Notation

Originally drafted by Brian Faulkner. Last updated 8/11/2017 by C. D. Schmitz

Everything is in SI units http://en.wikipedia.org/wiki/SI_derived_unit
When variables and units are together in the same equation/expression, the equation is in italics, but the unit is in non-italics. For example, $V_b = 10$ mV

Use Microsoft's equation editor for ***all*** symbols and values and units.

The VISIO Template:

When using the VISIO template created for ECE110, size matters. Most symbols are constructed to span a space of 1.5 inches between terminal ends. It generally provides sufficient spacing for labels without being excessive. Most figures are saved and used 1:1 in scale, but the final diagram may be scaled when the size is difficult to work with.

Vertical and horizontal connectors may be used as interconnecting wires when needed. When additional space between symbols is required, increase spacing using the vertical or horizontal connectors in distances of 0.25 inches.

Vocabulary

Common terms used in ECE110:

- source and load (sub-circuits)
- deliver and absorb (power)

Term	Similar terms	Definition	Notes
load	sink	A device generally expected to absorb power.	**load** preferred
absorb	dissipate	The transformation of electrical energy into another form such as heat or EM waves.	**absorb** preferred
deliver	generate, produce	To transform nonelectrical forms of energy (mechanical, solar, or chemical, for example), into electrical energy.	**deliver** preferred
generate	deliver, produce	not used.	**deliver** preferred
produce	deliver, generate	Same as deliver.	**deliver** preferred

inject	deliver, generate	Same as deliver.	**deliver** preferred. Inject is used by Kudeki's text.
dissipate		Like absorb, but suggestive of transformation of electrical energy into heat.	**absorb** preferred
source	generator	A device generally expected to deliver power to a circuit by creating an electrical potential energy of charge carriers.	**source** preferred. A device referenced as a source may, indeed, be a load (as in a battery being charged).
node	junction	A node is a concept, not a physical point in a circuit. It refers the equi-potential point joining two or more lumped circuit elements.	Nodes are labeled using capital letters and, often, an open-circle terminal.
nonessential node	node	A node that joins two elements only.	It is called non-essential in that application of KCL is rather trivial or unnecessary for solving.
supernode	super node, super-node, node, junction	A portion of a circuit enclosed by a surface (or an irregular "circle" on a 2-dimensional circuit schematic) that may include circuit elements in addition to circuit nodes.	Kudeki's ECE210 text writes it as a hyphenated word. KCL applies to a supernode. It is an abuse of the term "node" as different exit points of the supernode typically have different electric potentials.
junction	node	a junction is the connecting point of three or more conductors. It is a subset of a node. Junctions of a schematic need not correspond to physical junction of the same circuit as physical wires or traces may not exactly match a simplified diagram.	Do not confuse a junction with a node.
sink	load	Not used in ECE110	**load** preferred

protoboard	breadboard, perf-board	a construction base for connecting circuit elements with or without the use of solder	**breadboard** preferred if solderless
breadboard	protoboard	a construction base for connecting circuit elements without the use of solder	**breadboard** preferred if solderless
current source		an element that maintains a specified current flow between its terminals independent of the value of the voltage potential that forms across the same two terminals.	We specify if a current source is dependent but otherwise assume it is independent
power-providing			currently-used in lab when introducing the concept
power-consuming			currently-used in lab when introducing the concept
circuit schematic		A simple diagram depicting a circuit using abstract symbols for circuit elements	**circuit schematic** preferred
circuit symbol		The symbol of an element appropriate for a circuit schematic.	**circuit symbol** perferred.
(schematic) circuit diagram	circuit schematic	From Wikipedia: ...a simplified conventional graphical representation of an electrical circuit. A schematic is a representation of the elements of a system using abstract, graphic symbols rather than realistic pictures.	**circuit schematic** preferred
physical (circuit) diagram	circuit schematic	From Wikipedia: ...pictorial diagram uses simple images of components. Similar to a circuit schematic, the physical diagram uses very few (or no) abstract symbols, but rather more-realistic images of the components.	**physical diagram** preferred. Don't use the word "circuit" as all pictorial diagrams in ECE110 will be likely be of circuits.
physical symbol		The symbol of an element appropriate for a physical diagram.	
significant figures	significant digits	The digits of a number that carry significance in value precision.	**digits** preferred

instrument precision		The number of digits readable from the display of a laboratory instrument. It corresponds to the best-case significant figures, but might exceed this due to instrument mis-calibration or natural fluctuation in the signal being measured.	
series			
parallel	shunt		**parallel** preferred.
multimeter	multi-meter		**multimeter** preferred with no hyphen. It is a common word today.
probe		*noun*: a device containing one or more wires with the end designed to contact junctions within a circuit. *verb*: the act of connecting a probe (noun) to the circuit. A probe is generally assumed to be a parallel connection such that it is done without breaking the circuit at any point.	
break a circuit		To disconnect a circuit at a junction. It does not imply any permanent "damage" to any wire or electronic component.	
loop	closed path	A path through a circuit that start and ends at the same node after passing through other elements of the circuit. Referenced loops typically never cross through the same element twice so that a finite number of loops might be defined.	**loop** preferred
signal	waveform	From Wikipedia: a function that conveys information about the behavior or attributes of some phenomenon.	**signal** preferred when parameters are controlled (eg. PWM)
waveform	periodic signals, signals	More general than the term "signal", a waveform may or may not convey "information". Periodic signals (square, sinusoidal, sawtooth) are waveforms, but arguably not signals.	**waveform** or **periodic signals** preferred for most periodic signals**.**
Effective Resistance		The Thevenin or Norton resistance of a subcircuit. It differentiates from the	
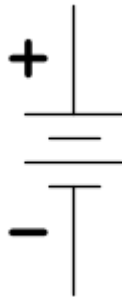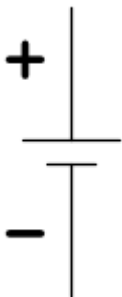
		equivalent resistance of a pure-resistive network.	
Equivalent resistance		The V/I for a group of resistors only.	

Basic Mathematics

CONCEPT	NOTATION	NOTES
Multiplication	~~· (cdot)~~ ~~e.g. 3 · 9~~ Since Cross Produce is no longer used in ECE110, the "times" symbol × is now allowed and even preferred.	Mixed numbers, such as 5½ are not accepted notation × is preferred
	Juxtaposition e.g. V=IR or V=3R	
~~Cross Product~~	~~× (cross product symbol)~~	~~Do not use this symbol to multiply scalar numbers.~~ No longer used in ECE110.
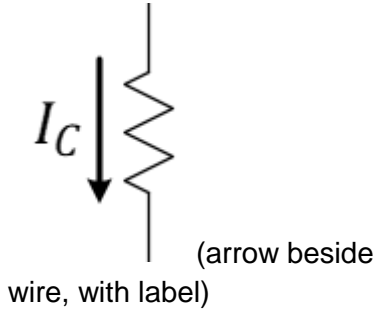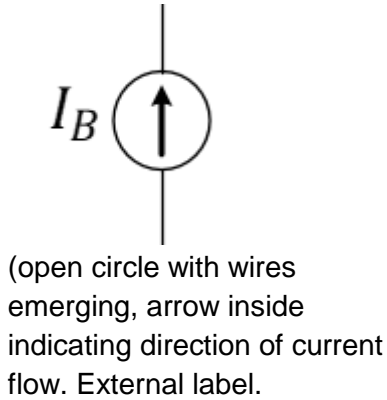
Voltage concepts

Voltage	V (capital roman VEE)	Voltages in diagrams will always have subscripts
Voltage *at* a point/node	V_a (capital roman VEE, subscript with node label)	nodes are labeled with lowercase letters a,b,c,d,e,f. Capitals are used when referencing transistor points C, B, E, and G, D, S.
Voltage *across* an element	V_2 (capital roman VEE, subscript element label)	Elements are labeled with numerals that reference the element's numeric label.
Voltage *from* point a *to* point b	V_{ab} (capital roman VEE subscript with node labels. labels are not separated by commas or spaces. .	$V_{ab} = V_a - V_b$ It is the voltage measured with the positive voltage reference at node a and the negative voltage reference at node b.
Thevenin Equivalent voltage	V_T (roman uppercase VEE, subscript capital roman TEE)	read as "vee thevenin"
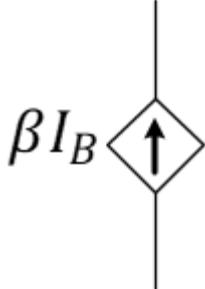
Diode on voltage	V_{on} (uppercase roman VEE, subscript lowercase roman oh enn)	read as "vee on"
Ideal Voltage source	(open circle with wires emerging, both a + and - sign indicating orientation	ECE110 has not had a need for a dependent voltage source and (non-ideal) batteries are specifically represented by a different symbol. Therefore, simply **voltage source** is preferred.
Battery	(big line small line big line small line)	Always means actually a battery. May or may not be adequately modeled by an ideal source. Students should assume non-ideal qualities should be considered. When turned horizontal, the negative sign should be rotated to *remain* horizontal.
Cell	(big line small line with + and - labels)	Single-cell alkaline typically measure around $1.5\ V$ while single-cell NiMH $1.2\ V$.

Sinusoidal voltage source	(circle with one period of sine wave inside)	Keep the voltage reference as well.
Triangle voltage source	(open circle containing one zigzag triangle wave period)	This is not a sawtooth, by the way.
Electrical Ground	Electrical ground connected to earth ground (long line perpendicular to the wire, with a medium and short line below it)	ECE110 abuses this notation, allowing earth ground to represent chassis ground, signal ground, etc. This may be changed in the future as labs are restructured to explore the impact of grounded and non-grounded benchtop devices. The simple term **ground** is currently preferred
Signal Ground	(inverted obtuse triangle)	Arbitrary voltage zero node for a two-conductor signal.
Chassis (Floating) Ground		A local ground reference, generally on the exposed metal of a chassis or board. Its voltage potential is not necessarily tied to earth ground.

Current Concepts
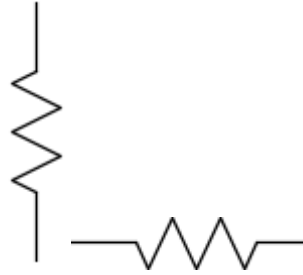
Current	I (capital roman EYE).	
Norton equivalent current:	I_N (uppercase roman EYE, subscript uppercase roman ENN)	
Current through diode	I_D (uppercase roman EYE, subscript capital roman DEE)	
Current through resistor R_2	I_2 (uppercase roman EYE, subscript resistor index)	
Saturation Current	I_{sat} (uppercase roman EYE, subscript lowercase roman ess ay tee)	
Current Direction	I_C (arrow beside wire, with label)	
Ideal Current Source	I_B (open circle with wires emerging, arrow inside indicating direction of current flow. External label.	
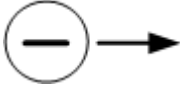
dependent current source	βI_B ⬦↑ (diamond with arrow), external label.	

Resistance Concepts

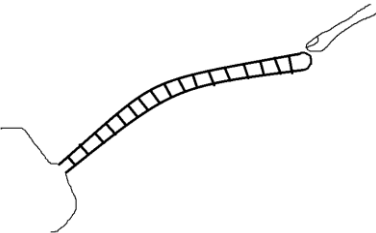| Resistance	R_1 (uppercase roman ARE)	Elements are labeled with numerals that reference the element's numeric label.
Equivalent Resistance	R_{eq} (uppercase roman ARE, subscript lowercase roman eee and lowercase roman que)	Used for purely resistive networks.
Effective Resistance	R_{eff} (uppercase roman ARE, subscript lowercase roman eee and lowercase roman eff eff)	Used for mixed networks, but equivalent to Thevenin and Norton resistances.
Thevenin equivalent resistance	R_T (uppercase roman ARE, subscript uppercase roman TEE)	
Norton equivalent resistance	R_N (uppercase roman ARE, subscript uppercase roman ENN)	
In series with	+ (plus sign)	in the expression $R_1 \| R_2 + R_3$, | operates first, + operates second
In parallel with	|| (two pipes)	Used in the online textbook in Circuit Shortcuts and often used by the lecturers during class time.
Resistivity:	ρ (lowercase greek rho)	

Cross sectional area	A (uppercase roman AY)	also A for Amperes, Amplitude This is the most-significantly overloaded symbol in the course (and possibly in engineering??)
Conductance:	G (uppercase roman GEE)	
Power:	P (uppercase roman PEE)	
Indexing letter for resistors:	k (lowercase roman kay)	i.e. $I_1, \dots, I_k, \dots, I_N$ or $\sum_{k=1}^{k=N} I_k$
Resistor:	(2.5-toothed squiggle line)	

Charge Concepts:

Charge	q (lowercase roman que).	default for charge of a point charge
	Q (uppercase roman QUE)	default for a body of charge
Point Charge	Small circle with a + or - inside indicating charge sign	
Moving point charge	small circle with + or - inside, with arrow	moves in direction of arrow
Two dimensional sheet charge		

	rectangle with many +'s or -'s inside	
Velocity (scalar) :	v (lowercase script vee)	Lower-case and in script to avoid confusion with voltage
Generic energy:	E (upper case roman EEE)	

Magnetic Concepts…Not often used in ECE110
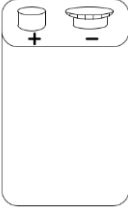
Field into board	(open circle crossed out)	Not often used in ECE110
Field out of board	(open circle with filled dot)	Not often used in ECE110
Length	ℓ (script lowercase roman ell)	Script to make sure it doesn't look like a numerical "1" when hand-written in lecture.
Force (scalar):	F (capital roman EFF)	Not often used in ECE110
Magnetic field strength:	B (capital roman BEE)	Not often used in ECE110
Magnetic field vector:	$\vec{B}$ (capital roman BEE with over arrow)	Not often used in ECE110
Turns of wire	N (capital roman ENN)	also number of elements
Electromotive force:	V_{emf} (uppercase roman VEE, subscript lowercase roman eee emm eff)	
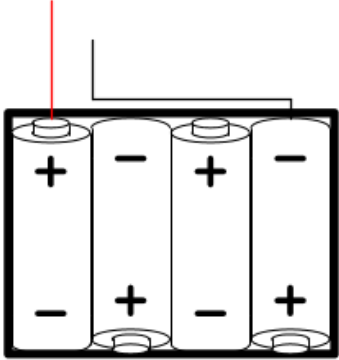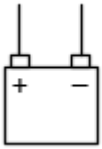
Signals Concepts
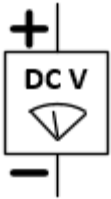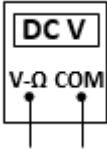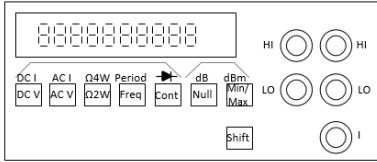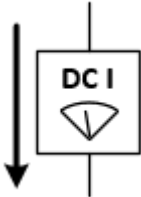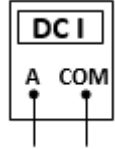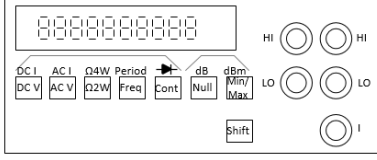
Time	t (lowercase roman tee)	used for continuous time variable
Period	T (Uppercase roman TEE)	often used for other fixed time intervals
Frequency	f (lowercase roman eff)	
Sampling frequency	f_s (lowercase roman eff, subscript lowercase roman ess)	

Angular frequency	ω (lowercase greek omega)	
Amplitude of signal	A (capital roman AY)	conflict with cross sectional area, amperes
Root mean square of voltage V	V_{rms} (quantity symbol subscript with lowercase roman are emm ess)	
Maximum value of quantity X	X_{max} (quantity symbol subscript lowercase roman emm ay ex)	
Arithmetic mean (average) over one cycle of quantity X	X_{avg} (quantity symbol, subscript lowercase roman ay vee gee)	This was changed from the original recommendation of X_{ave} since avg appears to be more common.
Phase offset	θ (lowercase greek theta)	
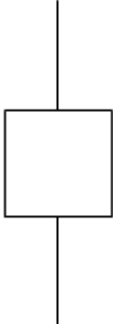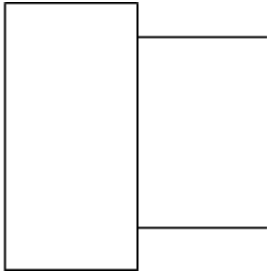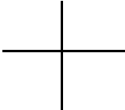
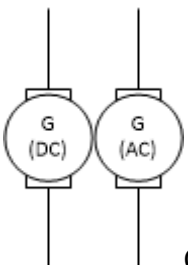# Physical circuit pieces
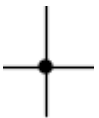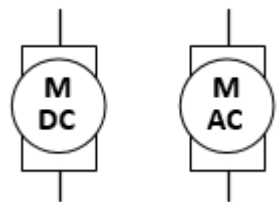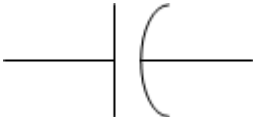
physical Battery Cell	I: Cylinder with two labeled wires for + and - , terminals	
9-V Battery		

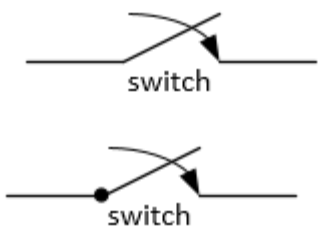|		
AA battery pack (4 cell)		
Physical battery, likely multiple-cell	 (square with two square bumps. + and - terminals indicated)	
Generic Bulb	 (circle with resistor shaped elevated filament)	
Flex sensor	 Bent arc with lateral stripes, wires emerging.	Alien's finger optional. Drawn on demand. Does not exist in the current VISIO library.
Diode	 (rectangle with off-center lateral stripe)	

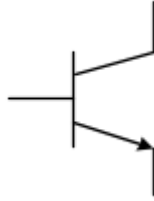|		
Ideal Voltmeter		Ideal properties assumed unless otherwise noted. Polarity of measurement shown.
Generic Voltmeter		Physical symbol suggests possible non-ideal behavior.
Lab-specific voltmeter		Physical symbol suggests possible non-ideal behavior.
Ideal Ammeter		Ideal properties assumed unless otherwise noted. Polarity of measurement shown.
Generic Ammeter		Physical symbol suggests possible non-ideal behavior.
Lab-specific Ammeter		Physical symbol suggests possible non-ideal behavior.

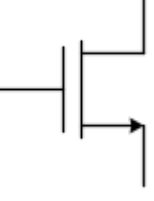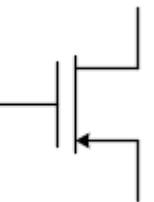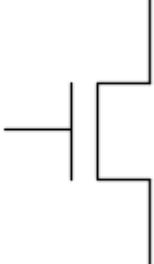## Circuit Concepts

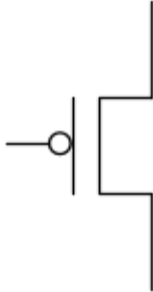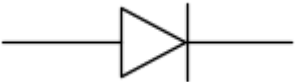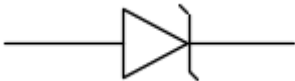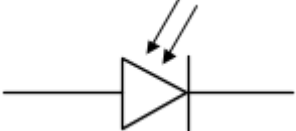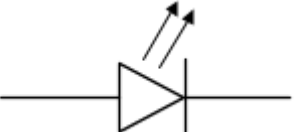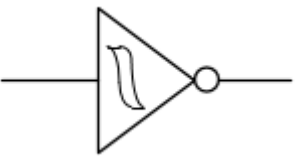|		
Generic 2-terminal element	(square box with + and - labeled, with an identifier in the center	Wires out top and bottom usually signifies a single element
Generic 2-terminal subsystem		wires out the sides usually signifies a subsystem of many elements
Terminal	◌ (small open circle)	Connect something here, either another "sub" circuit or even a multimeter for measurement. **Open circle, open circuit**
Test point/junction	● (small filled circle)...same as circuit intersection or "junction", at the intersection of conductors.	only for junctions (okay for non-essential node to emphasize the connection of two elements)
Open Circuit	Two nearby small open circles	
Ideal Wire/Conductor	(simple straight line with sharp corners)	
Circuit Jump		These wires are not connected in this course, but **ask your instructor** if you run into it as it is an easy error to forget to add the

	lines crossing, not connected if no dot	circuit intersection (junction) symbol to clarify the intent.
Circuit intersection	(lines crossing with filled dot)	These wires are connected in this course
Motor:	capital roman EMM inside open circle with two rectangular connectors,	Labeled with AC or DC Only DC motors used in ECE110.
Generator	Capital roman GEE with circle and rectangular end caps	Can have AC or DC inside Not used in ECE110.
Inductor	(three semicircular bumps)	Rarely used in ECE110
Electrolytic capacitor	Straight and concave line,	Curved side has negative voltage reference and sits at the typically-lower potential
Capacitor		Polarity labeled when needed. Capacitor assumed symmetric in build.

switch	 switch switch (closed circle for hinge and diagonal, no right side circle	Current version has no "hinge". Which looks better??

Transistors and diodes concepts

Bipolar Junction Transistor (BJT)		npn shown
nMOS transistor (circuit)		
nMOS transistor (circuit)		
nMOS transistor (logic)		

pMOS transistor (logic)		
Diode	open triangle with line.	preferred current direction is in direction of triangle's point.
Zener diode	(same as diode symbol, but with parallel lines added at end of perpendicular line)	
Photodetector Diode	(same as diode symbol, with two straight diagonal arrows coming in)	
Light Emitting Diode (LED)	diode symbol ~~with circle~~, outbound straight arrows	Correction: The circle has been eliminated.
Alligator clip		
Schmitt Trigger (Inverter)		
Common emitter current gain:	β (lowercase greek beta)	

AC Voltage Gain	G_V (Capital roman GEE, subscript capital roman VEE)	