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Electrical Engineering Workshop
3 Weeks: August 28 – September 15, 2017
3 Hours/Day
Teaching at JAAGO Foundation, Rayer Bazar, Dhaka
Class VI

Subunit Topic of Lesson	Understanding and Essential Questions	Students will be able to…	Activities to Enforce Understanding	Materials (worksheets) (analogies!!!!) (super simple animated interactives to explain theory of different components)
Week 1: From Electrons to Circuits				LOOK ON elec-goldmine to buy parts!
1.1 Fundamentals of Electricity: Wires, Ohm's Law, Resistors, Diodes, and LED's	• What is an electron? What is a hole? • What is a wire? • What is electricity (energy flow)? • What is current? • What is voltage? • What is resistance? • What is a resistor? • How can we represent circuits in a universally understandable language? • What does Ohm's law mean? • What is a battery? • How can we emit light using this principle of moving electrons? How does an LED work? • What happens when we have too low of a resistance with a relatively high voltage?	• Explain the concept of electrical current in terms of electrons and holes moving in a material. • Explain the relation between voltage, current, and resistance in a circuit. • Use Ohm's Law to solve for V, I, or R in a circuit given two. • Design voltage dividers. • Draw schematics for circuits. • Explain how LED's emit light from energy released when electrons combine with holes. • Explain the forward voltage of an LED. • Hook up a simple LED circuit and explain how it works on different levels of abstraction (voltage and resistance → current → electrons). • Explain the concept of power dissipation as heat when too much current flows through a small amount of material. • Explain the operation of a plasma cutter (creation of plasma by	• Make a resistor by rubbing pencil lead on paper, light an LED • Blow up an LED • Burn a resistor • Make a tiny plasma cutter (video)	• Safety Glasses • Pencil 1 • Paper 2 • Multimeters .25 • Aluminum foil 1 • LED's 2 • Resistor • Alligator clips 2 • Pencil Lead 2 • 9V Batteries 4

		ionizing and vaporizing the graphite tip when too much current flows and it gets too hot → plasma forms closed circuit and also cuts the foil from high heat)		
1.2 Fundamentals of Electricity: Capacitors, Inductors, Motors	• What are series and parallel circuits? • What happens with resistors in series and parallel? • How can we plot how a voltage changes over time? • What is meant by DC and AC electrical signal? • What is a capacitor? • What is an inductor? • What happens with capacitors and inductors in series and parallel? • What is a motor? • How can we model a motor?	• Explain parallel and series geometrically. • Explain how resistance, capacitance, and inductance change in series and parallel. • Explain what an electrical signal is. • Explain the difference between an AC and a DC electrical signal. • Explain the theory of a capacitor (how it stores energy). • Explain what a capacitor does when it sees a rapidly changing voltage. • Explain what a capacitor does when it sees a steady voltage. • Explain the theory of an inductor (how it stores energy). • Explain what an inductor does when it sees a rapidly changing voltage. • Explain what an inductor does when it sees a steady voltage. • Explain how a DC motor can be modeled.	• Charge capacitor with battery, then discharge into LED • Discharge caps to melt pennies (?) • Computer memory: DRAM (charging and discharging capacitors can store information) • Use a transformer to create a spark (similar theory of plasma cutter) (instructables) • Mini tesla coil (video)	• 9V battery 1 • Large capacitor 1 • LED 1 • VCR transformer 0.5 • Pushbutton switch 0.5 • Electrical tape • Wires (10 – 12 awg) • Materials for mini tesla coil
1.3 Diodes, How to Use a Breadboard & Resistor Circuits	• How can we limit current flow in a path to only one direction? What is a diode? • How can we sense light (opposite of emitting light)? What is a photodiode?	• Explain when it is desirable to control the direction of current flow. • Explain how a diode blocks reverse voltage and only allows forward current.	• Use a web app to map circuit schematics to breadboard layouts	• Computers + Wifi 1 • Web App 1 • Breadboard 1 • 9V battery 1 • LEDs 6

	• What is a zener diode? • How does a breadboard work? • How can we build simple circuits on a breadboard (converting a language to a product)?	• Explain how a diode has its own forward voltage. • Explain how a photodiode works with an opposite theory to LED's. • Explain the function of a zener diode. • Draw a model showing the connections in a breadboard. • Translate nodes in a circuit schematic to connections in a breadboard. • Map a given circuit to a breadboard layout.	• Make LED circuits on physical breadboard	• Resistors 6
Week 2: Designing Basic Circuits				
2.1 Transistors	• What is a switch? • How can we make a voltage-controlled switch (transistor)? • How can we use the same device to make voltages and currents bigger (amplification)? • What is the difference between a BJT and a MOSFET?	• Explain why it is desirable to be able to open and close a node in a circuit. • Explain why it is desirable to make signals (voltages and currents) larger. • Explain how a transistor (BJT) works (physics theory). • Explain how the voltage and current flowing through a BJT change with changing voltage and current at its gate. • Draw the voltage to current graphs of a BJT. • Explain the difference between a BJT and a MOSFET. • Explain for which applications a BJT is better than a MOSFET and vice versa.	• Walk through designing an LED driver using a BJT. • Walk through design of a battery bad indicator (using FET's and zener diode).	• 2N3906 1 • 9V battery 1 • 2N7000 2 • LED 2 • 4.7V Zener 1 • Resistors

		• Design an LED driver using a BJT. • Design a battery bad indicator with MOSFETs and a Zener diode.		
2.2 Push-Pull Amplifiers	• What is a negative voltage? • Why do we need to amplify an audio output? • Why do we need positive and negative voltages for the audio amplifier we will build? • How can we use transistors to amplify an audio signal to power a high power speaker (loud music!)?	• Explain the need to amplify a sound signal to hear loud music. • Explain the need to use a positive and negative voltage rail for an audio amplifier. • Design a push-pull amplifier. • Explain the function of a push-pull amplifier. • Explain crossover distortion and why it is an issue.	• Walk through the design of a push-pull amplifier • Use web app to model breadboard layout of push-pull amplifier • Build it and play loud music!	• Dual 15V power supply 1/5 • All components for push-pull amplifier (L3) • Audio cable • Audio cable insert
2.3 Op Amp Buffers and Motor Control	• What is an operational amplifier? • Why would we want to isolate two parts of a circuit (signal and actuator)? • What is a buffer? • What does an op amp buffer look like? • How can we use a buffer to drive a DC motor? • How can we drive a DC motor in both directions?	• Draw a black box model of an operational amplifier. • Explain the three main operating principles of an op amp. • Explain the need for buffers. • Explain the concept of impedance (?) • Explain how an op amp buffer works. • Explain the model of a motor as a small resistor. • Explain the need for a buffer to drive a motor.	• Finish push-pull if not finished • Buffered motor control • Bidirectional motor control	• Dual 15V power supply 1/5 • All components for push-pull amplifier (L3) • Audio cable • Audio cable insert • Motors 1 • Op amp 2 • Potentiometer 2
2.4 Op Amp Amplifiers	• How can we make an amplifier with an op amp? • What is an inverting amplifier? • What is a non-inverting amplifier?	• Explain the operation of inverting and non-inverting amplifiers. • Explain how an op amp can get rid of crossover distortion. • Design a modified push-pull amplifier. • Explain input offset current and input bias current and how to get rid of them.	• Modify push-pull circuit with op-amp feedback • Use web app to model breadboard layout • Build and play loud music again!	• Dual 15V power supply 1/5 • All components for push-pull amplifier (L3) • Audio cable • Audio cable insert

2.5 555 Timers and Oscillators	• What is an oscillator? • How can we build an oscillator with an op amp? • What is a 555 timer? • How can we build an oscillator with a 555 timer?	• Explain the function of an oscillator. • Explain the concept of frequency. • Explain the concept of duty cycle. • Explain how an op amp can convert a sine or triangle wave to a square wave. • Explain how the charging and discharging of a capacitor (in conjunction with the previous theory) can be used to make a square wave oscillator. • Explain how a 555 timer works. • Explain how a 555 astable multivibrator works. • Design and build astable oscillators with op amps and 555 timers. • Analyze and communicate the tradeoffs of each design.	• Design, use web app, and build an astable oscillator to blink an LED (web) • Design, use web app, and build 555 circuit to blink an LED (web) • Extended example (if time: combine astable oscillator with push push amplifier from before to play square waves)	• 555 timer • Op Amp • Resistors • LED 2 • Capacitors • 9V battery • 15V Power Supply

2.6 Filters and Bode Plots	• What is unwanted electrical noise? • How can we design a filter to eliminate noise? • What is a bode plot? • How can we construct bode plots? • What is a passive filter? • What is a low pass filter? • What is a high pass filter? • What is a bandpass filter? • What are the problems with a passive filter? • What is an active filter? • How can we use an op amp to design an active filter? • What is the benefit of an active filter over a passive filter?	• Explain noise in terms of electrical signals. • Explain the purpose of a filter. • Explain what an RC time constant is. • Calculate RC time constants. • Explain the difference between low pass, high pass, and bandpass filters. • Design a passive filter (low and high pass). • Draw a rough bode plot to describe the function of a passive filter. • Draw the output of a black box circuit given an input and the bode plot of the black box. • Design an active filter (low pass, high pass, and bandpass). • Explain the benefit of an active filter over a passive filter (electrical isolation). • Combine an oscillator with a tunable bandpass filter and predict the output signal. • Explain why the LED blinks or not depending on the frequency of the oscillator and the bode plot of the filter.	• Combine astable oscillator with bandpass filter (Predict and examine conditions under which LED still blinks) (use pots and trimmer caps)	• 15V power supply • Trimmer cap • Potentiometer • Previous astable oscillator circuit • Capacitors • Resistors • Op amp
2.7 Filters continued & Comparators	• Continue filters if not finished • Why would we want to compare two voltages? • What is a comparator? • What is the difference between a comparator and an op amp?	• Continue filters if not finished • Explain the function of a comparator • Explain some applications of a comparator.	• Continue filters if not finished • Walk through design of voltage level detector (web)	• Comparator 4 • LED 4 • Resistors • Potentiometer • 9V battery

		• Explain the difference between a comparator and an op amp.		
Week 3: Build A Heartbeat Monitor: I Heart Circuits	**PPG or EKG???**			
3.1 Demo and Theory	• How can photodiodes be used to detect a heartbeat? • How can we describe a circuit in terms of functional blocks? • With what conditions can we use functional blocks to design circuits? • What functional blocks are needed to display the output of a PPG on an LED?	• Explain how a PPG/EKG sensor works. • Explain the importance of electrical isolation when using functional blocks to design circuits. • Design the series of functional blocks needed to turn a PPG/EKG heartbeat current into a visible blinking of an LED to match heartbeat.	• Demo of PPG/EKG • Different students, different feedback resistors • Independent student design time for functional blocks • Check and correct functional blocks	• All materials for PPG/EKG circuit
3.2 DC Offset and Amplification	• What is a transimpedance amplifier? • Why do we want to create a DC offset when using a 9V battery to power this circuit? • How can we create a DC offset for our amplifier?	• Explain how a transimpedance amplifier works. • Explain the need for a DC offset to carry a signal when using a single supply rail. • Explain how to create a DC offset at the output of the transimpedance amplifier.	• Independent student time to design DC offset transimpedance amplifier • Check and correct circuit designs • Use web app and build circuit	• All materials for PPG circuit
3.3 Filtering and Comparator LED drive	• What frequency is our heartbeat? • What kind of filter(s) would be best to remove noise from our PPG? • How can we design a comparator circuit to drive an LED to match the heartbeat signal?	• Explain different possibilities of filter(s) that could be used to remove noise from a heartbeat signal. • Explain the reason for the chosen filter. • Explain how a signal can be amplified through the filter as well. • Explain the design of the comparator LED drive circuit.	• Independent student time to design filter and comparator LED drive circuits • Check and correct circuit designs • Use web app and build circuit	• All materials for PPG circuit

3.4 Integration & Debugging	• How do we put all of our circuit blocks together? • What component can we use to help make the PPG circuit less sensitive to DC or AC noise from our surroundings?	• Explain how to tie together the different functional blocks in the circuit. • Explain the use of buffers for isolation if needed. • Explain the need for a capacitor at the output of the PPG (if needed).	• Build time to integrate circuit components	• All materials for PPG circuit
3.5 Integration & Debugging, Stretch: Generate Sound	• Same as above • Student questions or concerns	• Same as above	• Same as above • Ensure all students' heartbeat monitors are working	• All materials for PPG circuit