00111001	071	39	9	89	01011001	131	59	Y	121	01111001	171	79	y
26	00011010	032	1A	SUB	58	00111010	072	3A	:	90	01011010	132	5A	Z	122	01111010	172	7A	z
27	00011011	033	1B	ESC	59	00111011	073	3B	;	91	01011011	133	5B	[	123	01111011	173	7B	{
28	00011100	034	1C	FS	60	00111100	074	3C	<	92	01011100	134	5C	\	124	01111100	174	7C	|
29	00011101	035	1D	GS	61	00111101	075	3D	=	93	01011101	135	5D	]	125	01111101	175	7D	}
30	00011110	036	1E	RS	62	00111110	076	3E	>	94	01011110	136	5E	^	126	01111110	176	7E	~
31	00011111	037	1F	US	63	00111111	077	3F	?	95	01011111	137	5F	_	127	01111111	177	7F	DEL

Talk about character codes, how they are represented in binary and why they are important.

Digital Logic Gates

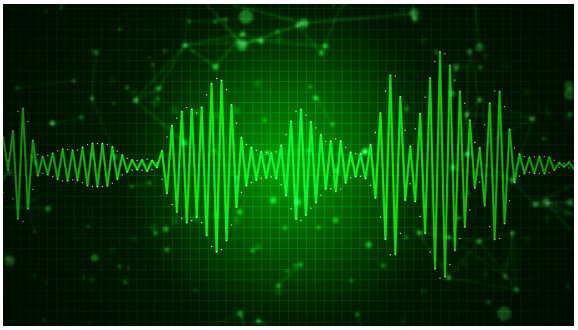
- AND
- OR
- NOT
- NAND
- NOR
- XOR
- XNOR



Talk about digital logic gates as per pamphlet (page 62-63).

Audio

- Hi-Fi Stereo
- The Spoken Word
- Musical Instruments



Talk about how Electronics is used in Audio as per the pamphlet (page 77). Explain the following about frequence:

- What is Frequency? (Hz, Cycles per Second)
- How is Frequency measured?
- Oscillation: How electronic circuits can be used to generate specific frequencies.

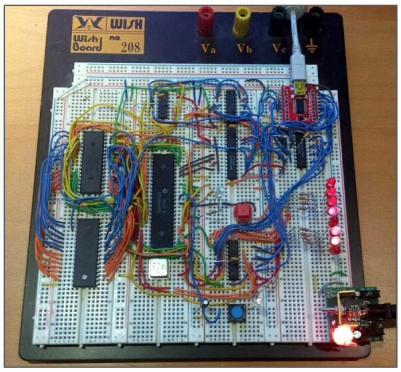
BREAK OUT: Requirements

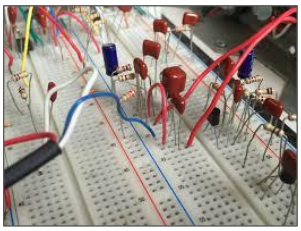
Let's work on the following requirements:

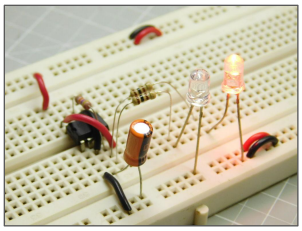
- 4aii. Discuss the basic principles of digital techniques.
- 4aiii. Discuss how to use electronics for 3 different audio applications.
- 4b. Show how to change 3 decimal numbers into binary numbers and 3 binary numbers into decimal numbers.

Skills

- Soldering/Desoldering
- Printed Circuit Boards
- Breadboards/Prototyping
- Wire Wrapping







- Demonstrate the proper way to solder and desolder.

  Include hints from the pamphlet (page 45 soldering and 48 desoldering):

  Soldering
  1) Wear safety goggles
  2) Most solder contains lead - always wash your hands after touching solder
  3) Make sure the tip is clean
  4) Use pliers to hold the leads - not your fingers.
  5) Make sure all wires and circuit board are clean
  6) Make a good mechanical joint before heating
  7) Heat the joint first - then apply the solder
  8) Allow the solder to cool and set before moving or handling the parts

  Desoldering
  1) Wear safety goggles
  2) Start with a little melted solder on the tip of the soldering iron before you begin
  3) When the solder is melted suck it up with the solder pump.

- Show them a printed circuit board and explain it.
- Show them a breadboard and demonstrate how to use it for prototyping.
- Talk about wire wrapping. Demonstrate how to wire wrap.

BREAK OUT: Requirements

Let’s work on the following requirements:

- 3a. Show the right way to solder and desolder.
- 3b. Show how to avoid heat damage to electronic components.

Project

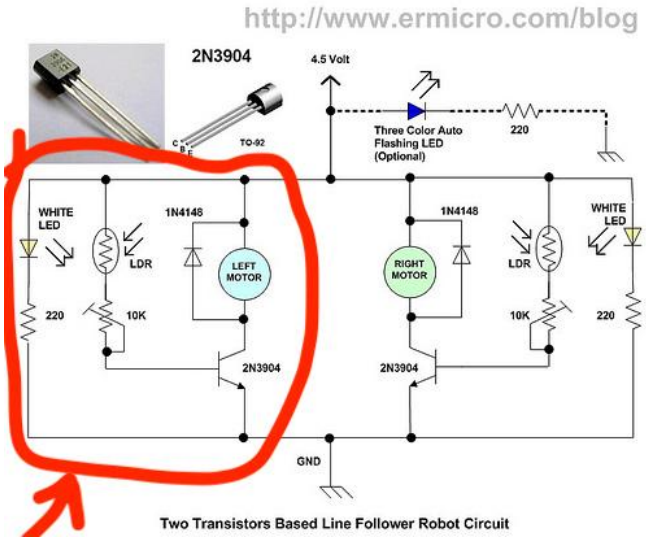
- Problem we are trying to solve?
- Control Circuit
- Drive System
- Add-on: Blinking LED
- Assembly

Because of time constraints the Scouts do not have to complete the entire project during the workshop as long as they make good progress, understand the concepts and complete the final requirements they can earn this Merit Badge. It's the components that are important. They can always finish putting them all together at home. No need to rush things, get everyone stressed and take all the fun away from them. The main goal of this final project is to complete the requirements and give them the knowledge/skills they need to continue exploring electronics.

PROBLEM TO BE SOLVED: Explain to the Scouts that we want to build a Vampire Bristlebot. This little robot's sole purpose in life is to move around until it finds darkness. Once it finds darkness it stops moving and just sits there happy… until it becomes light again at which time it will continue to seek darkness again. The Scouts can elaborate on the design. For instance have an LED turn on once it finds the darkness and stops or even better a blinking LED which would involve a capacitor and a few more components. This is covered in the Add-On slide.

Talk about the importance of breaking the project into pieces: Control Circuit, Drive System and Blinking LED (which will involve a capacitor).

Control Circuit



- Find an existing application that does what you need and extract the relevant Circuit.
- LDR Circuit (Light Dependent Resistor) from a Classic Line Follower.
- Uses a Light Sensitive Resistor.
- Light lowers the resistance and allows Current to Flow.
- We can use this Circuit as an electronic switch to make the Vampire Bristlebot stop moving when it detects darkness.

Talk about what a control circuit is. Why do we need one for our Vampire Bristlebot?

Explain about the importance of reuse and we can take parts of popular existing circuits to satisfy our design needs.

Go over the line following Circuit in depth with the Scouts. Explain to them how it works from a high level perspective and then go into the detail of each electronic component:

- Pager Motor
  - From a cell phone
  - Vibrates and can be used to make the bristles move
  - Motors need a good amount of current to run

- 2N3904 Transistor - NPN Bipolar Junction Transistor (BJT)
  - Acts as an electronic switch (ON/OFF)
  - Collector, Base, Emitter
  - A little tiny bit of current into the base can cause a LOT of current to flow from the Collector to the Emitter and run the motor. (ON)
  - If the little tiny bit of current stops - so will the current flow from the Collector to the Emitter. (OFF)

- LDR (Light Dependent Resistor)
  - Light lowers the resistance and allows Current to Flow
  - Controls the current thru the base of the transistor and hence the motor speed.

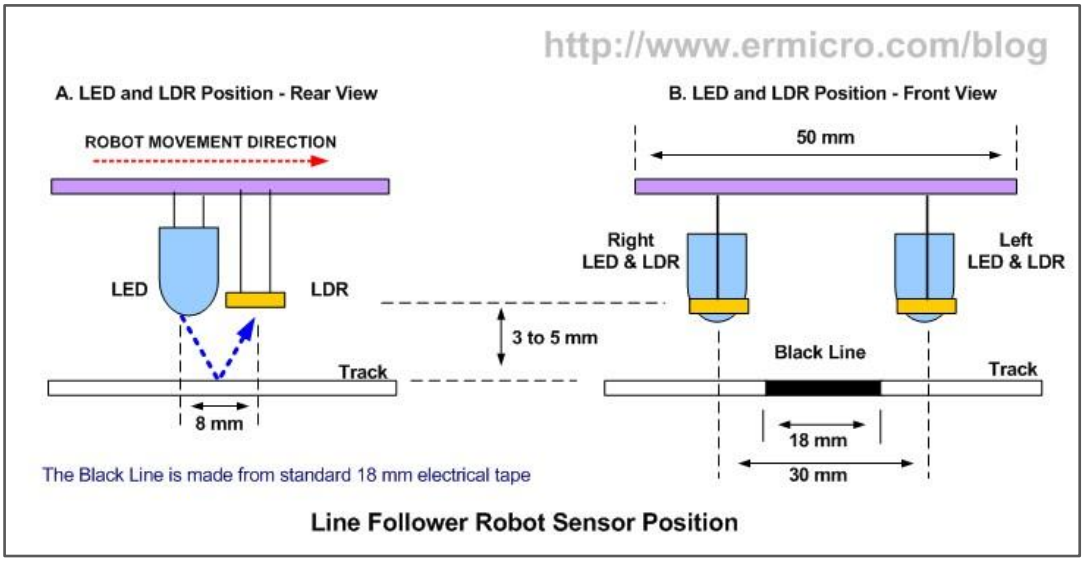
- White LED (Light Emitting Diode)
  - The white led reflects light back to the LDR (if the surface is not black)
  - See next slide for more details about how the LED and LDR work together

- 220 Ohm Resistor
  - This is a *ballast* resistor.
  - A common technique used to limit the current through the LED so it does not burn out.

- 10k Ohm Variable Resistor (Trimmer Potentiometer also called a Trimpot)
  - Controls the speed of the motor
  - More resistance will slow down the motor - can be used to control the max speed of the motor since it is constant.

- The Diode (1N4148)
  - Protects the transistor against the Back EMF (counter electromotive force) generated by the DC motor's inductor (coil) when it switches off.
  - Any surge of current that would reverse back into the collector of the transistor would be directed instead thru the diode and hence back into the motor (round and round) until it dissipates.

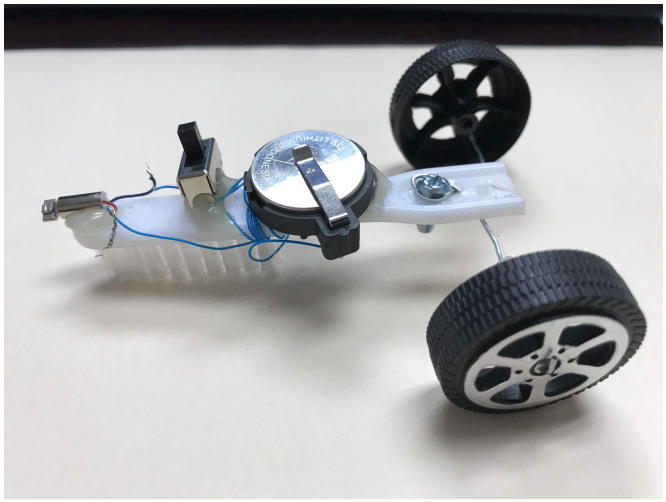
LDR Light Sensor



Optional: This slide will help illustrate how the LDR Circuit works.

Reference: More info can be found here: http://www.ermicro.com/blog/?p=1097

Drive System



- Vibration (Like a HexBug)
- Toothbrush Bristle
- Paper Clip
- Plastic Tires
- Pager Motor
- Switch

Talk about the Drive System portion of the Vampire Bristlebot. *Keep emphasizing "componentization" and its importance when working on large projects with many teams.*

- Discuss possible drive systems for the vampire bristlebot.
- Have them use their imaginations.
- Explain how the vibration drive system works and why it's so simple.
- Talk about how other drive systems might need a motor driver for speed control.
- Talk about servo and stepper motors.

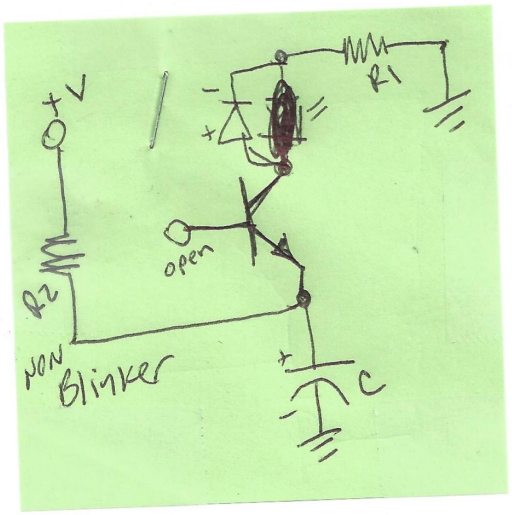
Vampire Bristlebot - Parts List

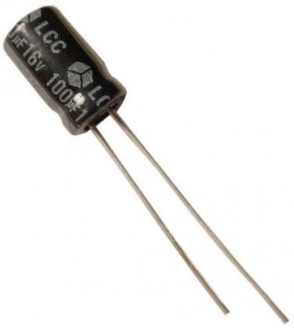
- PCB
- 2N3904 Transistor
- LDR (Light Dependent Resistor)
- 1N4148 Diode
- 220 & 1k Ohm Resistors
- 10k Ohm Variable Resistor
- White LED / Other LED
- Toothbrush
- 3v Tiny Pager Motor
- Switch (on/off)
- Paper Clip
- 2 Plastic tires
- 3v Coin Battery Holder
- 3v Coin Battery
- Wire Wrap Tool & Wire
- 100uf 10v Electrolytic Capacitor

NOTE: All the parts were purchased from Amazon. They have a nice selection now that the Arduino has sparked an interest in these as supporting components.

- Distribute the parts to the Scouts. Have them sort, organize and identify them.

Add-On: Blinking Light



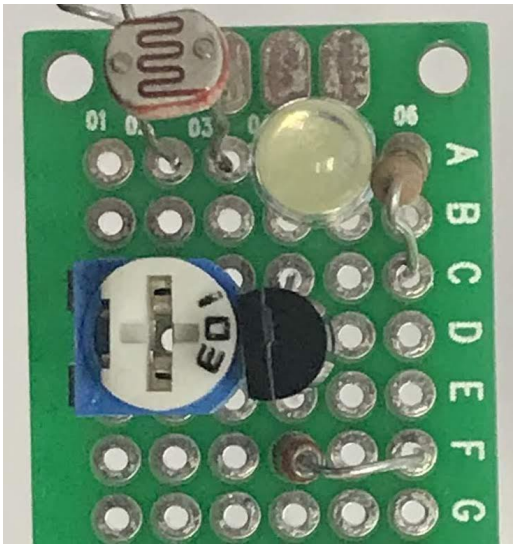


If we want to add an additional feature to our vampire bristlebot:

- Instead of just a plain LED - we want it to blink.
- Explain to the Scouts how this can be accomplished by introducing a **capacitor** and a resistor to the circuit.
- For a nice effect use these values for the blinker: (V=5v, R1=100, R2=1k, C=3300uf 16v, Transistor=2N2222A NPN)
- Have the Scouts draw a simple schematic of the LDR circuit with the additional components including the motor and a battery holder. They can use this in the next section for assembly.

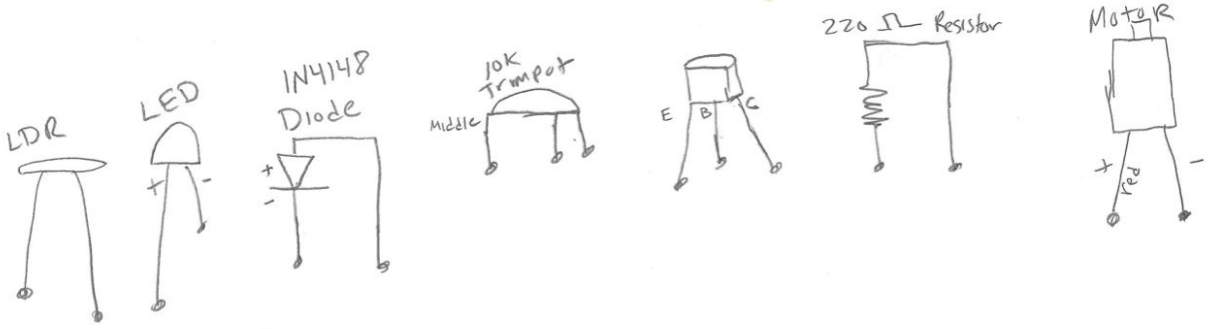
Reference: https://blog.jongallant.com/2015/01/simple-blinking-led/

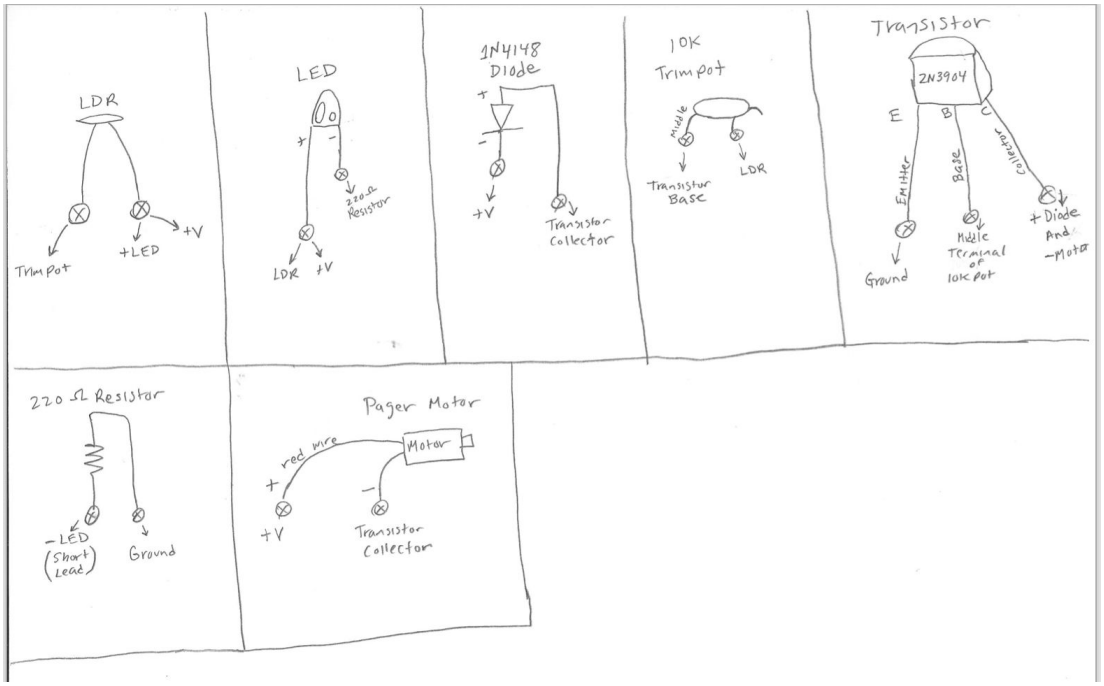
Assembly

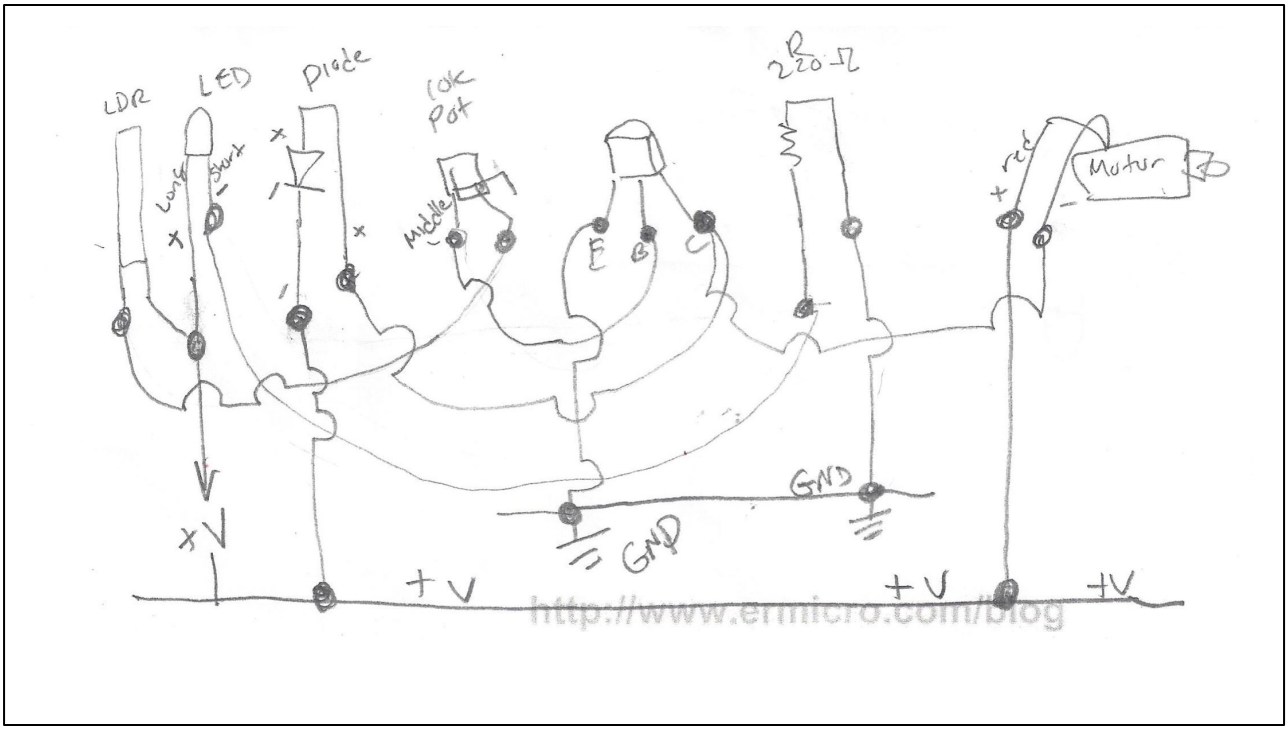


NOTE (Again) - *Assembly does NOT have to be fully completed to earn this merit badge. This is a challenging project to get working. It can be finished or expanded at home.*

The next few slide can help the Scouts layout the components on a PCB board and wire wrap them together under your direction. Allow them to be creative about what the assembly will look like and try and figure things out for themselves. For instance, an LED can be an “eye” - etc...


LDR
LED
+
-
IN4148
Diode
+
-
10K
Trimpot
Middle
E
B
C
220 Ω Resistor
Motor
+
Red
-


LDR
Trim Pot
+LED
+V
LED
220Ω Resistor
LDR
+V
1N4148 Diode
+V
Transistor Collector
10K Trim pot
Middle
Transistor Base
LDR
Transistor
2N3904
E
B
C
Emitter
Base
Collector
Ground
Middle Terminal of 10K Pot
+ Diode And -Motor
220Ω Resistor
-LED (Short Lead)
Ground
Pager Motor
red wire
Motor
+V
Transistor Collector


LDR
LED
Diode
10K Pot
220Ω
Motor
Long
Short
Middle
E
B
C
+V
GND
http://www.emmicro.com/blog

Requirements

The following requirements will be satisfied while working on the Project:

- 2a. Draw a simple schematic diagram. It must show resistors, capacitors and transistors or integrated circuits. Use the correct symbols. Label all parts.
- 2b. Tell the purpose of each part.
- 4ai. Discuss how to use electronics for a control purpose.
- 4c. Explain how the circuit you built operates.

Resources

Want to learn more???

- Micro center - STEM Section
- Amazon
- AllElectronics.com
- LittleBits
- Snap Circuits
- YouTube

Feedback

Hand out feedback forms here:

https://docs.google.com/document/d/1lyVvZobaMvzqZSjwRHaMY48Fk9T8jK6Ss6dqIgU_a5Q/edit?usp=sharing