# EE1002 Lab 7: Study of Transformers and DC Power Supply Design

| | Activities Completed | Verified By | Marks From 5 |
|---|---|---|---|
| **Name**:______________________________ | **Preparatory Work** | | |
| **Matric. No.**_________________________ | **a** | | |
| | **b** | | |
| **Group**:_____________________________ | **c** | | |

## SAFETY PRECAUTIONS

- Follow the laboratory safety guidelines strictly.
- After making any modifications to the circuit, get your connections thoroughly verified by your GA, before plugging in the transformer to the supply.

  **WARNING:** **<u>You would be dealing with 230 V rms to supply to the primary of the transformer and therefore safety is of prime importance.</u>**
- Please mind the polarities (positive and negative) of the electrolytic capacitor.

  **WARNING:** **<u>If connected with an incorrect polarity, they can explode</u>**.
- **WARNING:** <u>DO NOT</u> connect any of the oscilloscope probes directly to the mains 230 V AC supply.
- **WARNING:** <u>DO NOT</u> touch power resistors **(of 10 W)** or the 7805 IC with bare hands when the circuit is ON. **<u>They can get extremely hot.</u>** Use mini-pliers to insert or remove them.
- Take care to ensure that there are **<u>no short circuits</u>** of the power supply and transformer windings in your circuit connections. Take care not to short the transformer winding end points when energized.
- If you are unsure about anything, consult your GA before proceeding further.

# 1. Objectives

a) To understand the basic principles of operation of a transformer and verify the dot convention
b) To step-up and step-down AC voltage using transformer
c) To understand the basic principles of operation of a diode and a single-phase diode-bridge rectifier circuit
d) To design a capacitor filter for a given load current and specified voltage ripple content
e) To set up a voltage regulator circuit using IC-7805 for powering digital logic circuits with +5 V DC

# 2. Equipment to be used

- Oscilloscope
- Digital multi-meter
- Breadboard

# 3. Components

- Transformers
- Diodes
- Resistors with different power dissipation ratings
- Capacitors
- 7805 regulator IC

# 4. Preparatory work (Individual)

***<u>This component is to be completed at your own time before coming for your lab session.</u>***

Build and simulate the circuit shown in Fig. 1 using LTspice, according to following requirements:

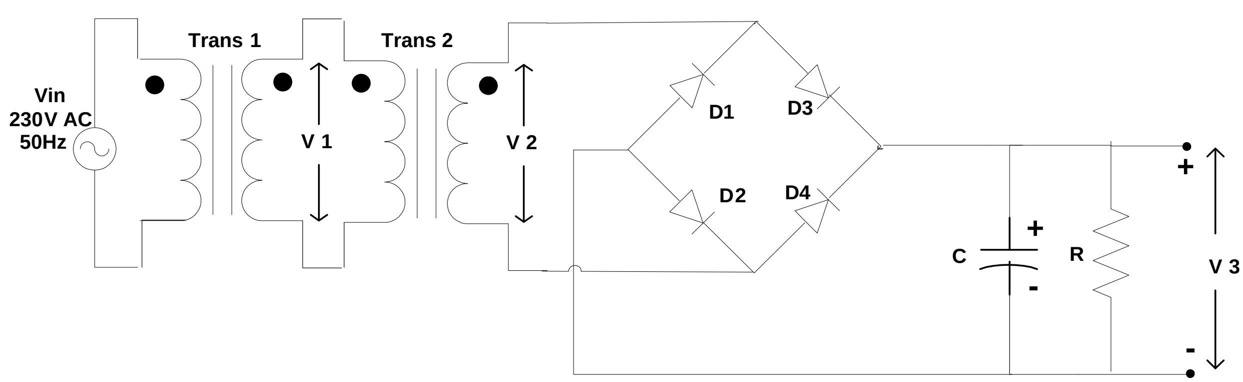
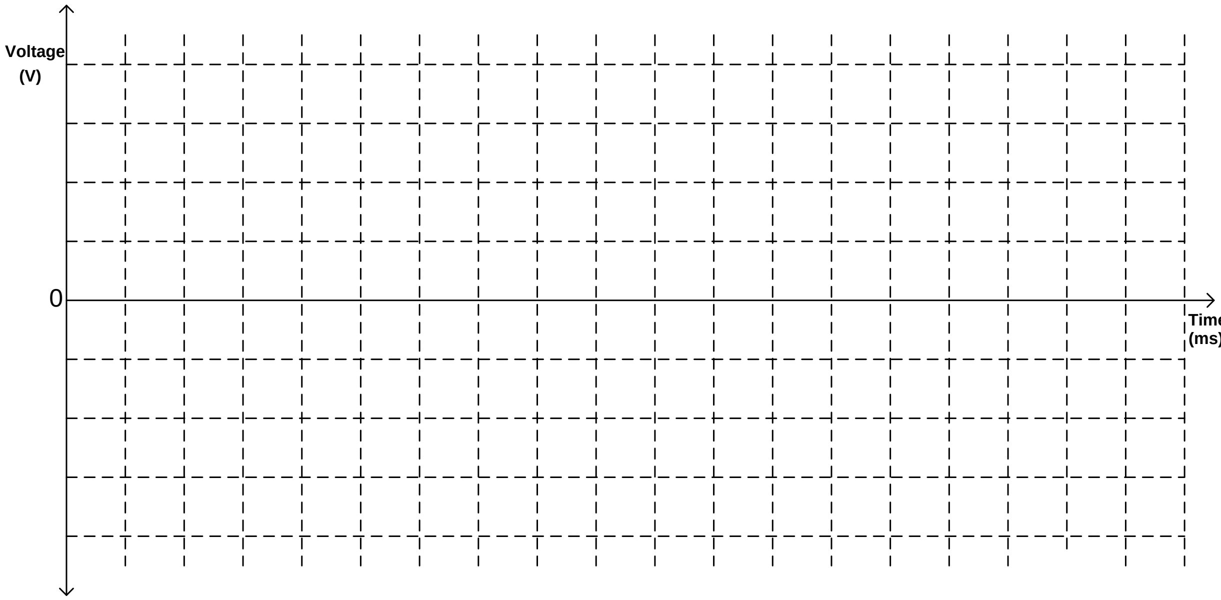



Fig. 1 Transformer with diode bridge rectifier circuit

i) Let $R = 10\Omega$ and $C = 0F$, measure the voltages $V_1$, $V_2$ and plot $V_3$ in the given graph:

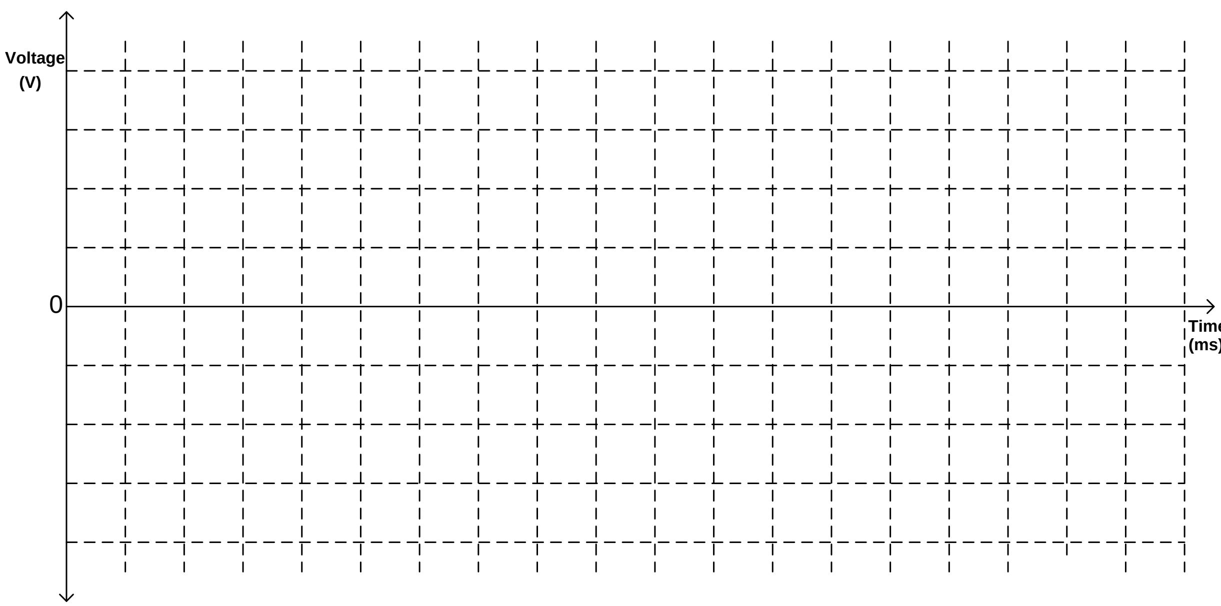
$V_{1\_RMS}$ = ___________ $V_{2\_RMS}$ = ___________




Volts/Div = Time/Div =

ii) Let $R = 1.2\ k\Omega$ and $C = 0F$, measure voltages $V_1$, $V_2$ and plot $V_3$ in the given graph:

$V_{1\_RMS}$ = ___________ $V_{2\_RMS}$ = ___________




Volts/Div = Time/Div =

iii) Let $R = 10\ \Omega$, find the minimum value of $C$ to make sure the circuit output $V_{3\_RPP} < 1\%\ of\ V_{3\_MAX}$, where $V_{RPP}$ is the allowable peak-to-peak ripple voltage;

*C* = __________*F*

iv) Let $R = 1.2\ k\Omega$, find the minimum value of $C$ to make sure the circuit output $V_{3\_RPP} < 1\%\ of\ V_{3\_MAX}$, where $V_{RPP}$ is the allowable peak-to-peak ripple voltage;

$C$ = __________F

# 5. In-lab activities

## a) Verification of the dot convention for the transformer

Keep the secondary winding of the Transformer 1 (Trans-1: 230 to 9 V, 36 VA) open circuit and connect it to the oscilloscope CH1 as shown in Fig. 2. Observe the secondary voltage waveform using the oscilloscope and complete Table-1.

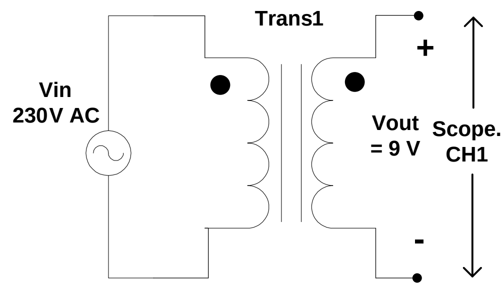



Fig. 2 Step-down transformer

Table -1

| $V_{peak}$ = | $V_{RMS}$ = |
|---|---|
| | |

Now, connect the secondary of the transformer 1 (Trans-1) to the primary winding of the transformer 2 as shown in Fig. 3 (Trans-2 using a suitable winding of your choice from the available transformer windings, 0-9 V, 0-9-12 V, 0-9 V. You can step-up or step-down the voltage as you prefer). Connect the primary winding of transformer 1 to the CH1 of the oscilloscope and secondary of the transformer 2 to the CH2 (see Fig 3). Choose $R_L$ = 1.2 kΩ, 0.25 W. **Plot the CH1 and CH2 waveforms on the same graph**.

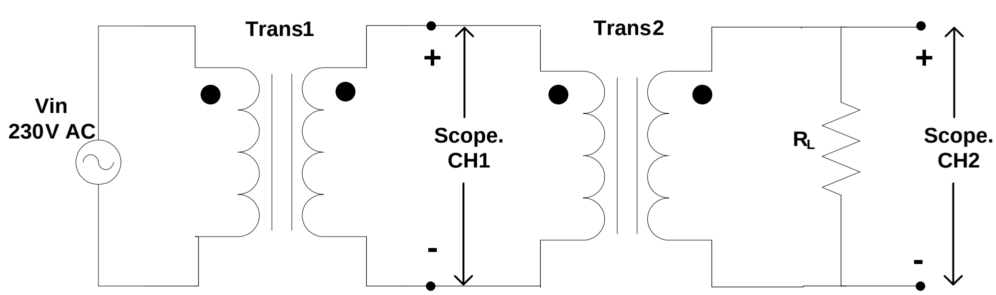
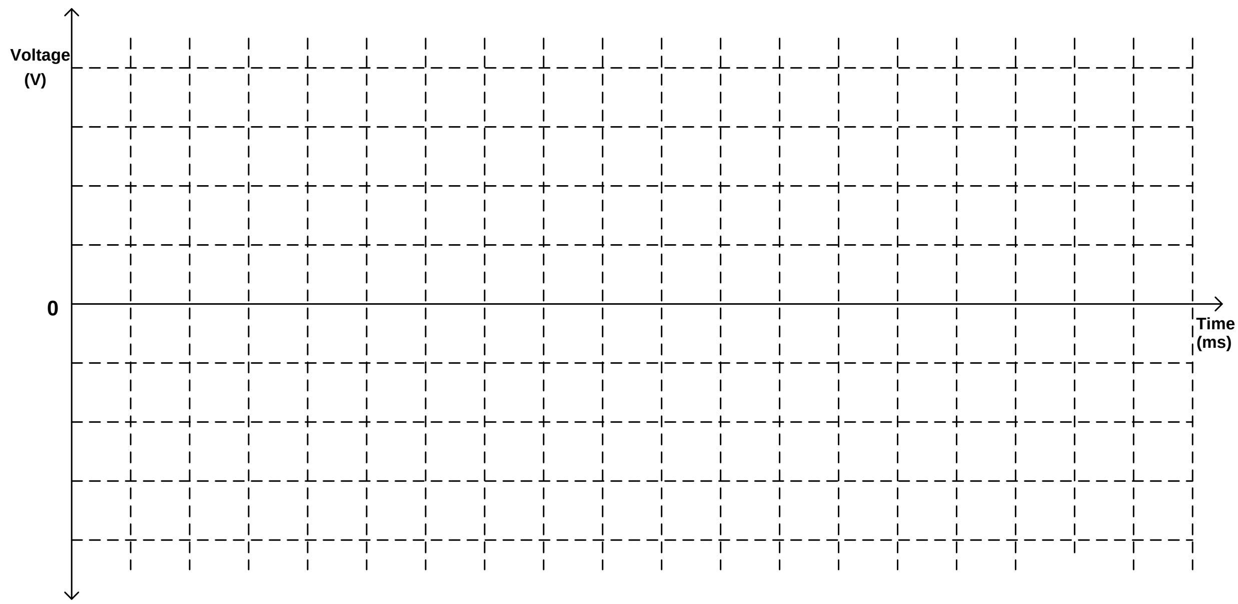



Fig.3 Step-up and step-down of voltage using transformer




CH1 Volts/Div =       CH2 Volts/Div =       Time/Div =

Now make use of all the three secondary windings of transformer 2 (0-9 V, 0-9-12 V, 0-9 V) to obtain 3 V and 21 V respectively. First design your circuits by connecting some or all of the seven nodes together (shown in circles) in Fig. 4(a) and Fig. 4(b) to obtain 3V and 21V in scope CH2. Then build the circuits according to your designs in Fig. 4(a) and Fig. 4(b). **Plot the waveforms of CH1 and CH2 in both cases**. Choose $R_L$ = 1.2 kΩ, 0.25 W.

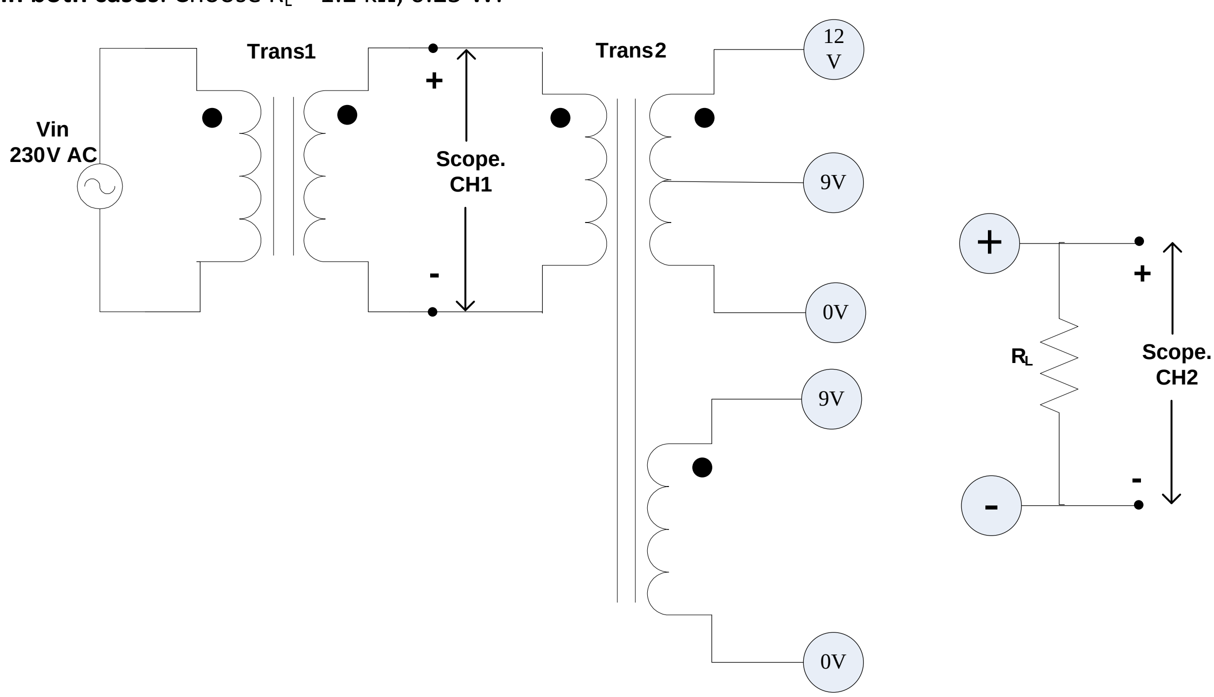
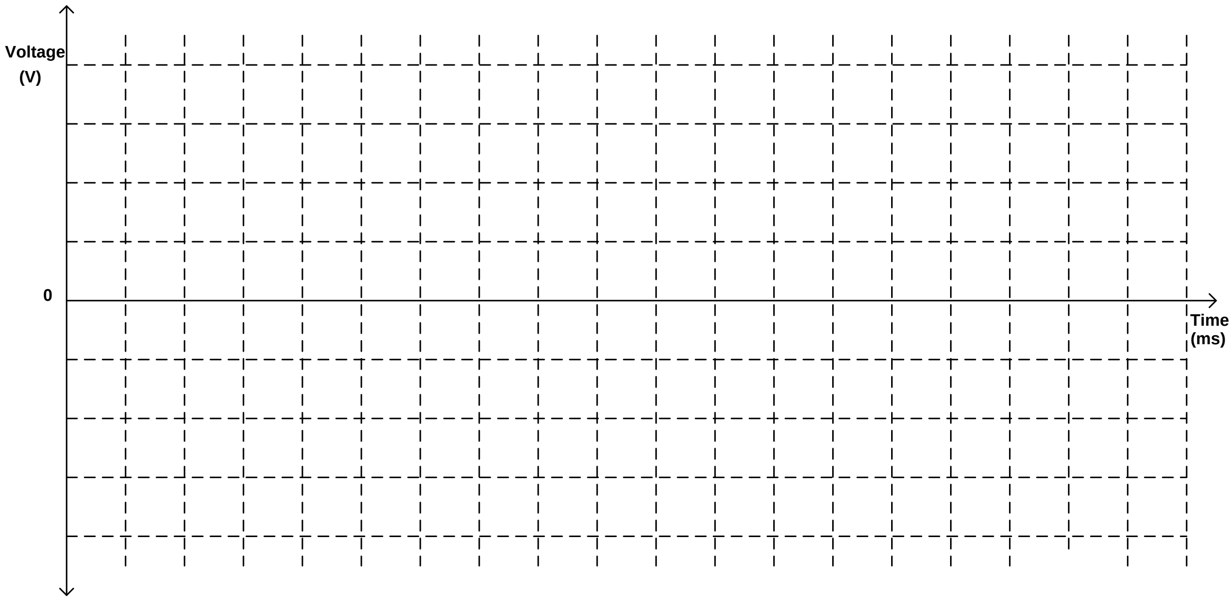



Fig. 4(a) Testing of dot convention of transformer windings—3V design




CH1 Volts/Div = CH2 Volts/Div = Time/Div =

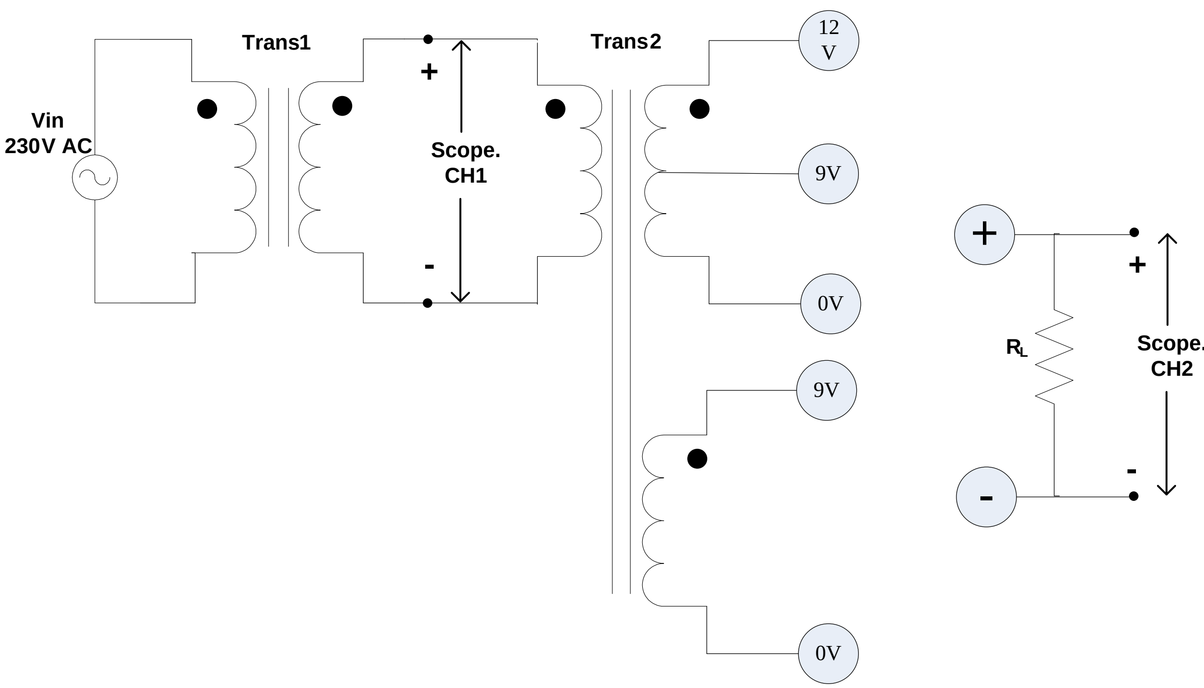
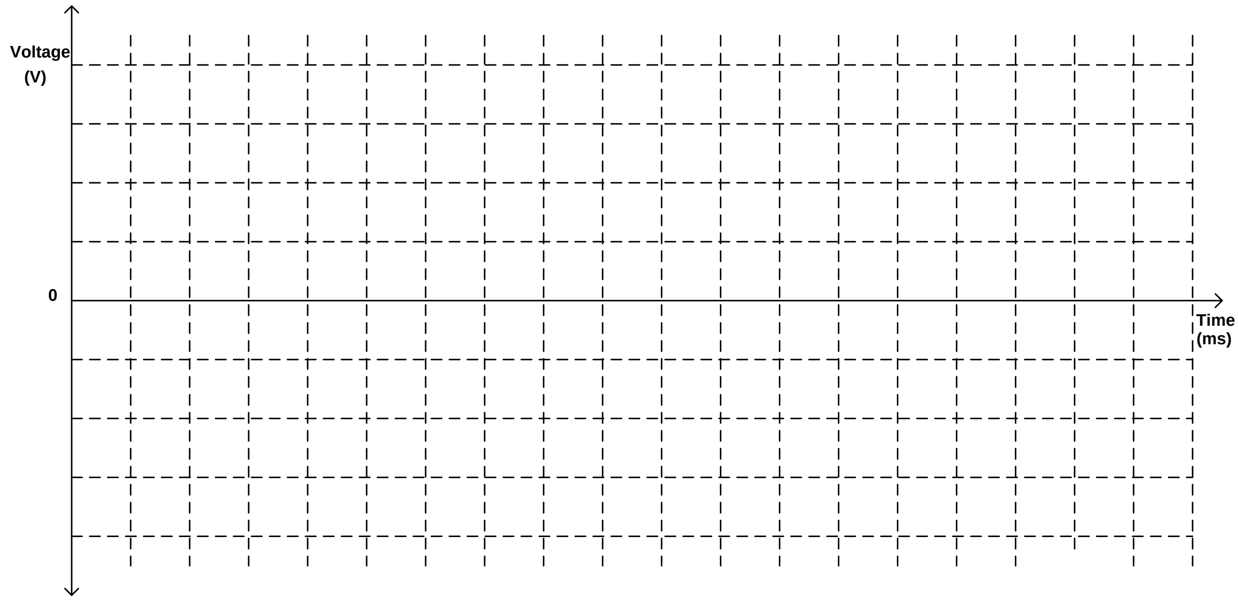



Fig. 4(b) Testing of dot convention of transformer windings—21V design




CH1 Volts/Div =          CH2 Volts/Div =          Time/Div =

Explain your observations with regards to the phase relationship between primary and secondary voltages of transformer 2 using the **dot convention**.

**<u>Why shouldn't you use oscilloscope to observe the mains supply voltage at 230 V directly? (WARNING: DON'T TRY IT)</u>**

## b) Setting up a diode-bridge rectifier circuit

To convert AC voltage to DC voltage, we need to setup a diode-bridge rectifier circuit as shown in the Fig. 5 (using IN4001 diodes). Choose an $R_L$ = 10 Ω, 10 W resistor which draws a current of approximately 1 A. (PLEASE TAKE NOTE THAT THE RESISTOR WOULD GET HOT SO DO NOT TOUCH THE RESISTOR NOR KEEP THE CIRCUIT ON FOR MORE THAN 2 MINS.)

Plot the voltage across $R_L$ and complete Table-2.

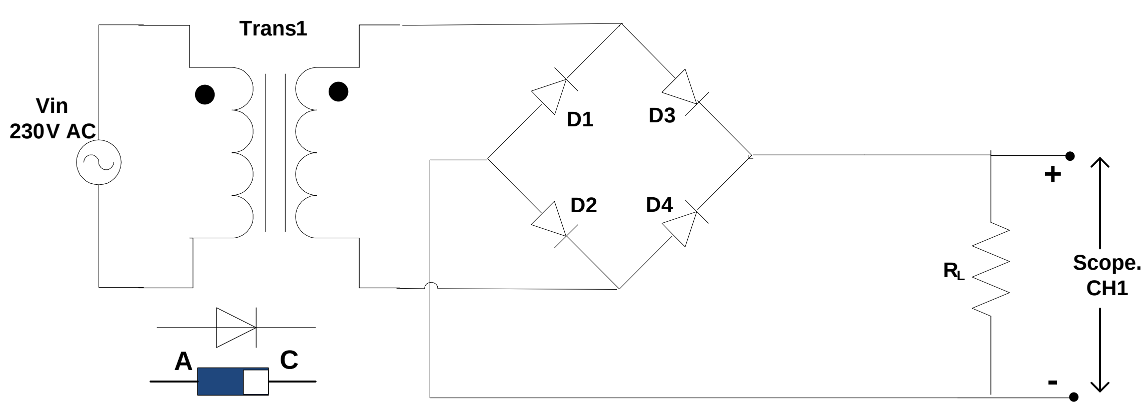
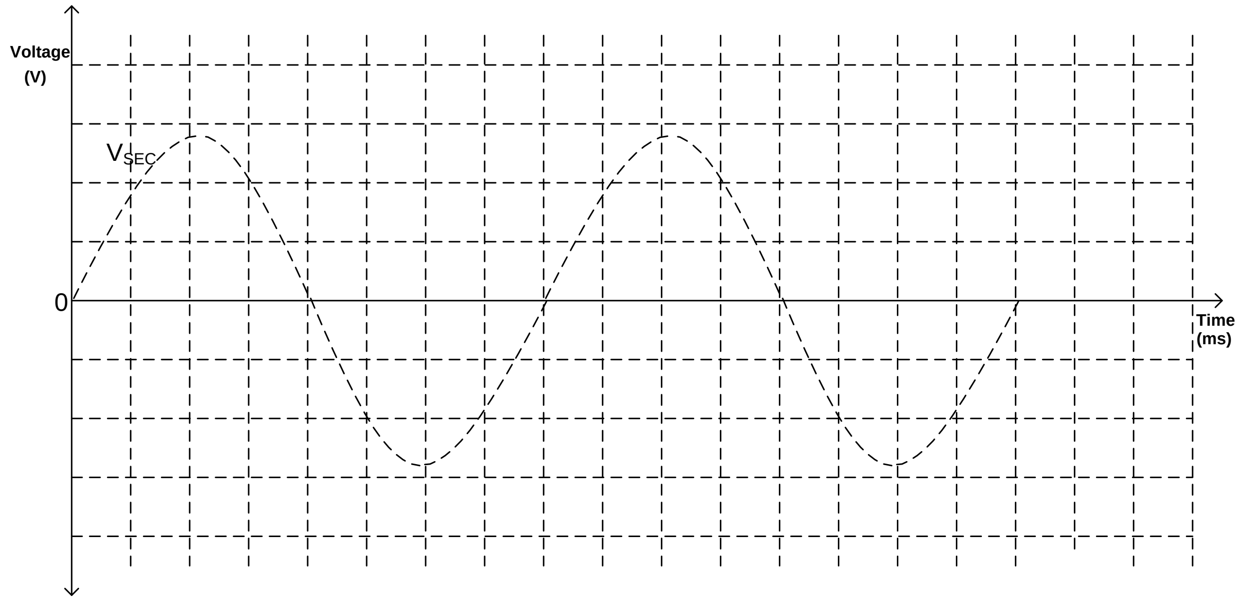



Fig. 5 Diode bridge rectifier circuit




Volts/Div = Time/Div =

Table -2

| $V_{max}(R_L)$ = | $V_{min}(R_L)$ = | $V_{Rpp}(R_L)$ = | $V_{RMS}(R_L)$ = | $V_{ave}(R_L)$ = |
|---|---|---|---|---|
| | | | | |

Is it possible to use the oscilloscope to observe the waveforms at the transformer secondary and across $R_L$ simultaneously? Justify your answer.

**Designing a capacitor filter**

We use an electrolytic capacitor (with voltage polarity + and – and BE CAREFUL TO USE CORRECT POLARITY OF THE CAPACITOR) as filter (Fig. 6) to reduce the ripples at the output voltage. Design a capacitor filter which ensures that the voltage across $R_L$ (when $R_L = 10\ \Omega$) never drops below 7V. [Hint: The formula for calculating the approximate capacitance value required, $C_1 = I/2fV_{Rpp}$ where '$V_{Rpp}$' is the allowable peak-to-peak ripple voltage, '$I$' is the current drawn, and '$f$' is the supply frequency.]

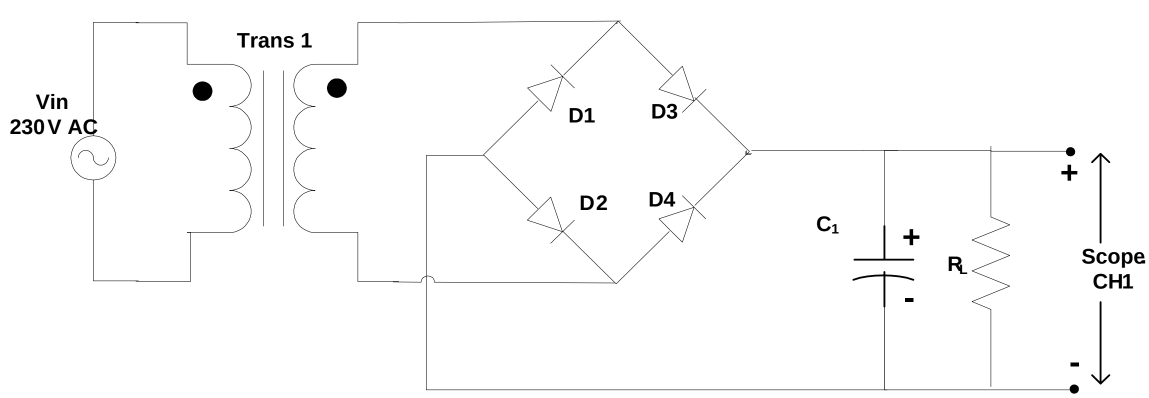



Fig. 6 Diode bridge rectifier circuit with filter capacitor

Identification of positive and negative leads can be done through the following two ways:

1) The positive lead is usually longer than the negative lead.
2) Adjacent to the negative lead, there is a *white strip* running through the length of the capacitor and marked with a '-'(refer to Fig. 7).

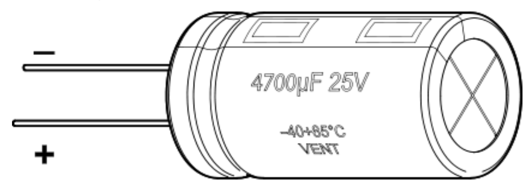


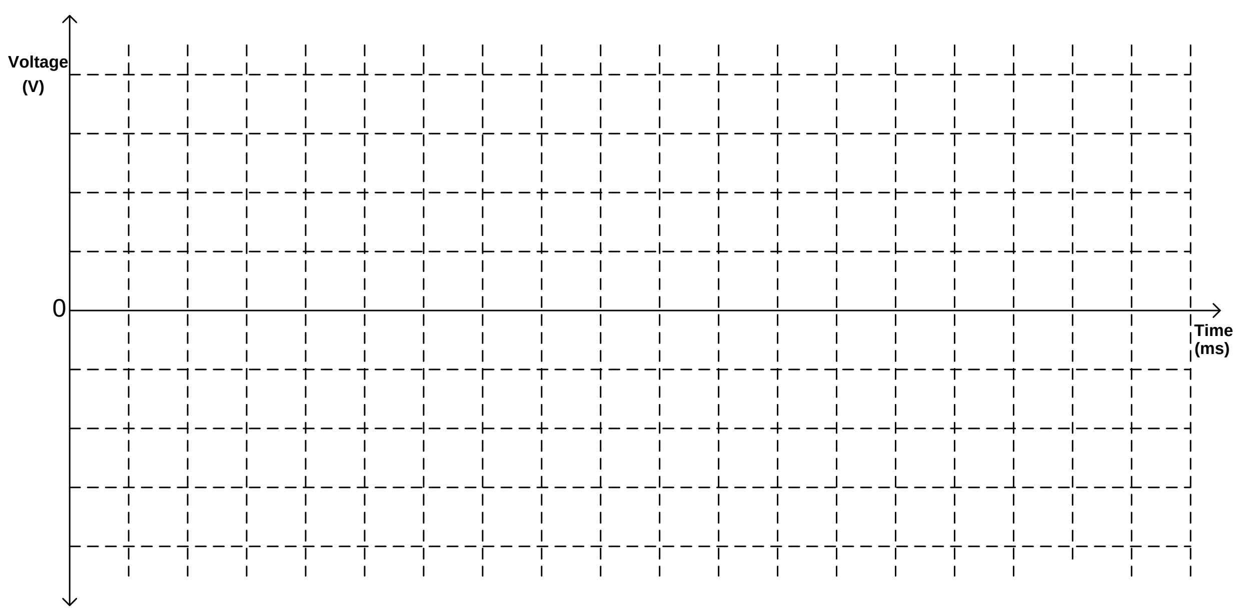

Fig. 7 Identification of polarities of an electrolytic capacitor

Complete Table-3 and plots based on your observations using $C_1$ as designed in the previous step. You may increase the capacitance by twice its original value or higher and then observe the effect of increasing the filter capacitance on the output voltage ripples and justify your observations using the above mentioned equation for capacitor.

Table -3

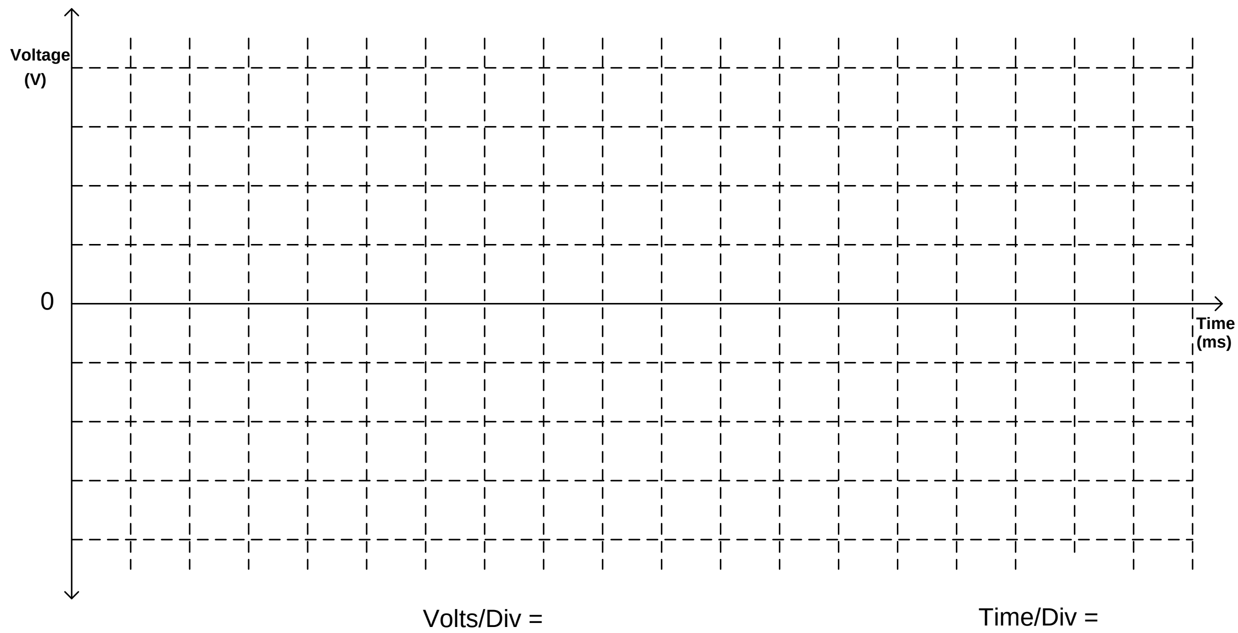
| | $V_{max}(R_L)$ = | $V_{Rpp}(R_L)$ = | $V_{min}(R_L)$ = | $V_{RMS}(R_L)$ = | $V_{ave}(R_L)$ = |
|---|---|---|---|---|---|
| $R_L$ = 10 Ω, 10W | | | | | |
| $R_L$ = 1.2 kΩ, 0.25W | | | | | |

Plot for $R_L$ = 10Ω, 10W




Volts/Div = Time/Div =

Plot for $R_L$ = 1.2 kΩ, 0.25W




What are the advantages and limitations of the capacitor filter?

### c) Voltage regulator using 7805 IC

Make use of the IC 7805 and provide the input voltage from the power supply as shown in the Fig. 8. Choose a capacitor of around 0.1 µF for $C_2$. Fill in the followings in Table-4 based on your observations.

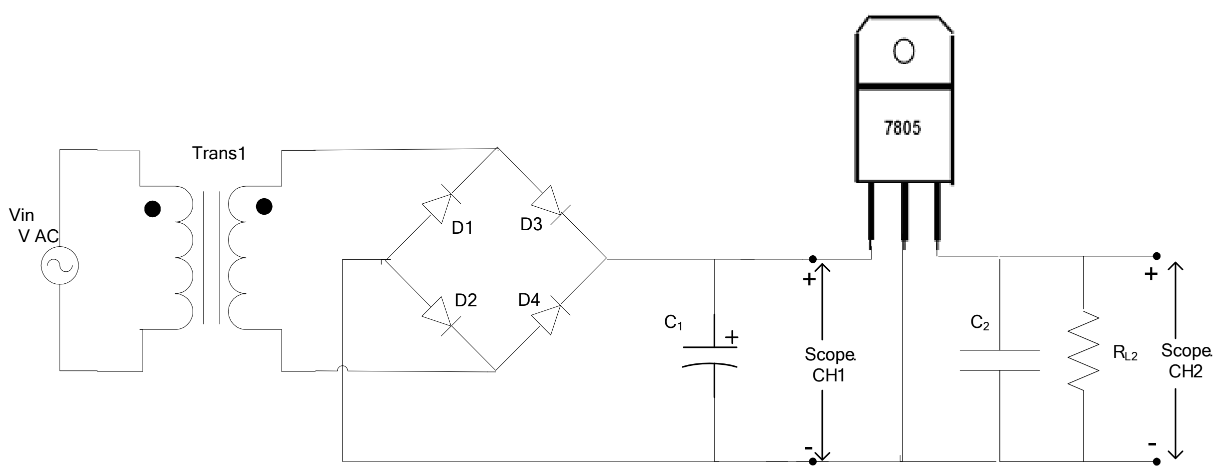



Fig. 8 Regulated DC power supply for logic circuits

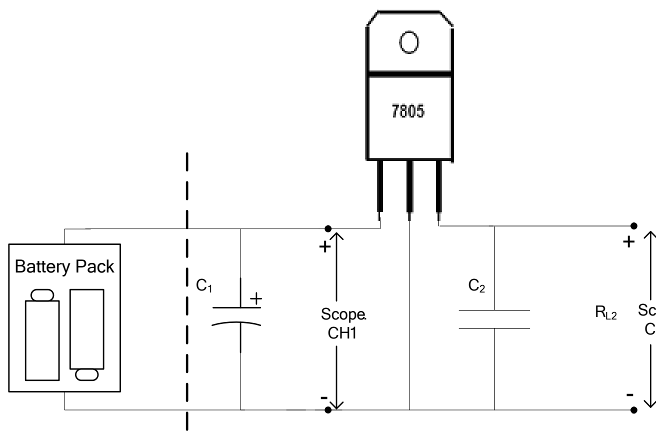
Table - 4

| | $V_{Rpp}(R_{L2})$ = | $V_{ave}(R_{L2})$ = |
|---|---|---|
| $R_{L2}$ = 1.2 kΩ, 0.25W; $R_L = \infty$ | | |
| $R_{L2}$ = 50 Ω, 1W; $R_L = \infty$ | | |

Comment on the working of IC 7805 based on your observations. Can the output from the IC 7805 be considered as emanating from an ideal voltage source?

Why do you need $C_2$? Is it advantageous to increase $C_2$?

**<u>Project Implementation</u>**




Observe how the transformer and diode bridge rectifier can be replaced by a battery pack. This circuit is commonly used to obtain a fixed 5V supply from higher and unregulated voltage sources (e.g. 8V – 15V).