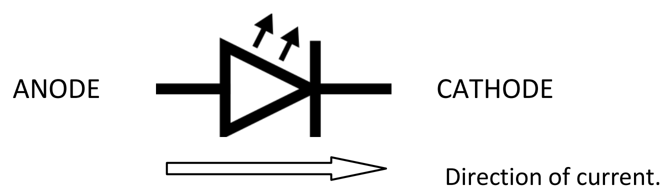
Electronics Merit Badge Kit
Theory of Operation

This is an explanation of how the merit badge kit functions. There are several topics worthy of discussion. These are:

1. LED operation.
2. Resistor function in this design.
3. Switch operation.
4. Microcontroller operation.

LED Operation

The schematic symbol for an LED is:

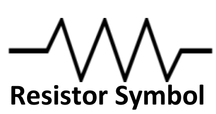


LED stands for light emitting diode. A <u>diode</u> is a more general term that describes an electronic component that allows electrons to flow through it (current) in only 1 direction. Current will only flow from the anode to the cathode. A <u>light emitting diode</u> has an additional characteristic, in that when enough current flows through it, the LED will light up. The amount of light the LED puts out is proportional to how much current flows through it, up to a limit. If too much current flows through it, the LED can overheat and 'burn up'.

It is important to install an LED correctly in the PCB when assembling the kit. If installed backwards, no current will flow through the diode, and the LED will not turn on.

Resistor Operation

The schematic symbol for a resistor is:



A resistor is an electrical component that resists the flow of electrons (current). Units for resistance is ohms. The larger the resistor value, in ohms, the more resistance to electron flow the resistor exhibits.

This is important in the operation of the kit, because a resistor is used to control how much current is allowed to flow through the LED. This accomplishes two things in this design:

Firstly, and most obviously, setting the resistor value (in our case, it is set to 200 ohms) will limit how much current can flow through the diode, and consequently how much light the diode will emit.

Secondly, this resistor value will have a direct effect on battery life. If we used a smaller resistor, then more current would flow through the diode, more light would be emitted, but the batteries would run down more quickly.

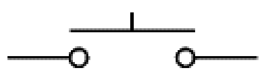
Switch Operation

There are two types of switches used in the kit design. The first switch is a SPST, or single pole, single throw switch. The schematic symbol for that is:

SPST Switch

This switch is used to connect the battery to the rest of the circuit. It is the on/off switch. If the switch is in the off position, there is not connection from the battery to the circuit board components. Hence, the circuit is off. Note that this type of switch is used in many places, though the size and amount of current the switch can handle varies. A good example of general use of this switch type is the wall switch that turns on the lights in a room.

The second type of switch used in this design is the momentary, push button switch. The schematic symbol for this switch is:



Momentary Switch

There are 2 of these switches used in this design. One switch is used as a 'START' button, and the second is used as a 'MODE' button. The operation of this switch is fairly straight forward. Pressing the button down will connect the two terminals of the switch, while releasing the switch disconnects the two terminals.

Microcontroller Operation

The microcontroller is a small computer chip that can be programmed to perform a specific function. In the case of this merit badge kit, the microcontroller (micro) waits for the 'START' or 'MODE' button press, and controls the LED display accordingly.

Several display modes are available, but we will only discuss in detail the single LED mode (available when the circuit is powered up, before the 'MODE' button is pressed), and discuss briefly the two LED mode.

First, let's discuss the technique used to turn on an LED. For this design, there are 12 LEDs that can be lit. The way the circuit is designed, and the way the software has been written, only 1 LED is turned on at any moment. This is necessary for those LEDs 1-8 and 12, since all these LEDs share 1 current limiting resistor. Since all these LEDs share a single resistor, if 2 LEDs where turned on at the same time, their light intensity would go down, because total current is determined by the resistor. This would basically allow only half the amount of current to go through each of these 2 LEDs, and their intensity would be dramatically less. So, for this circuit's operation, only 1 LED may be turned on at a time.

LED Multiplexing

I use a simple technique called multiplexing when lighting the LEDs. Let's use the case when we want to show 2 LEDs on at the same time (the 2 LED mode). Since we are only allowed to turn on 1 LED at a time by virtue of the circuit design, we turn one LED on for a short time, and then turn the second one on for a short time, and we repeat this sequence very quickly. Even though we are turning 1 LED on and then off, and turning the other LED on and then off, to our eyes it appears that both LEDs are turned on at the same time. This technique can be extended so that all 12 LEDs can appear to be turned on at the same time. This is a very popular technique used on many displays.

A benefit of using this technique is that it reduces the number of components used for this design, and more importantly, it reduces how much current we need from the batteries, which makes the batteries last longer. Since we are only turning on one LED at a time, we use a minimal amount of current from the battery. Imagine if the circuit was designed such that all 12 LEDs could be turned on simultaneously, we would use the batteries up 12 times faster.

Circuit Operation

So, here is a description of the software that is running in the micro, and how that relates to the circuit operation.

Once the circuit is powered up, a single LED is illuminated, which indicates the micro is ready for an input from one of the switches. If the 'MODE' button is pressed, the micro adjusts itself to change how the LEDs will be controlled. When the 'START' button is pressed, the micro begins displaying the LEDs in the selected sequence. As long as the 'START' button is pressed, the LED spin rate will stay at its maximum rate. Once the 'START' button is released, the micro will begin slowing the spin at a predetermined rate. The randomness of the circuit (which is the last LED lit when the spin cycle is completed?) is determined by how long the 'START' button is pressed.

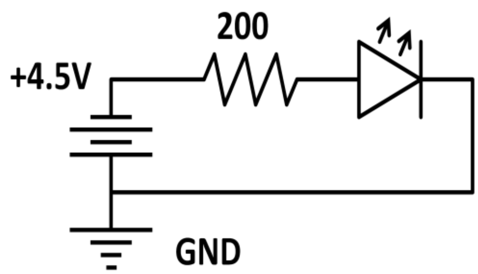
The micro consists of a CPU (central processing unit), memory and I/O.

The CPU executes the command sequences defined by the program I wrote to do this function. This program is written in the 'C' programming language.

Memory holds temporary values that the program uses while controlling the circuit. An example of a memory item would be which LED is currently being displayed. This would take on the value of 0 to 11 (for 12 LEDs), and would be changed when a different LED is to be displayed.

I/O stands for Input/Output, and is the part of the microcontroller that interfaces to our circuit. There are 2 inputs defined for this design; 'START' and 'MODE'. When one of these buttons is pressed, the voltage that is present at that particular input will be connected to ground (0 volts). When the button is released, the voltage will return to a voltage value that is the same as the battery voltage (approximately 4.5 volts). Logically we can say that when the button is pressed, a logical 0 is presented to the microcontroller pin, and when the button is released, a logical '1' is presented to the pin. The operating program is continuously monitoring these 2 inputs, and can detect when the input changes from a 1 to a 0 and when it changes from a 0 to a 1. The program modifies its operation based on how it interprets these 2 inputs.

There are 12 outputs in this design, each one controlling a single LED. When the output pin is driven to a logical '1', the LED connected to that pin will light up. The following schematic diagram illustrates one LED circuit.



For the purposes of this discussion, we will use a green LED as an example. From a datasheet of a typical green LED:

Electrical / Optical Characteristics at TA=25°C

Symbol	Parameter	Device	Typ.	Max.	Units	Test Conditions
λpeak	Peak Wavelength	Green	565		nm	I_F=20mA
λD [1]	Dominant Wavelength	Green	568		nm	I_F=20mA
$\Delta\lambda$1/2	Spectral Line Half-width	Green	30		nm	I_F=20mA
C	Capacitance	Green	15		pF	V_F=0V;f=1MHz
V_F [2]	Forward Voltage	Green	2.2	2.5	V	I_F=20mA
I_R	Reverse Current	Green		10	uA	V_R = 5V

Notes:
1.Wavelength: +/-1nm.
2. Forward Voltage: +/-0.1V.

Of importance from this datasheet, the forward voltage drop across this LED is typically 2.2V, but a maximum of 2.5V. If we assume a maximum voltage drop across the LED, we can calculate how much current will go through the LED in our circuit.

From Ohms LAW: I = V / R. Since V_BATTERY = 4.5V, and V_LED = 2.5V, the current will be:

(4.5-2.5) / 200 = .010 Amps => 10 milliamps.

From this, we can say that the each LED, when lit, sees about 10 milliamps of current. This determines the light intensity of the LED (and as previously discussed, the longevity of the batteries).

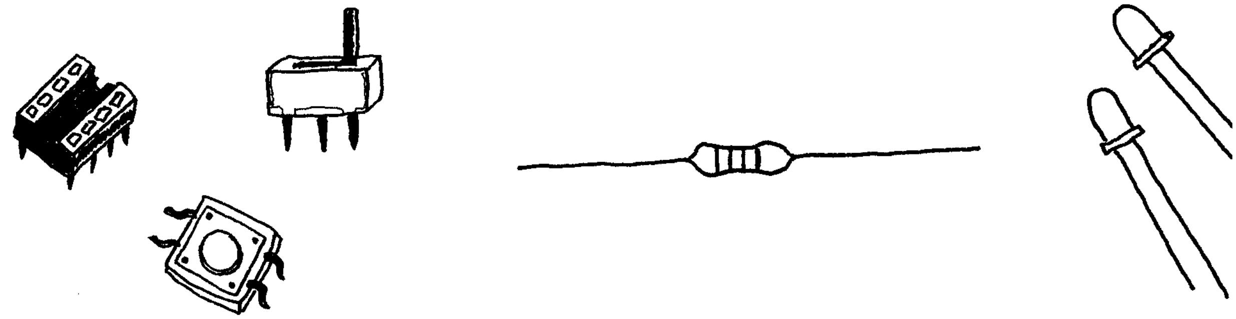
So, when the micro sets one of its outputs to logical 1, the LED will turn on, and its intensity will be determined by the 200 ohm resistor. The micro program will control the order of LEDs and timing of LEDs, until the predetermined sequence has concluded.

I will make a final comment about R2-R4, which are individual 200 ohm resistors dedicated to a single micro output and LED. These separate circuits are identical in function to the other LEDs that share a single resistor, but the separation is necessary when I want to write a new control program into the micro. There are 4 special pins used when writing a new program, three of which are also used to control LEDs.

Also, R5, which is a 56K resistor, connects to a special pin on the micro that has no functional purposes when operating the circuit, but does have a purpose when operating the micro in a special debug mode, which is used when writing the program.

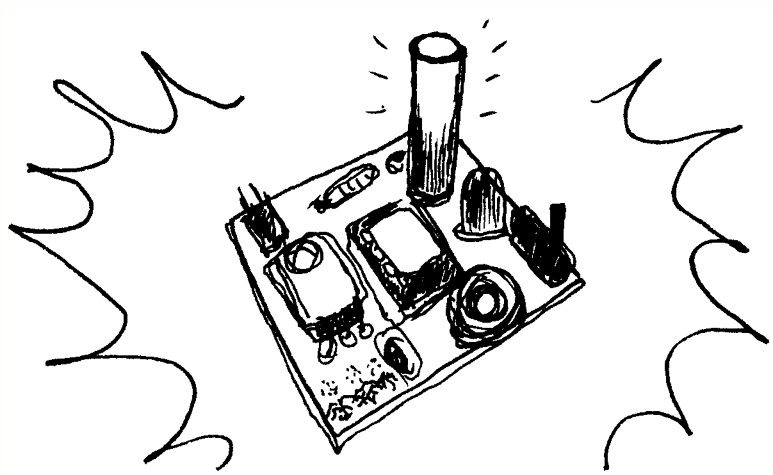
Decimal - Binary - Octal - Hex – ASCII
Conversion Chart

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



SOLDERING IS EASY

HERE'S HOW TO DO IT



BY: **MITCH ALTMAN**
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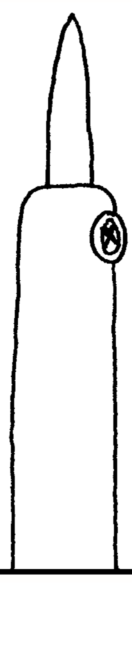
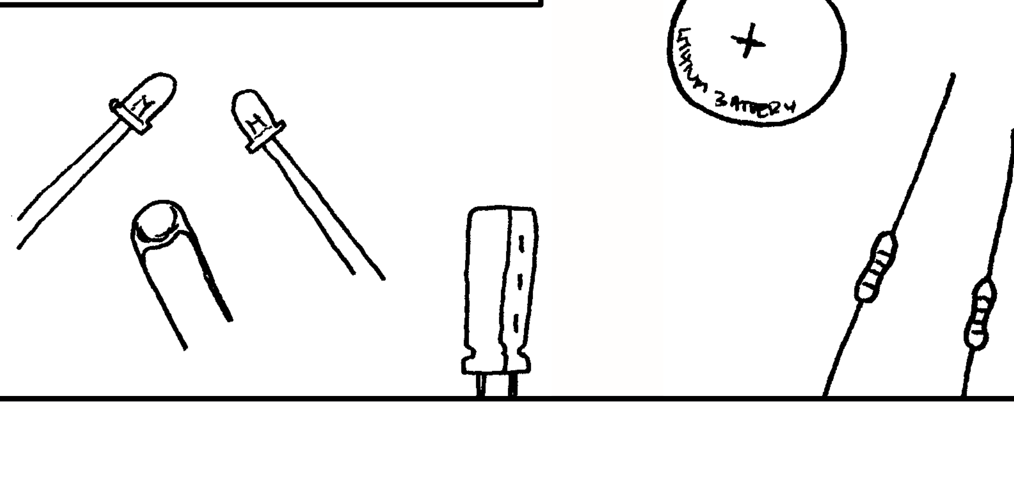
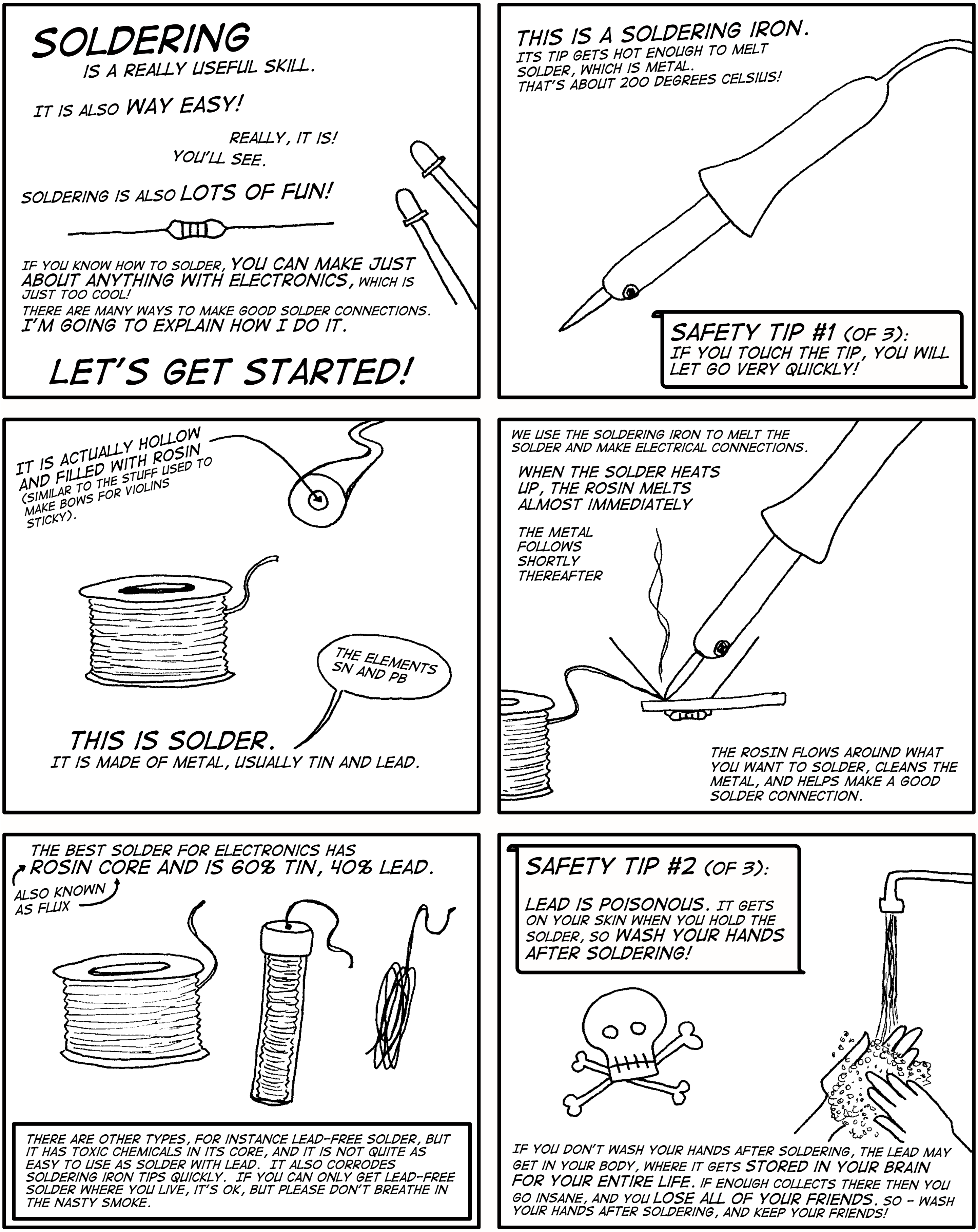
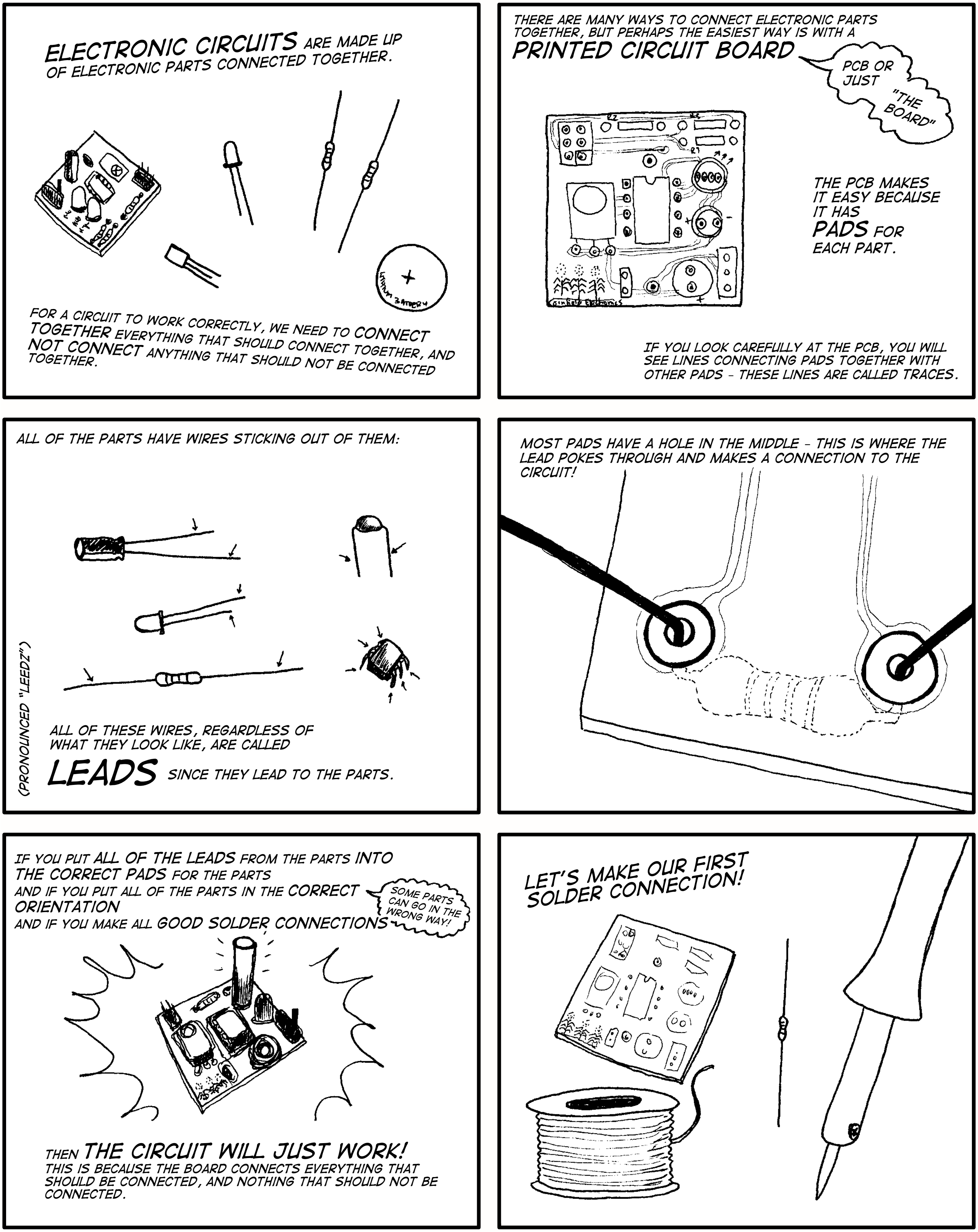


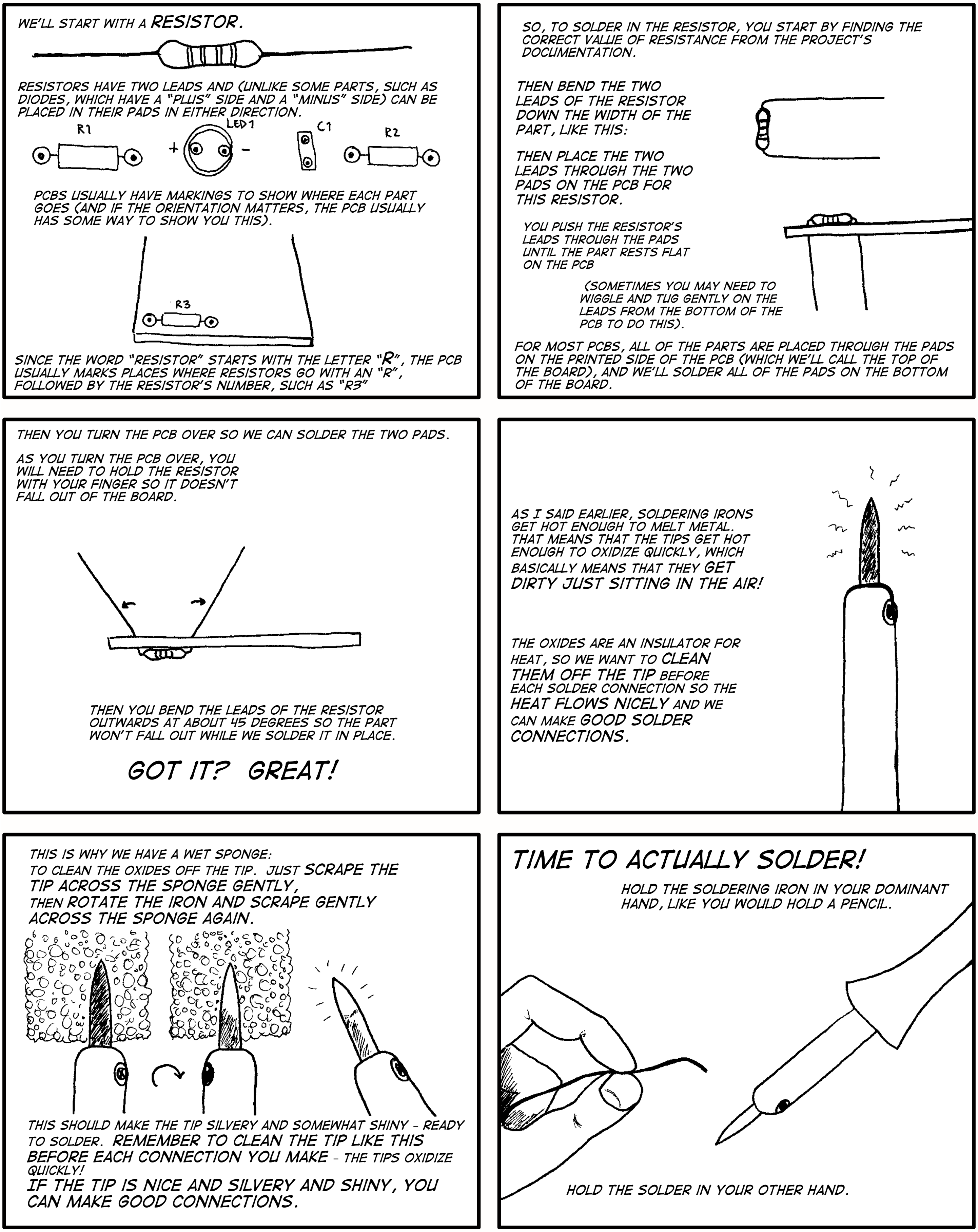
DOWNLOAD THIS COMIC BOOK AND SHARE IT WITH YOUR FRIENDS!

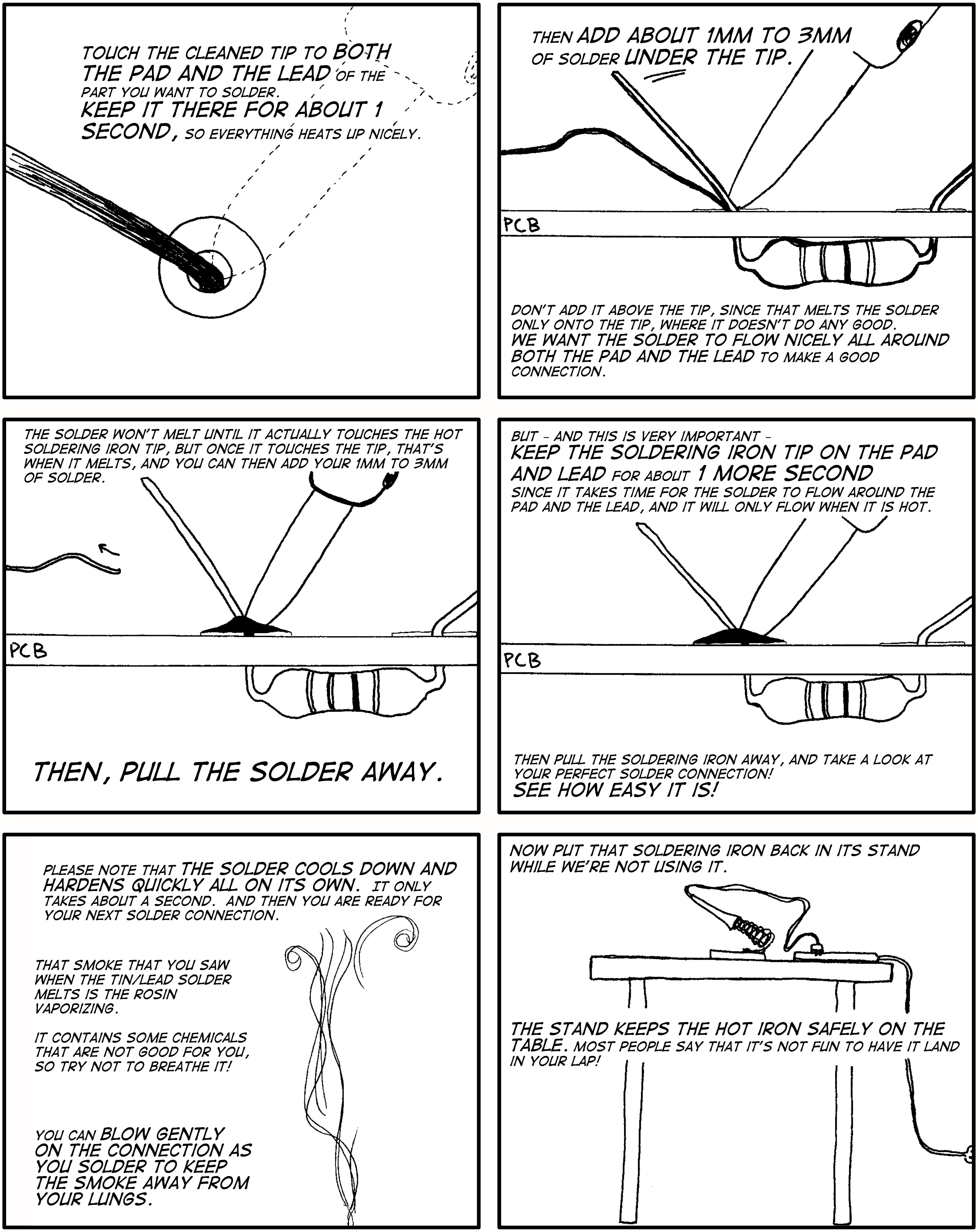
HTTP://MIGHTYOHM.COM/SOLDERCOMIC

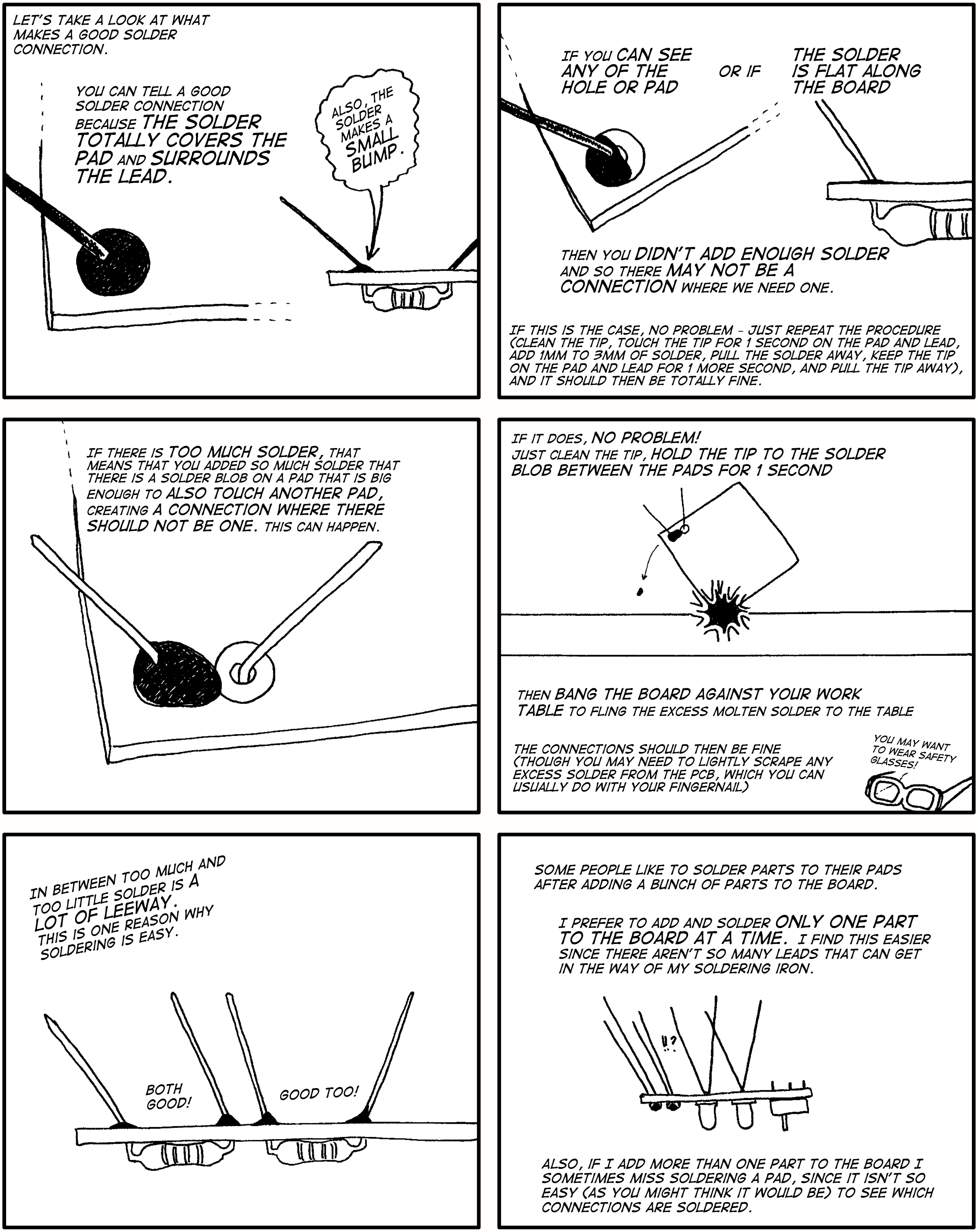


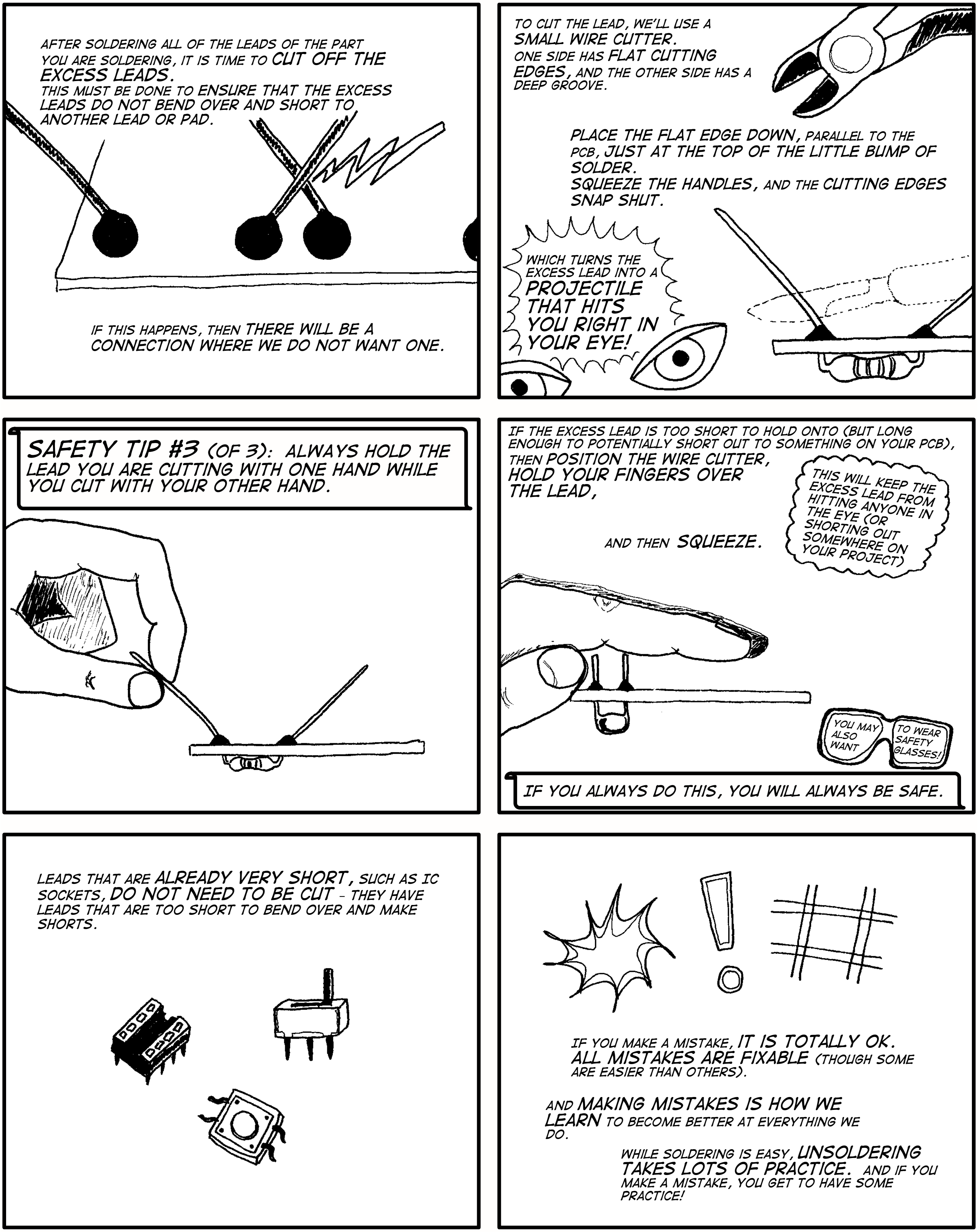

SOLDERING
IS A REALLY USEFUL SKILL.
IT IS ALSO WAY EASY!
REALLY, IT IS!
YOU'LL SEE.
SOLDERING IS ALSO LOTS OF FUN!
IF YOU KNOW HOW TO SOLDER, YOU CAN MAKE JUST ABOUT ANYTHING WITH ELECTRONICS, WHICH IS JUST TOO COOL!
THERE ARE MANY WAYS TO MAKE GOOD SOLDER CONNECTIONS.
I'M GOING TO EXPLAIN HOW I DO IT.
LET'S GET STARTED!
THIS IS A SOLDERING IRON.
ITS TIP GETS HOT ENOUGH TO MELT SOLDER, WHICH IS METAL.
THAT'S ABOUT 200 DEGREES CELSIUS!
SAFETY TIP #1 (OF 3):
IF YOU TOUCH THE TIP, YOU WILL LET GO VERY QUICKLY!
IT IS ACTUALLY HOLLOW AND FILLED WITH ROSIN
(SIMILAR TO THE STUFF USED TO MAKE BOWS FOR VIOLINS STICKY).
THE ELEMENTS SN AND PB
THIS IS SOLDER.
IT IS MADE OF METAL, USUALLY TIN AND LEAD.
WE USE THE SOLDERING IRON TO MELT THE SOLDER AND MAKE ELECTRICAL CONNECTIONS.
WHEN THE SOLDER HEATS UP, THE ROSIN MELTS ALMOST IMMEDIATELY
THE METAL FOLLOWS SHORTLY THEREAFTER
THE ROSIN FLOWS AROUND WHAT YOU WANT TO SOLDER, CLEANS THE METAL, AND HELPS MAKE A GOOD SOLDER CONNECTION.
THE BEST SOLDER FOR ELECTRONICS HAS ROSIN CORE AND IS 60% TIN, 40% LEAD.
ALSO KNOWN AS FLUX
THERE ARE OTHER TYPES, FOR INSTANCE LEAD-FREE SOLDER, BUT IT HAS TOXIC CHEMICALS IN ITS CORE, AND IT IS NOT QUITE AS EASY TO USE AS SOLDER WITH LEAD. IT ALSO CORRODES SOLDERING IRON TIPS QUICKLY. IF YOU CAN ONLY GET LEAD-FREE SOLDER WHERE YOU LIVE, IT'S OK, BUT PLEASE DON'T BREATHE IN THE NASTY SMOKE.
SAFETY TIP #2 (OF 3):
LEAD IS POISONOUS. IT GETS ON YOUR SKIN WHEN YOU HOLD THE SOLDER, SO WASH YOUR HANDS AFTER SOLDERING!
IF YOU DON'T WASH YOUR HANDS AFTER SOLDERING, THE LEAD MAY GET IN YOUR BODY, WHERE IT GETS STORED IN YOUR BRAIN FOR YOUR ENTIRE LIFE. IF ENOUGH COLLECTS THERE THEN YOU GO INSANE, AND YOU LOSE ALL OF YOUR FRIENDS. SO - WASH YOUR HANDS AFTER SOLDERING, AND KEEP YOUR FRIENDS!


ELECTRONIC CIRCUITS ARE MADE UP OF ELECTRONIC PARTS CONNECTED TOGETHER.
FOR A CIRCUIT TO WORK CORRECTLY, WE NEED TO CONNECT TOGETHER EVERYTHING THAT SHOULD CONNECT TOGETHER, AND NOT CONNECT ANYTHING THAT SHOULD NOT BE CONNECTED TOGETHER.
THERE ARE MANY WAYS TO CONNECT ELECTRONIC PARTS TOGETHER, BUT PERHAPS THE EASIEST WAY IS WITH A PRINTED CIRCUIT BOARD
PCB OR JUST "THE BOARD"
THE PCB MAKES IT EASY BECAUSE IT HAS PADS FOR EACH PART.
IF YOU LOOK CAREFULLY AT THE PCB, YOU WILL SEE LINES CONNECTING PADS TOGETHER WITH OTHER PADS - THESE LINES ARE CALLED TRACES.
ALL OF THE PARTS HAVE WIRES STICKING OUT OF THEM:
ALL OF THESE WIRES, REGARDLESS OF WHAT THEY LOOK LIKE, ARE CALLED LEADS SINCE THEY LEAD TO THE PARTS.
(PRONOUNCED "LEEDZ")
MOST PADS HAVE A HOLE IN THE MIDDLE - THIS IS WHERE THE LEAD POKES THROUGH AND MAKES A CONNECTION TO THE CIRCUIT!
IF YOU PUT ALL OF THE LEADS FROM THE PARTS INTO THE CORRECT PADS FOR THE PARTS
AND IF YOU PUT ALL OF THE PARTS IN THE CORRECT ORIENTATION
AND IF YOU MAKE ALL GOOD SOLDER CONNECTIONS
SOME PARTS CAN GO IN THE WRONG WAY!
THEN THE CIRCUIT WILL JUST WORK!
THIS IS BECAUSE THE BOARD CONNECTS EVERYTHING THAT SHOULD BE CONNECTED, AND NOTHING THAT SHOULD NOT BE CONNECTED.
LET'S MAKE OUR FIRST SOLDER CONNECTION!

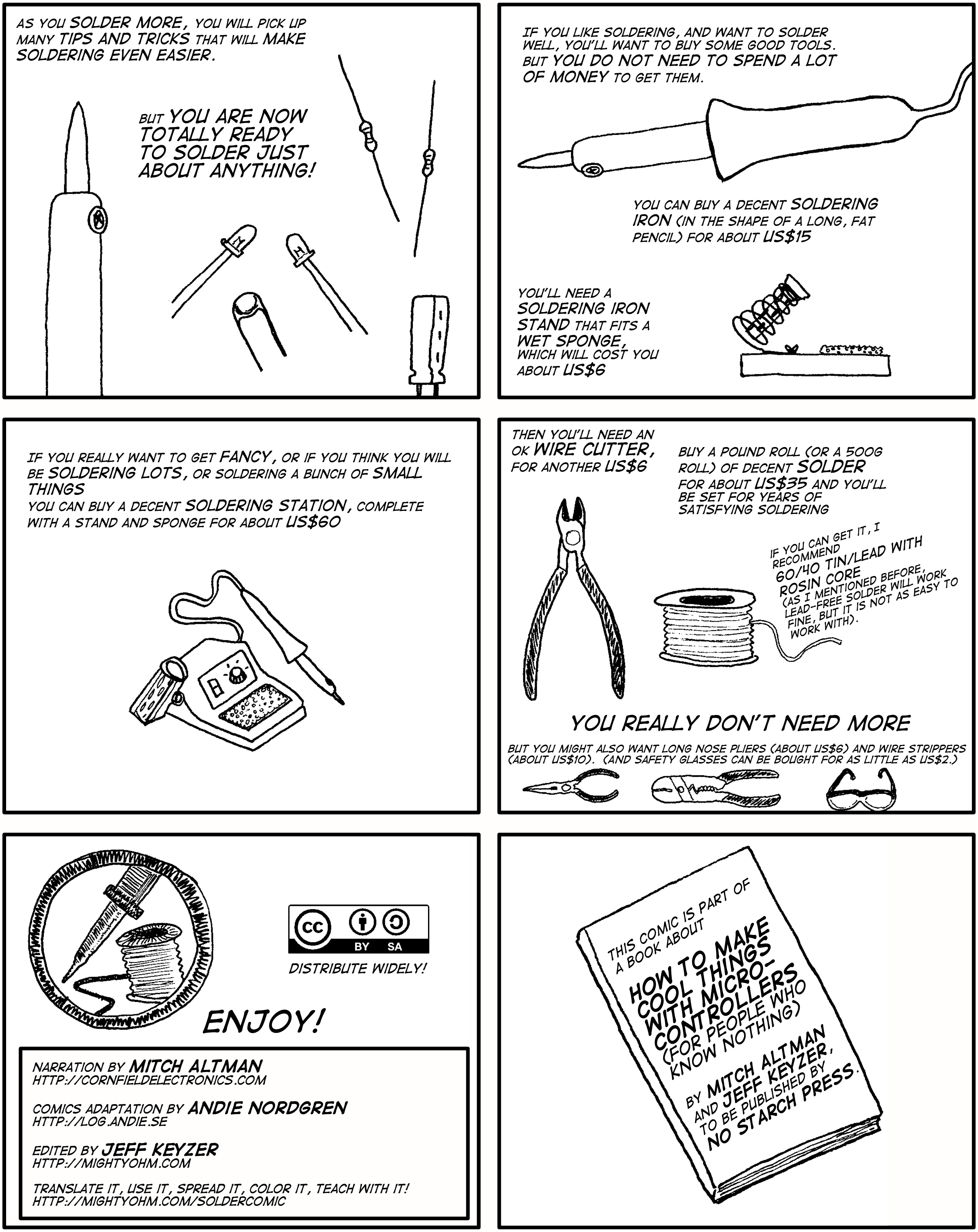

WE'LL START WITH A RESISTOR.
RESISTORS HAVE TWO LEADS AND (UNLIKE SOME PARTS, SUCH AS DIODES, WHICH HAVE A "PLUS" SIDE AND A "MINUS" SIDE) CAN BE PLACED IN THEIR PADS IN EITHER DIRECTION.
R1
LED1
C1
R2
+
-
PCBS USUALLY HAVE MARKINGS TO SHOW WHERE EACH PART GOES (AND IF THE ORIENTATION MATTERS, THE PCB USUALLY HAS SOME WAY TO SHOW YOU THIS).
R3
SINCE THE WORD "RESISTOR" STARTS WITH THE LETTER "R", THE PCB USUALLY MARKS PLACES WHERE RESISTORS GO WITH AN "R", FOLLOWED BY THE RESISTOR'S NUMBER, SUCH AS "R3"
SO, TO SOLDER IN THE RESISTOR, YOU START BY FINDING THE CORRECT VALUE OF RESISTANCE FROM THE PROJECT'S DOCUMENTATION.
THEN BEND THE TWO LEADS OF THE RESISTOR DOWN THE WIDTH OF THE PART, LIKE THIS:
THEN PLACE THE TWO LEADS THROUGH THE TWO PADS ON THE PCB FOR THIS RESISTOR.
YOU PUSH THE RESISTOR'S LEADS THROUGH THE PADS UNTIL THE PART RESTS FLAT ON THE PCB
(SOMETIMES YOU MAY NEED TO WIGGLE AND TUG GENTLY ON THE LEADS FROM THE BOTTOM OF THE PCB TO DO THIS).
FOR MOST PCBS, ALL OF THE PARTS ARE PLACED THROUGH THE PADS ON THE PRINTED SIDE OF THE PCB (WHICH WE'LL CALL THE TOP OF THE BOARD), AND WE'LL SOLDER ALL OF THE PADS ON THE BOTTOM OF THE BOARD.
THEN YOU TURN THE PCB OVER SO WE CAN SOLDER THE TWO PADS.
AS YOU TURN THE PCB OVER, YOU WILL NEED TO HOLD THE RESISTOR WITH YOUR FINGER SO IT DOESN'T FALL OUT OF THE BOARD.
THEN YOU BEND THE LEADS OF THE RESISTOR OUTWARDS AT ABOUT 45 DEGREES SO THE PART WON'T FALL OUT WHILE WE SOLDER IT IN PLACE.
GOT IT? GREAT!
AS I SAID EARLIER, SOLDERING IRONS GET HOT ENOUGH TO MELT METAL. THAT MEANS THAT THE TIPS GET HOT ENOUGH TO OXIDIZE QUICKLY, WHICH BASICALLY MEANS THAT THEY GET DIRTY JUST SITTING IN THE AIR!
THE OXIDES ARE AN INSULATOR FOR HEAT, SO WE WANT TO CLEAN THEM OFF THE TIP BEFORE EACH SOLDER CONNECTION SO THE HEAT FLOWS NICELY AND WE CAN MAKE GOOD SOLDER CONNECTIONS.
THIS IS WHY WE HAVE A WET SPONGE: TO CLEAN THE OXIDES OFF THE TIP. JUST SCRAPE THE TIP ACROSS THE SPONGE GENTLY, THEN ROTATE THE IRON AND SCRAPE GENTLY ACROSS THE SPONGE AGAIN.
THIS SHOULD MAKE THE TIP SILVERY AND SOMEWHAT SHINY - READY TO SOLDER. REMEMBER TO CLEAN THE TIP LIKE THIS BEFORE EACH CONNECTION YOU MAKE - THE TIPS OXIDIZE QUICKLY!
IF THE TIP IS NICE AND SILVERY AND SHINY, YOU CAN MAKE GOOD CONNECTIONS.
TIME TO ACTUALLY SOLDER!
HOLD THE SOLDERING IRON IN YOUR DOMINANT HAND, LIKE YOU WOULD HOLD A PENCIL.
HOLD THE SOLDER IN YOUR OTHER HAND.


TOUCH THE CLEANED TIP TO BOTH THE PAD AND THE LEAD OF THE PART YOU WANT TO SOLDER.
KEEP IT THERE FOR ABOUT 1 SECOND, SO EVERYTHING HEATS UP NICELY.
THEN ADD ABOUT 1MM TO 3MM OF SOLDER UNDER THE TIP.
PCB
DON'T ADD IT ABOVE THE TIP, SINCE THAT MELTS THE SOLDER ONLY ONTO THE TIP, WHERE IT DOESN'T DO ANY GOOD.
WE WANT THE SOLDER TO FLOW NICELY ALL AROUND BOTH THE PAD AND THE LEAD TO MAKE A GOOD CONNECTION.
THE SOLDER WON'T MELT UNTIL IT ACTUALLY TOUCHES THE HOT SOLDERING IRON TIP, BUT ONCE IT TOUCHES THE TIP, THAT'S WHEN IT MELTS, AND YOU CAN THEN ADD YOUR 1MM TO 3MM OF SOLDER.
PCB
THEN, PULL THE SOLDER AWAY.
BUT - AND THIS IS VERY IMPORTANT -
KEEP THE SOLDERING IRON TIP ON THE PAD AND LEAD FOR ABOUT 1 MORE SECOND
SINCE IT TAKES TIME FOR THE SOLDER TO FLOW AROUND THE PAD AND THE LEAD, AND IT WILL ONLY FLOW WHEN IT IS HOT.
PCB
THEN PULL THE SOLDERING IRON AWAY, AND TAKE A LOOK AT YOUR PERFECT SOLDER CONNECTION!
SEE HOW EASY IT IS!
PLEASE NOTE THAT THE SOLDER COOLS DOWN AND HARDENS QUICKLY ALL ON ITS OWN. IT ONLY TAKES ABOUT A SECOND. AND THEN YOU ARE READY FOR YOUR NEXT SOLDER CONNECTION.
THAT SMOKE THAT YOU SAW WHEN THE TIN/LEAD SOLDER MELTS IS THE ROSIN VAPORIZING.
IT CONTAINS SOME CHEMICALS THAT ARE NOT GOOD FOR YOU, SO TRY NOT TO BREATHE IT!
YOU CAN BLOW GENTLY ON THE CONNECTION AS YOU SOLDER TO KEEP THE SMOKE AWAY FROM YOUR LUNGS.
NOW PUT THAT SOLDERING IRON BACK IN ITS STAND WHILE WE'RE NOT USING IT.
THE STAND KEEPS THE HOT IRON SAFELY ON THE TABLE. MOST PEOPLE SAY THAT IT'S NOT FUN TO HAVE IT LAND IN YOUR LAP!


LET'S TAKE A LOOK AT WHAT MAKES A GOOD SOLDER CONNECTION.
YOU CAN TELL A GOOD SOLDER CONNECTION BECAUSE THE SOLDER TOTALLY COVERS THE PAD AND SURROUNDS THE LEAD.
ALSO, THE SOLDER MAKES A SMALL BUMP.
IF YOU CAN SEE ANY OF THE HOLE OR PAD
OR IF
THE SOLDER IS FLAT ALONG THE BOARD
THEN YOU DIDN'T ADD ENOUGH SOLDER AND SO THERE MAY NOT BE A CONNECTION WHERE WE NEED ONE.
IF THIS IS THE CASE, NO PROBLEM - JUST REPEAT THE PROCEDURE (CLEAN THE TIP, TOUCH THE TIP FOR 1 SECOND ON THE PAD AND LEAD, ADD 1MM TO 3MM OF SOLDER, PULL THE SOLDER AWAY, KEEP THE TIP ON THE PAD AND LEAD FOR 1 MORE SECOND, AND PULL THE TIP AWAY), AND IT SHOULD THEN BE TOTALLY FINE.
IF THERE IS TOO MUCH SOLDER, THAT MEANS THAT YOU ADDED SO MUCH SOLDER THAT THERE IS A SOLDER BLOB ON A PAD THAT IS BIG ENOUGH TO ALSO TOUCH ANOTHER PAD, CREATING A CONNECTION WHERE THERE SHOULD NOT BE ONE. THIS CAN HAPPEN.
IF IT DOES, NO PROBLEM! JUST CLEAN THE TIP, HOLD THE TIP TO THE SOLDER BLOB BETWEEN THE PADS FOR 1 SECOND
THEN BANG THE BOARD AGAINST YOUR WORK TABLE TO FLING THE EXCESS MOLTEN SOLDER TO THE TABLE
THE CONNECTIONS SHOULD THEN BE FINE (THOUGH YOU MAY NEED TO LIGHTLY SCRAPE ANY EXCESS SOLDER FROM THE PCB, WHICH YOU CAN USUALLY DO WITH YOUR FINGERNAIL)
YOU MAY WANT TO WEAR SAFETY GLASSES!
IN BETWEEN TOO MUCH AND TOO LITTLE SOLDER IS A LOT OF LEEWAY. THIS IS ONE REASON WHY SOLDERING IS EASY.
BOTH GOOD!
GOOD TOO!
SOME PEOPLE LIKE TO SOLDER PARTS TO THEIR PADS AFTER ADDING A BUNCH OF PARTS TO THE BOARD.
I PREFER TO ADD AND SOLDER ONLY ONE PART TO THE BOARD AT A TIME. I FIND THIS EASIER SINCE THERE AREN'T SO MANY LEADS THAT CAN GET IN THE WAY OF MY SOLDERING IRON.
!!?
ALSO, IF I ADD MORE THAN ONE PART TO THE BOARD I SOMETIMES MISS SOLDERING A PAD, SINCE IT ISN'T SO EASY (AS YOU MIGHT THINK IT WOULD BE) TO SEE WHICH CONNECTIONS ARE SOLDERED.



AFTER SOLDERING ALL OF THE LEADS OF THE PART YOU ARE SOLDERING, IT IS TIME TO CUT OFF THE EXCESS LEADS.
THIS MUST BE DONE TO ENSURE THAT THE EXCESS LEADS DO NOT BEND OVER AND SHORT TO ANOTHER LEAD OR PAD.
IF THIS HAPPENS, THEN THERE WILL BE A CONNECTION WHERE WE DO NOT WANT ONE.
TO CUT THE LEAD, WE'LL USE A SMALL WIRE CUTTER.
ONE SIDE HAS FLAT CUTTING EDGES, AND THE OTHER SIDE HAS A DEEP GROOVE.
PLACE THE FLAT EDGE DOWN, PARALLEL TO THE PCB, JUST AT THE TOP OF THE LITTLE BUMP OF SOLDER.
SQUEEZE THE HANDLES, AND THE CUTTING EDGES SNAP SHUT.
WHICH TURNS THE EXCESS LEAD INTO A PROJECTILE THAT HITS YOU RIGHT IN YOUR EYE!
SAFETY TIP #3 (OF 3): ALWAYS HOLD THE LEAD YOU ARE CUTTING WITH ONE HAND WHILE YOU CUT WITH YOUR OTHER HAND.
IF THE EXCESS LEAD IS TOO SHORT TO HOLD ONTO (BUT LONG ENOUGH TO POTENTIALLY SHORT OUT TO SOMETHING ON YOUR PCB), THEN POSITION THE WIRE CUTTER, HOLD YOUR FINGERS OVER THE LEAD,
THIS WILL KEEP THE EXCESS LEAD FROM HITTING ANYONE IN THE EYE (OR SHORTING OUT SOMEWHERE ON YOUR PROJECT)
AND THEN SQUEEZE.
YOU MAY ALSO WANT TO WEAR SAFETY GLASSES!
IF YOU ALWAYS DO THIS, YOU WILL ALWAYS BE SAFE.
LEADS THAT ARE ALREADY VERY SHORT, SUCH AS IC SOCKETS, DO NOT NEED TO BE CUT - THEY HAVE LEADS THAT ARE TOO SHORT TO BEND OVER AND MAKE SHORTS.
IF YOU MAKE A MISTAKE, IT IS TOTALLY OK. ALL MISTAKES ARE FIXABLE (THOUGH SOME ARE EASIER THAN OTHERS).
AND MAKING MISTAKES IS HOW WE LEARN TO BECOME BETTER AT EVERYTHING WE DO.
WHILE SOLDERING IS EASY, UNSOLDERING TAKES LOTS OF PRACTICE. AND IF YOU MAKE A MISTAKE, YOU GET TO HAVE SOME PRACTICE!



AS YOU SOLDER MORE, YOU WILL PICK UP MANY TIPS AND TRICKS THAT WILL MAKE SOLDERING EVEN EASIER.
BUT YOU ARE NOW TOTALLY READY TO SOLDER JUST ABOUT ANYTHING!
IF YOU LIKE SOLDERING, AND WANT TO SOLDER WELL, YOU'LL WANT TO BUY SOME GOOD TOOLS. BUT YOU DO NOT NEED TO SPEND A LOT OF MONEY TO GET THEM.
YOU CAN BUY A DECENT SOLDERING IRON (IN THE SHAPE OF A LONG, FAT PENCIL) FOR ABOUT US$15
YOU'LL NEED A SOLDERING IRON STAND THAT FITS A WET SPONGE, WHICH WILL COST YOU ABOUT US$6
IF YOU REALLY WANT TO GET FANCY, OR IF YOU THINK YOU WILL BE SOLDERING LOTS, OR SOLDERING A BUNCH OF SMALL THINGS
YOU CAN BUY A DECENT SOLDERING STATION, COMPLETE WITH A STAND AND SPONGE FOR ABOUT US$60
THEN YOU'LL NEED AN OK WIRE CUTTER, FOR ANOTHER US$6
BUY A POUND ROLL (OR A 500G ROLL) OF DECENT SOLDER FOR ABOUT US$35 AND YOU'LL BE SET FOR YEARS OF SATISFYING SOLDERING
IF YOU CAN GET IT, I RECOMMEND 60/40 TIN/LEAD WITH ROSIN CORE (AS I MENTIONED BEFORE, LEAD-FREE SOLDER WILL WORK FINE, BUT IT IS NOT AS EASY TO WORK WITH).
YOU REALLY DON'T NEED MORE
BUT YOU MIGHT ALSO WANT LONG NOSE PLIERS (ABOUT US$6) AND WIRE STRIPPERS (ABOUT US$10). (AND SAFETY GLASSES CAN BE BOUGHT FOR AS LITTLE AS US$2.)
BY SA
DISTRIBUTE WIDELY!
ENJOY!
NARRATION BY MITCH ALTMAN
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TRANSLATE IT, USE IT, SPREAD IT, COLOR IT, TEACH WITH IT!
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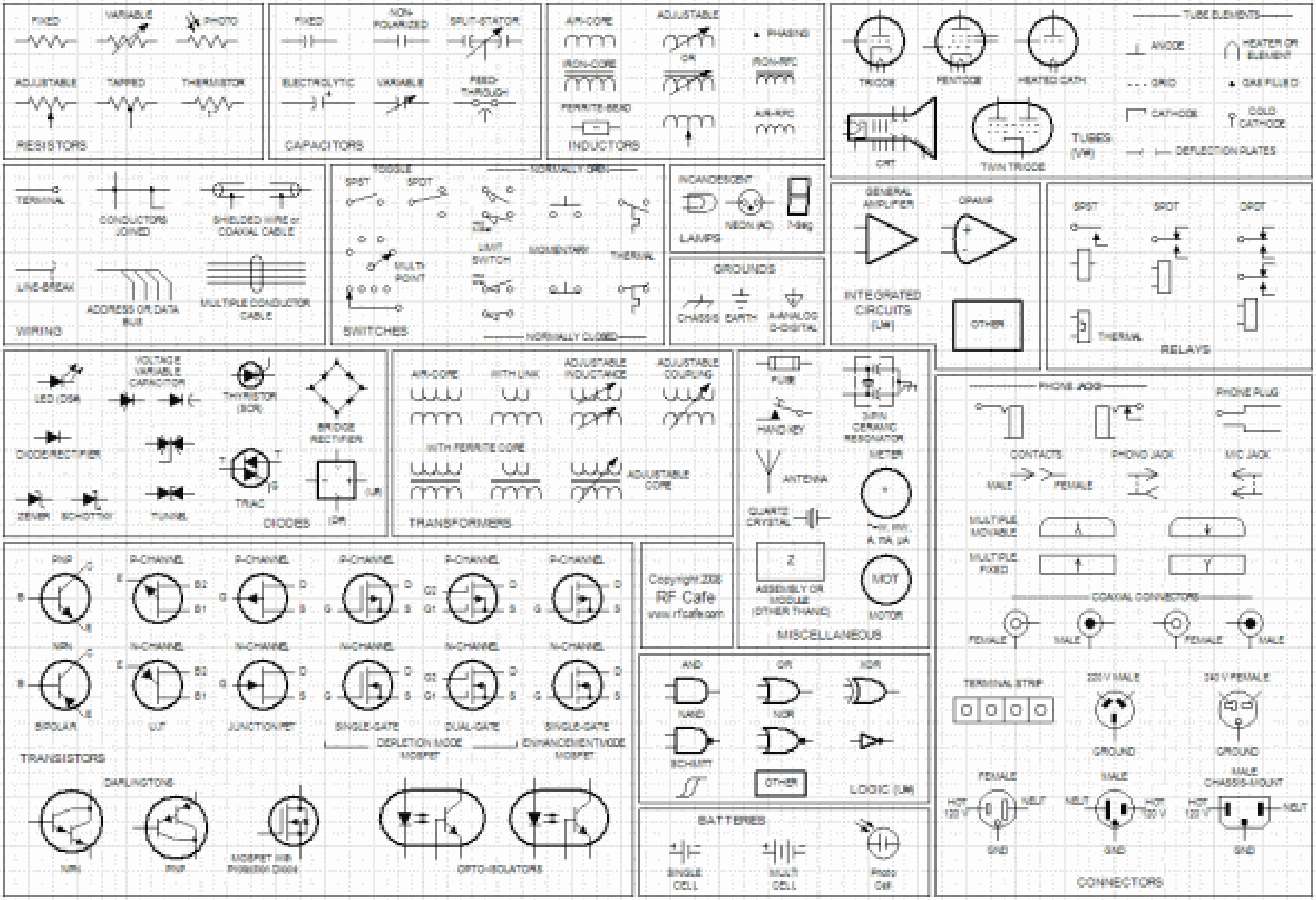
THIS COMIC IS PART OF A BOOK ABOUT
HOW TO MAKE COOL THINGS WITH MICRO-CONTROLLERS (FOR PEOPLE WHO KNOW NOTHING)
BY MITCH ALTMAN AND JEFF KEYZER, TO BE PUBLISHED BY NO STARCH PRESS.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FEED-THROUGH
INDUCTORS
AIR-CORE
ADJUSTABLE
PHASING
IRON-CORE
OR
IRON-RFC
FERRITE-BEAD
AIR-RFC
TUBES (Vx)
TUBE ELEMENTS
TRIODE
PENTODE
HEATED CATH
ANODE
HEATER OR ELEMENT
GRID
GAS FILLED
CATHODE
COLD CATHODE
DEFLECTION PLATES
CRT
TWIN TRIODE
WIRING
TERMINAL
CONDUCTORS JOINED
SHIELDED WIRE or COAXIAL CABLE
LINE-BREAK
ADDRESS OR DATA BUS
MULTIPLE CONDUCTOR CABLE
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TOGGLE
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SPDT
NORMALLY OPEN
MULTI-POINT
LIMIT SWITCH
MOMENTARY
THERMAL
NORMALLY CLOSED
LAMPS
INCANDESCENT
NEON (AC)
7-seg
GROUNDS
CHASSIS
EARTH
A-ANALOG D-DIGITAL
INTEGRATED CIRCUITS (Ux)
GENERAL AMPLIFIER
OPAMP
OTHER
RELAYS
SPST
SPDT
DPDT
THERMAL
DIODES
LED (DSx)
VOLTAGE VARIABLE CAPACITOR
THYRISTOR (SCR)
BRIDGE RECTIFIER
DIODE/RECTIFIER
TRIAC
ZENER
SCHOTTKY
TUNNEL
(Ux)
TRANSFORMERS
AIR-CORE
WITH LINK
ADJUSTABLE INDUCTANCE
ADJUSTABLE COUPLING
WITH FERRITE CORE
ADJUSTABLE CORE
MISCELLANEOUS
FUSE
HAND KEY
3-PIN CERAMIC RESONATOR
ANTENNA
METER
QUARTZ CRYSTAL
ASSEMBLY OR MODULE (OTHER THAN IC)
MOTOR
MOT
CONNECTORS
PHONE JACK
PHONE PLUG
CONTACTS
PHONO JACK
MIC JACK
MALE
FEMALE
MULTIPLE MOVABLE
MULTIPLE FIXED
COAXIAL CONNECTORS
TERMINAL STRIP
120 V MALE
240 V FEMALE
GROUND
MALE CHASSIS-MOUNT
HOT 120 V
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GND
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NPN
BIPOLAR
P-CHANNEL
N-CHANNEL
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JUNCTION FET
SINGLE-GATE
DUAL-GATE
DEPLETION MODE MOSFET
ENHANCEMENT MODE MOSFET
DARLINGTONS
MOSFET With Protection Diode
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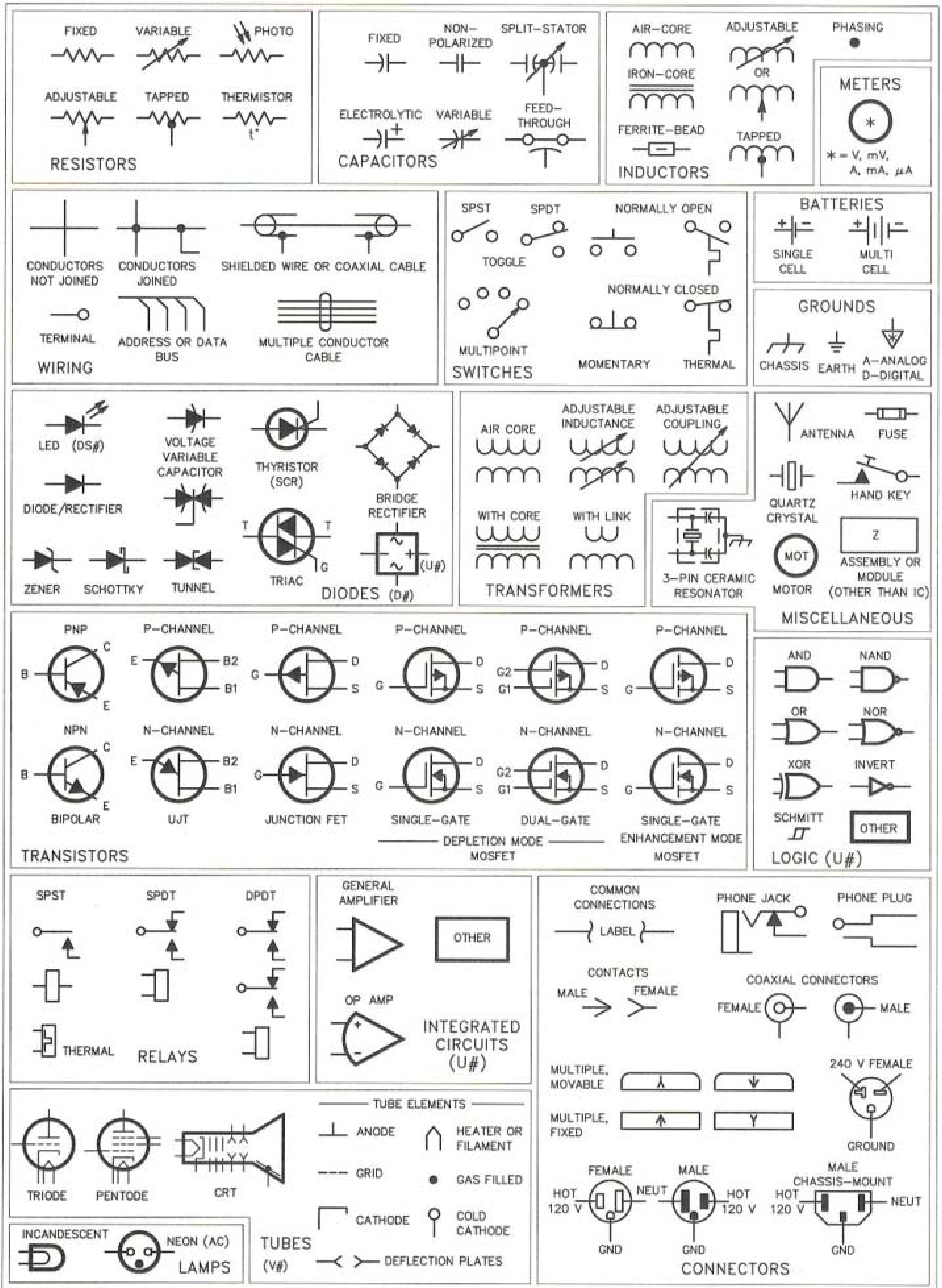
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GROUND
FEMALE
MALE
MALE CHASSIS-MOUNT
HOT 120 V
NEUT
HOT 120 V
HOT 120 V
NEUT
GND
GND
GND
CONNECTORS
TRIODE
PENTODE
CRT
TUBE ELEMENTS
ANODE
HEATER OR FILAMENT
GRID
GAS FILLED
CATHODE
COLD CATHODE
DEFLECTION PLATES
TUBES (V#)
INCANDESCENT
NEON (AC)
LAMPS

From http://www.electronics-tutorials.ws/dccircuits/dcp_2.html

Ohms Law

The relationship between Voltage, Current and Resistance in any DC electrical circuit was firstly discovered by the German physicist Georg Ohm, (1787 - 1854). Georg Ohm found that, at a constant temperature, the electrical current flowing through a fixed linear resistance is directly proportional to the voltage applied across it, and also inversely proportional to the resistance. This relationship between the Voltage, Current and Resistance forms the bases of Ohms Law and is shown below.

Ohms Law Relationship

$$Current, (I) = \frac{Voltage, (V)}{Resistance, (R)} \text{ in Amperes, (A)}$$

By knowing any two values of the Voltage, Current or Resistance quantities we can use Ohms Law to find the third missing value. Ohms Law is used extensively in electronics formulas and calculations so it is "very important to understand and accurately remember these formulas".

To find the Voltage, (V)

[V = I x R]   V (volts) = I (amps) x R (Ω)

To find the Current, (I)

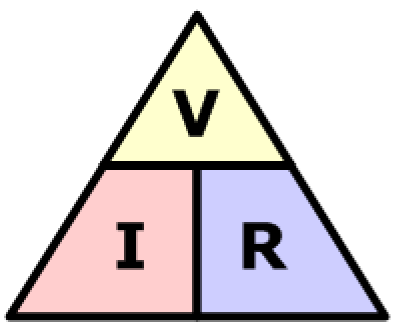
[I = V ÷ R]   I (amps) = V (volts) ÷ R (Ω)

To find the Resistance, (R)

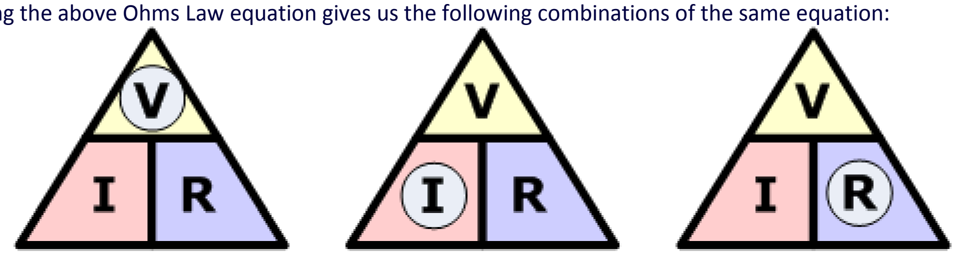
[R = V ÷ I]   R (Ω) = V (volts) ÷ I (amps)

It is sometimes easier to remember Ohms law relationship by using pictures. Here the three quantities of V, I and R have been superimposed into a triangle (affectionately called the Ohms Law Triangle) giving voltage at the top with current and resistance at the bottom. This arrangement represents the actual position of each quantity in the Ohms law formulas.

Ohms Law Triangle



and transposing the above Ohms Law equation gives us the following combinations of the same equation:



$$V = I \times R \qquad I = \frac{V}{R} \qquad R = \frac{V}{I}$$

Then by using Ohms Law we can see that a voltage of 1V applied to a resistor of 1Ω will cause a current of 1A to flow and the greater the resistance, the less current will flow for any applied voltage. Any Electrical device or component that obeys "Ohms Law" that is, the current flowing through it is proportional to the voltage across it (I α V), such as resistors or cables, are said to be "Ohmic" in nature, and devices that do not, such as transistors or diodes, are said to be "Non-ohmic" devices.

Power in Electrical Circuits

Electrical Power, (P) in a circuit is the amount of energy that is absorbed or produced within the circuit. A source of energy such as a voltage will produce or deliver power while the connected load absorbs it. The quantity symbol for power is P and is the product of voltage multiplied by the current with the unit of measurement being the Watt (W) with prefixes used to denote milliwatts (mW = 10^{-3}W) or kilowatts (kW = 10^{3}W). By using Ohm's law and substituting for V, I and R the formula for electrical power can be found as:

To find the Power (P)

$$[\ P = V \times I\ ] \qquad P\ (\text{watts}) = V\ (\text{volts}) \times I\ (\text{amps})$$

Also,

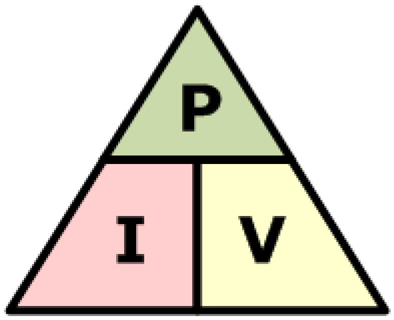
$$[\ P = V^2 \div R\ ] \qquad P\ (\text{watts}) = V^2\ (\text{volts}) \div R\ (\Omega)$$

Also,

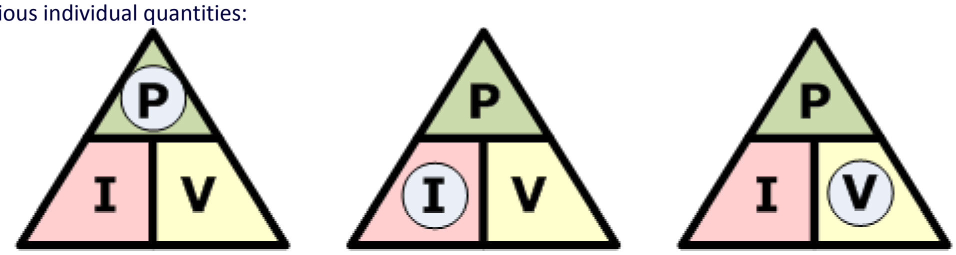
$$[\ P = I^2 \times R\ ] \qquad P\ (\text{watts}) = I^2\ (\text{amps}) \times R\ (\Omega)$$

Again, the three quantities have been superimposed into a triangle this time called the Power Triangle with power at the top and current and voltage at the bottom. Again, this arrangement represents the actual position of each quantity in the Ohms law power formulas.

The Power Triangle



and again, transposing the basic Ohms Law equation above for power gives us the following combinations of the same equation to find the various individual quantities:



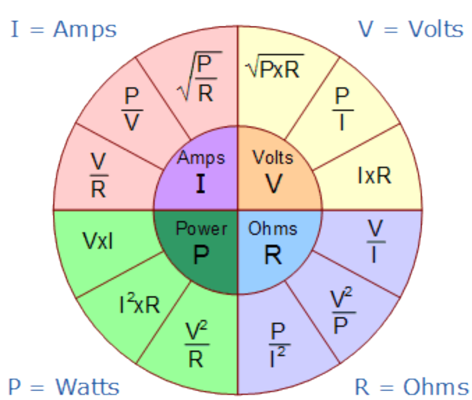
$$P = I \times V \qquad I = \frac{P}{V} \qquad V = \frac{P}{I}$$

One other point about Power, if the calculated power is positive in value for any formula the component absorbs the power, that is it is consuming or using power. But if the calculated power is negative in value the component produces or generates power, in other words it is a source of electrical energy.
Also, we now know that the unit of power is the *WATT*, but some electrical devices such as electric motors have a power rating in the old measurement of "Horsepower" or hp. The relationship between horsepower and watts is given as: 1hp = 746W. So for example, a two-horsepower motor has a rating of 1492W, (2 x 746) or 1.5kW.

Ohms Law Pie Chart

To help us understand the the relationship between the various values a little futher, we can take all of Ohm's Law equations from above for finding Voltage, Current, Resistance and Power and condense them into a simple Ohms Law pie chart for use in AC and DC circuits and calculations as shown.

Ohms Law Pie Chart



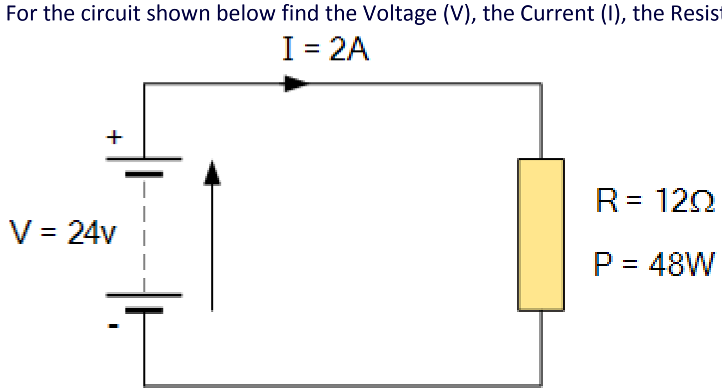
As well as using the *Ohm's Law Pie Chart* shown above, we can also put the individual Ohm's Law equations into a simple matrix table as shown for easy reference when calculating an unknown value.

Ohms Law Matrix Table

Ohms Law Formulas				
Known Values	Resistance (R)	Current (I)	Voltage (V)	Power (P)
Current & Resistance	---	---	$V = I x R$	$P = I^2 x R$
Voltage & Current	$R = \frac{V}{I}$	---	---	$P = V x I$
Power & Current	$R = \frac{P}{I^2}$	---	$V = \frac{P}{I}$	---
Voltage & Resistance	---	$I = \frac{V}{R}$	---	$P = \frac{V^2}{R}$
Power & Resistance	---	$I = \sqrt{\frac{P}{R}}$	$V = \sqrt{PxR}$	---
Voltage & Power	$R = \frac{V^2}{P}$	$I = \frac{P}{V}$	---	---

Example No1

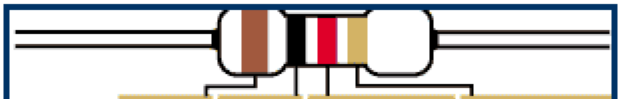
For the circuit shown below find the Voltage (V), the Current (I), the Resistance (R) and the Power (P).



Voltage [V = I x R] = 2 x 12Ω = 24V
Current [I = V ÷ R] = 24 ÷ 12Ω = 2A
Resistance [R = V ÷ I] = 24 ÷ 2 = 12 Ω
Power [P = V x I] = 24 x 2 = 48W

Power within an electrical circuit is only present when BOTH voltage and current are present for example, In an Open-circuit condition, Voltage is present but there is no current flow I = 0 (zero), therefore V x 0 is 0 so the power dissipated within the circuit must also be 0. Likewise, if we have a Short-circuit condition, current flow is present but there is no voltage V = 0, therefore 0 x I = 0 so again the power dissipated within the circuit is 0.

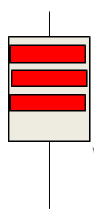
As electrical power is the product of V x I, the power dissipated in a circuit is the same whether the circuit contains high voltage and low current or low voltage and high current flow. Generally, power is dissipated in the form of Heat (heaters), Mechanical Work such as motors, etc Energy in the form of radiated (Lamps) or as stored energy



Gold	-	-	÷10	5% tolerance
Black	0			
Brown	1	1	0	1% tolerance
Red	2	2	00	
Orange	3	3	000	
Yellow	4	4	0000	
Green	5	5	00000	
Blue	6	6	000000	
Violet	7	7	0000000	
Grey	8	8		
White	9	9		

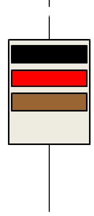
Resistor Value Examples

Ring
Black = 0
Brown = 1
Red = 2
Orange = 3
Yellow = 4
Green = 5
Blue = 6
Violet = 7
Gray = 8
White = 9



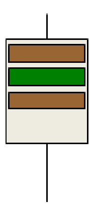
First Ring is units
Second Ring is Ten
Third Ring is number of zero's

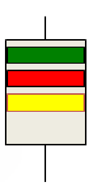
Example of Color Rings



First Ring		**Second Ring**		**Third Ring**			
Red	= 2	Red	= 2	Red	=	X 100	= 2200 ohms
Black	= 0	Red	= 2	Brown	=	X 10	= 020 ohms

Test of Color Rings





First Ring		**Second Ring**		**Third Ring**		
Brown	= ____	Green	= ____	Brown	= _____	= ______ ohms
Green	= ____	Red	= ____	Yellow	= _____	= ______ ohms