CG1111 Engineering Principles and Practice I

Designing a Phone Charger

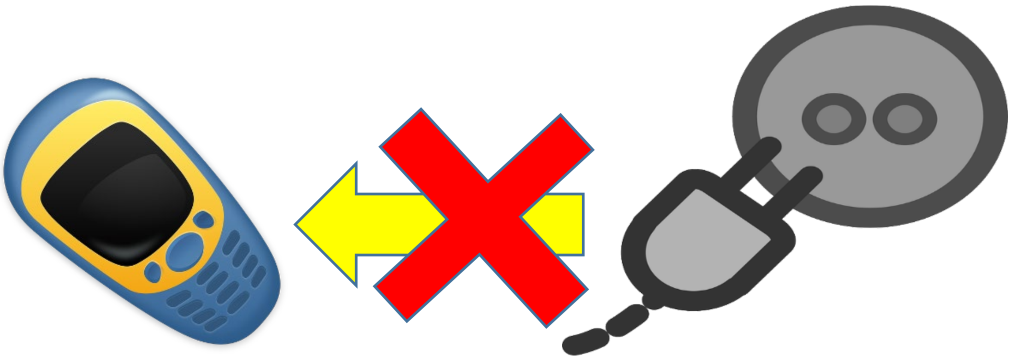
(Week 7 Studio)

Time	Duration (mins)	Activity
0:00	10	Briefing
0:10	60	Activity #1: Transformers
1:10	60	Activity #2: Understand the working of a diode bridge rectifier for converting AC to DC
2:10	20	Activity #3: To design a AC-DC phone charger
2:30	5	Final discussions and wrap-up

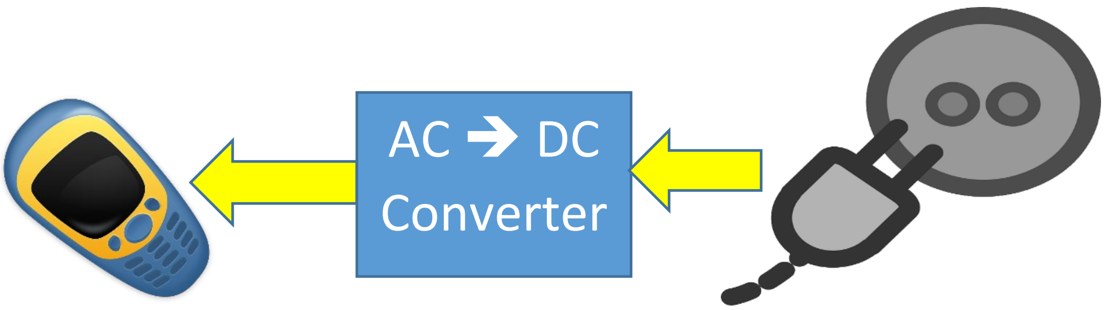
Introduction:

- A Phone uses a rechargeable DC battery to power itself. How do we recharge this battery?

- The power socket gives us AC voltage i.e. the voltage is alternating in nature. Can we connect a phone directly to the AC power socket to recharge its DC battery?



- We need to convert the AC to DC before we can connect it to the phone to recharge its battery. Today you will be designing the contents of the following converter box between the AC power supply and your phone.



- In Activity #1, you shall understand the working of a transformer. You will get to appreciate the step up and step-down capabilities of the transformers and verify the theoretical calculations of transformers with the oscilloscope observations.

- In Activity #2, you will first rectify the AC voltage using a diode bridge rectifier. Secondly, you will observe the rectified waveform in the oscilloscope and calculate the voltage ripple present in the waveform. Finally, you will analyse the effect of connecting different capacitors on the ripple voltage of the rectifier output.

- In Activity #3, you will complete the design of the phone charger by stabilising the voltage output of the rectifier using a linear regulator and connecting the charging cable.

Objectives:

- To appreciate the step up and step-down capabilities of a transformer.
- To understand the working of a diode bridge rectifier
- To estimate the output ripple voltage of a diode bridge rectifier with different filter capacitors
- To design a general-purpose phone charger

Materials:

- Breadboard and connecting wires
- Digital multimeter
- Laboratory Oscilloscope
- Transformer 1: 230V- 9 V step down transformer x 1
- Transformer 2: Step up/step down transformer x 1
- IN4001 Diode x 4
- Electrolytic Capacitors {10μF x 1, 22μF x 1, 100μF x 1}
- 2200 μF electrolytic capacitor x 1
- 1 kΩ resistor
- Protective goggles
- 7805 Linear Regulator x 1
- USB Female Header
- Connecting alligator clip cables x 2 pairs

Activity #1: Transformers (50 mins)

Transformer Primer:

- The primary side of a transformer is the side connected to the voltage source or the input while the secondary side of the transformer is the side connected to the load or the output.
- A transformer is called a **step-up transformer** if the number of turns of the secondary winding (**n_s**) is more than the number of turns of the primary winding (**n_p**).
- A transformer is called a **step-down transformer** if the number of turns of the primary winding (**n_p**) is more than the number of turns of the secondary winding (**n_s**).
- The voltage ratio of an ideal transformer is given as $\frac{V_p}{V_s} = \frac{N_p}{N_s}$

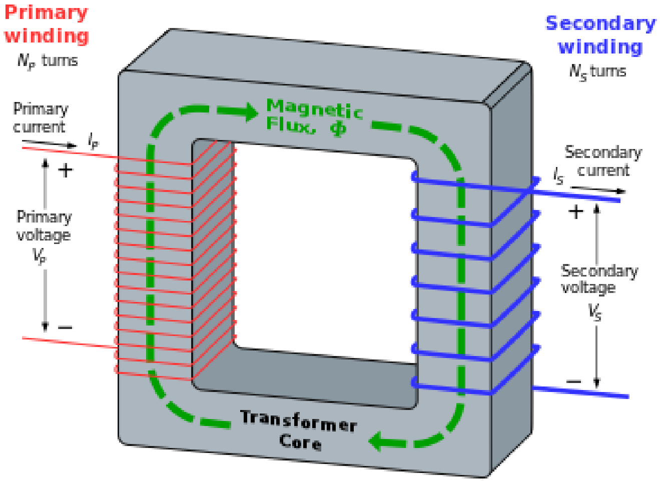


Figure 1: Primary and Secondary of a Transformer

- If the transformer turns ratio is not given you can use the primary and secondary voltages to find the turns ratio.
- The current ratio of an ideal transformer is given as $\dfrac{I_S}{I_P} = \dfrac{N_P}{N_S}$

Procedure:

1. Connect the 230V-9 V transformer to the AC power supply. Connect the 9V transformer side to the oscilloscope and observe the maximum and rms voltage of the waveform. (Please see the "CG1111 - Week 7 Studio - Laboratory Oscilloscope.pdf" in the 'Week 7 Preparatory Materials Folder' to understand on the usage of the laboratory oscilloscope)

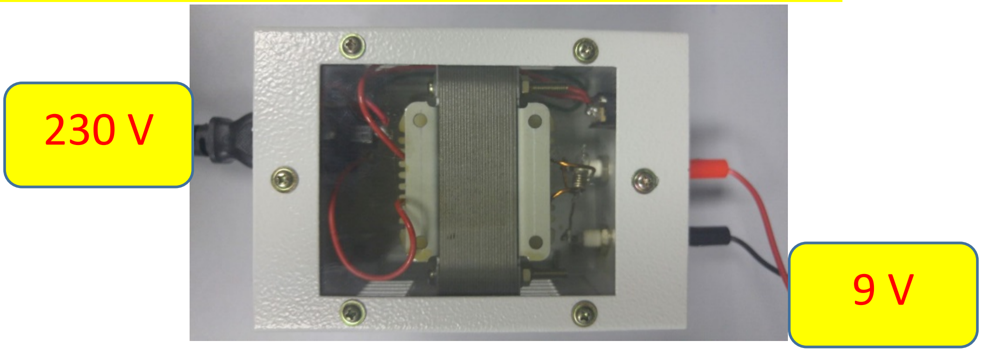


Figure 2: 230V-9V **Transformer 1**

Is the observed waveform purely sinusoidal? Is the notation '9V' the rms voltage or the maximum voltage.

2. Now, you need to get the following maximum voltages by connecting the secondary of the **Transformer 1** to the primary of **Transformer 2**. Draw the different configurations in your learning journal and theoretically calculate the secondary voltages of **Transformer 2** for the different configurations.

Configuration example:

- The 9V & 12V labels merely guide you about the relative number of coil turns on each side
- **Note that either side can serve as the primary side**

Figure 3: **Transformer 2** (Step up/ step down transformer)

- How to fill up the different parameters in the table for a required maximum voltage at **secondary** of **Transformer 2**, V_s= 20V ?
- The Maximum voltage at **primary** of **Transformer 2**, V_p= 13.5V
- **Turns Ratio required** = V_s/V_p= 20/13.5 = 1.48
- **Configuration**: Primary – 0 - 12V, Secondary- 0 - 18V
- Step Up Transformer (Transformer 2 is connected as shown in Figure 4)

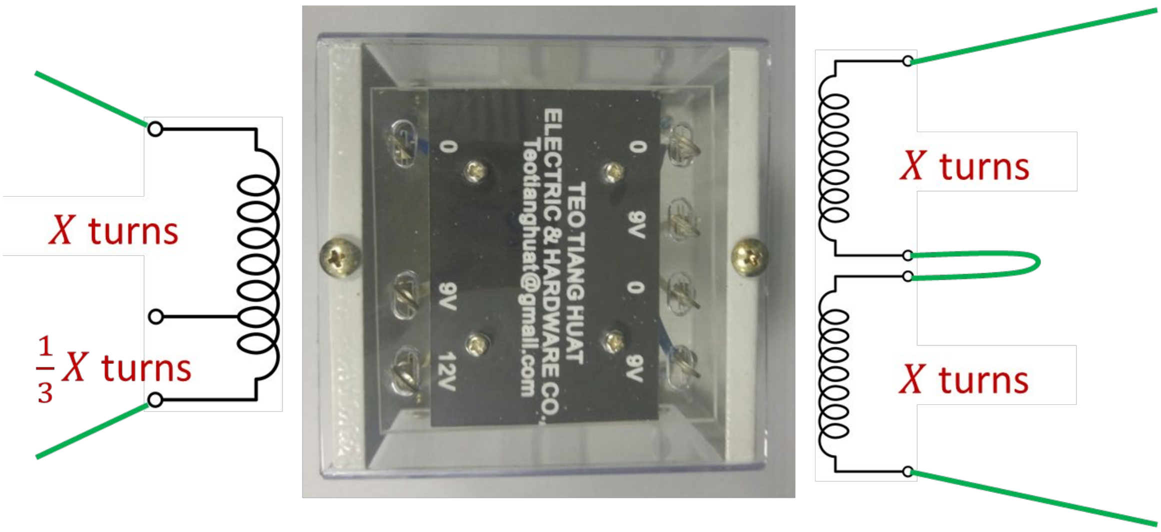


Figure 4: **Transformer 2** (Step up/ step down transformer) Configuration Example

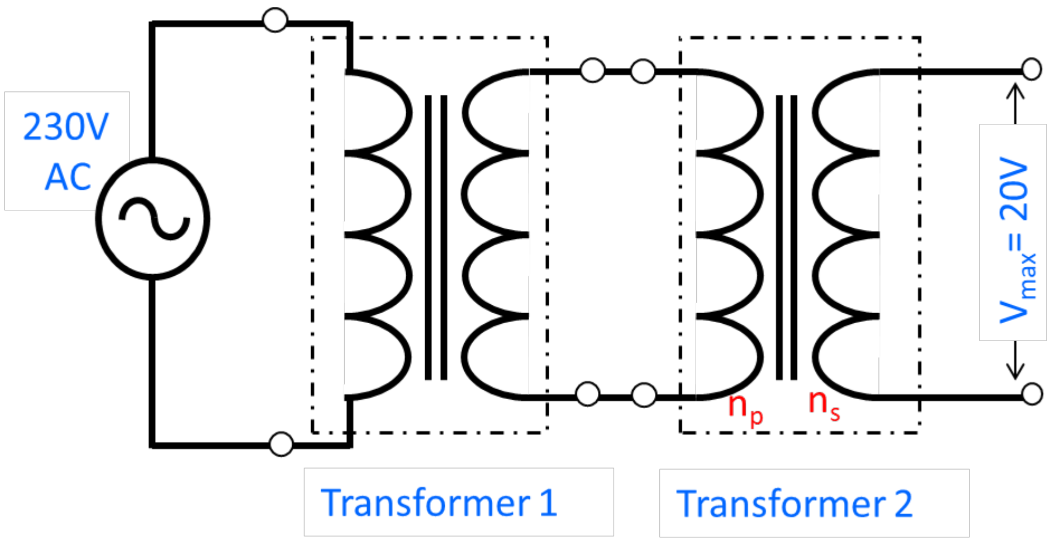


Figure 5: Circuit Diagram for Activity 1 -

3. Connect the transformers in the different configurations, observe the respective maximum voltages, and note it down in the following table.

Maximum Voltage at Secondary of Transformer 2	Configuration		Calculated Maximum Voltage (V)	Measured Maximum Voltage (V)	Is it a Step-up/Step-down transformer?
	Primary	Secondary			
20 V	0 - 12 V	0 - 18V	20.3	Use actual value measured from oscilloscope	Step-Up Transformer
13.5 V					
27 V					
6.5 V					
10 V					

Table 1: Observation Table for Activity 1

4. Compare the measured voltage and the calculated voltage and provide explanations on the variations.

Activity #2: Understand the working of a diode bridge rectifier for converting AC to DC (60 mins)

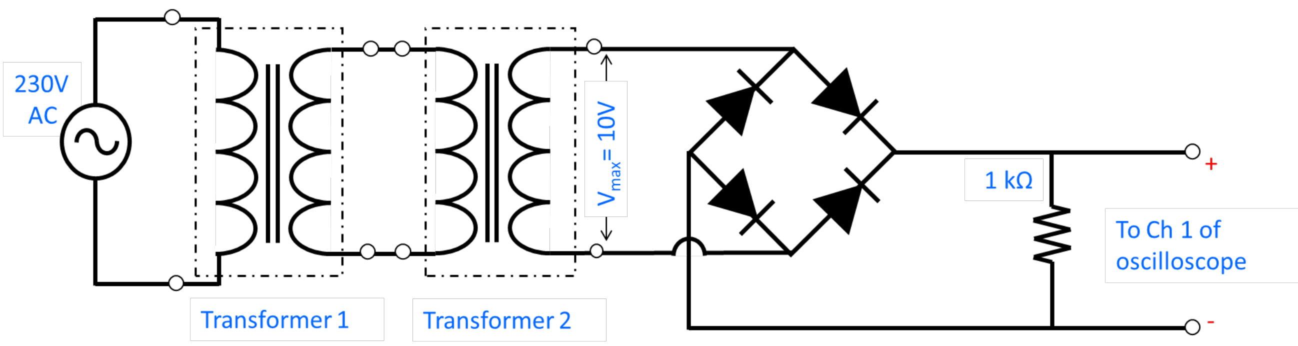


Figure 6: Circuit diagram for Activity 2 **without capacitor**

Procedure:

1. Connect the transformers such that the maximum voltage at the output of transformer 2 is 10 V.
2. First, using the breadboard, construct the circuit shown in Figure 6 **without** the capacitor.

Warning: Ensure that the diodes are connected in the right configuration. If the diode is connected wrongly, one or two branches of the rectifier will be short-circuited resulting in the transformer fuse getting blown.

3. Connect Channel 1 of the oscilloscope's probe across the output of the diode bridge rectifier. Set the **voltage/div to 5 V**, and the **time/div to 10 milliseconds**. Ensure that the oscilloscope channel is set to 'DC Coupling' and **not** 'AC coupling'. Observe the output voltage of the diode bridge rectifier at the oscilloscope **without** any capacitance connected. Measure the average voltage and the rms voltage of the rectified voltage output.

Voltage Ripple Primer:

- The output DC voltage is not a straight- line DC voltage.
- The output voltage has a maximum and minimum voltage.
- The different between the maximum voltage and the minimum voltage is known as voltage ripple.
- When a capacitor is connected across the output voltage of the diode rectifier the output waveform looks as below:

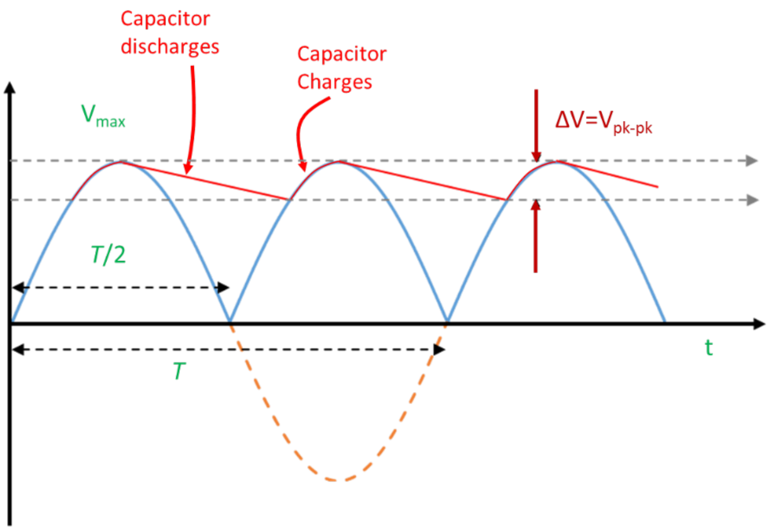


Figure 7: Voltage Ripple with capacitor

- $\Delta V \approx \frac{V_{Load}}{R_L} * \frac{1}{2 f_s} * \frac{1}{C}$
  - V_{Load} = Average voltage across the resistor 1kΩ
  - R_L = 1 kΩ resistor
  - f_s = Frequency of the AC power supply

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4. Measure the maximum (V_{max}) and minimum (V_{min}) values of the output voltage and calculate the voltage ripple present in the output voltage. The voltage ripple is defined as the V_{max} - V_{min}.

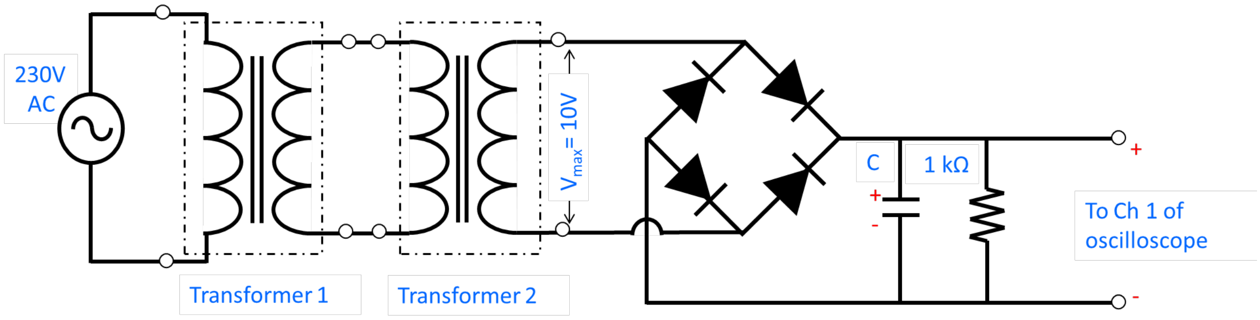


Figure 8: Circuit Diagram for Activity 2 **with capacitor**

5. Next, construct the circuit shown in Figure 8 with the smallest capacitor (10 μF). **Check that the polarity of the capacitor is correct.**

   Warning: Beware of the Electrolytic capacitor's polarity. Ensure that you use your safety goggles.

6. Connect Channel 1 of the oscilloscope's probe across the capacitor. Set the **voltage/div to 5V**, and the **time/div to 10 milliseconds**. Ensure that the oscilloscope channel is set to 'DC Coupling' and **not** 'AC coupling'. Observe the output voltage of the diode bridge rectifier at the oscilloscope **with** the 10μF capacitor connected. Measure the average voltage and the rms voltage of the rectified voltage output.
7. Next, change the oscilloscope coupling to '**AC coupling**'. Measure the maximum (V_{max}) and minimum (V_{min}) values of the output voltage and calculate the voltage ripple present in the output voltage. Adjust the **voltage/ div** to get accurate values for the V_{max} and V_{min}.
8. Repeat steps 5 to 7 with different values of capacitors.
9. Record all the data in the following table

Capacitance	V_{avg}	V_{rms}	V_{max}	V_{min}	**Voltage Ripple**
No Capacitance					
10 μF					
22 μF					
100 μF					
2200 μF					

Table 2: Observation Table for Activity 2

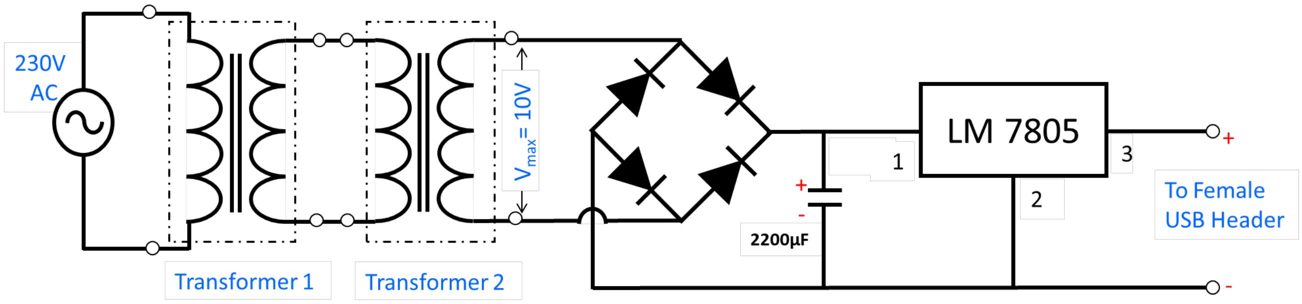
10. Comment on the suitability of the rectified voltage output waveform as a DC voltage source with respect to the voltage ripple present in the waveform.

<u>Activity #3: To design a AC-DC phone charger</u> (20 mins)

<u>Procedure:</u>

1. Using the breadboard, connect the circuit as shown in Figure 9. The value of the capacitance is **2200 μF**.
   Warning: Beware of the Electrolytic capacitor's polarity. Ensure that you use your safety goggles.

2. Note the three terminals of the LM7805 and ensure that you connect it in the correct configuration by verifying the pin diagram with the datasheet.
3. Connect Channel 1 of the oscilloscope's probe across the output (pin 3) and ground (pin 2) of the LM7805 voltage regulator. Set the **voltage/div to 2V**, and the **time/div to 10 milliseconds**. Ensure that the oscilloscope channel is set to 'DC Coupling' and **not** 'AC coupling'. Observe the output voltage and ensure that it is 5 V.
4. Connect the female USB header across pins 3 and 2 of the LM7805. You can connect your phone charger cable to charge your mobile phone.



<u>Figure 9: Circuit Diagram for Activity 3</u>

<u>Warning: Ensure that pin 3 of LM7805 is connected to the '+' terminal of the USB Header and pin 2 of the LM7805 is connected to the '-' terminal of the USB Header.</u>

5. What does the LM7805 do? How does it affect the output voltage of the diode bridge rectifier?

Please feel free to ask your GA or the Instructors any questions or doubts you may have.

END OF STUDIO SESSION

CHALLENGE YOURSELF (Optional)

What is the maximum current output of this phone charger circuit (Hint: Connect an ammeter in series between the LM7805 and the female USB header)