Name: ______________________________
Course/Year/Section: ______________________________
Date Started: ____________ Date Submitted: ____________
Assessed by: ____________________ Rating: ________

SUPPORT CIRCUIT DESIGN 1

Module 3

I. OBJECTIVES

At the end of the lesson, the students are expected to:

1. Learn the basic electronic circuits used to support microcomputer systems, such as a regulated power supply.
2. Appreciate the importance of certain electronic circuits to optimize the performance of various microcomputer applications.
3. Design a regulated power supply based on specific parameters or requirements.

II. GENERAL INFORMATION

1. **SUPPORT CIRCUIT DESIGNS –** complimentary electro-mechanical circuits that are designed to help microcomputers systems optimize their performance. In the context of this module, the focus will be on the design of a regulated power supply.

2. **BASIC OHM'S LAW FORMULAS:**

   a. E = IR = electromotive force (voltage, measured in volts or v) is the product of current (intensity, measured in A) and resistance (measured in ohms or Ω)
   b. I = E/R = current is the quotient of voltage and resistance
   c. R = E/I = resistance is the quotient of voltage and current.
   d. P = EI = power is the product of voltage and current.
   e. $P = I^2R$ = power is the product squared current and resistance.
   f. $P = E^2/R$ = power is the quotient of squared voltage over and resistance.

3. **REGULATED POWER SUPPLY –** a direct current (DC) power supply used to provide stable, regulated power source to MCU and its system peripherals.

Figure 1
DC Regulated Power Supply Design

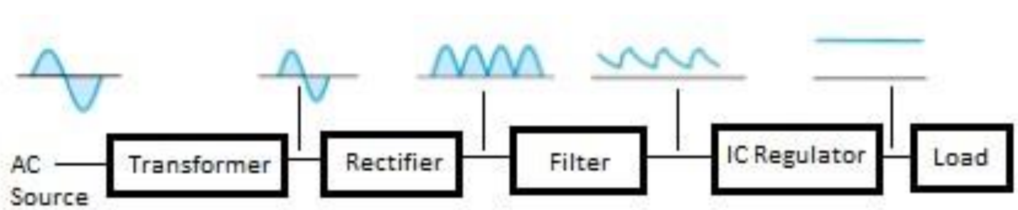
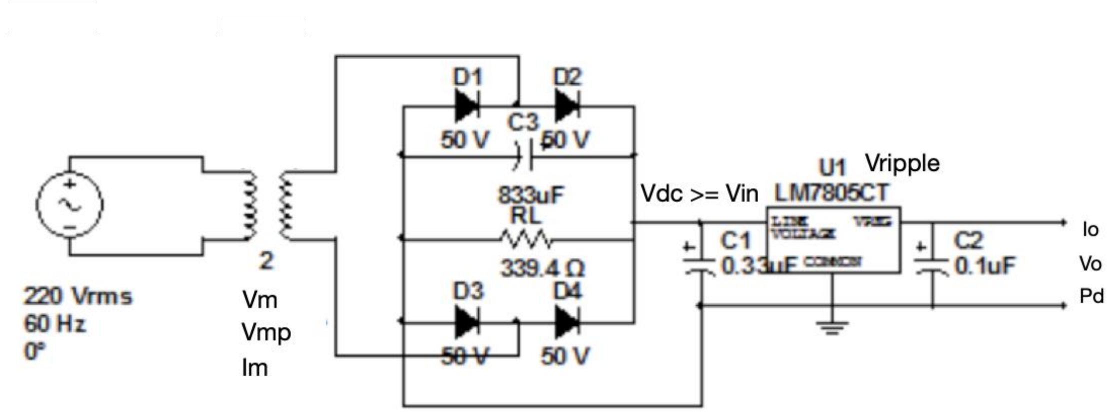


Figure 2

DC Regulated Power Supply Sample Schematic Diagram



4. DESIGN CONSIDERATIONS

- The load (R_L) is the output component. Parameters I_o and V_o or V_{dc} requirements should be considered first. $R_L = V_o/I_o$ or $R_L = V_{dc}/I_o$.
- The power dissipation ($P_D > I_O V_O$) of the RL to be used in laboratory should be greater than the computed value.
- Check the V_{mp} = voltage rating of the secondary winding of the transformer; it should ably meet the required range at the line voltage (V_{in}) of the regulator IC – refer to the datasheet.
- Check the I_m = maximum current rating of the transformer, which should able support the required current output of the power supply design. If I_O is stated as maximum, the designer can choose the desired I_O that fits within the range.
- Compute for the peak voltage rating of the V_m by using the formula: $V^{mp} = V_m \sqrt{2}$
- Using a general-purpose diode for the bridge-type rectifier circuit, the $V_k = 0.7V$ (Si).
- The equivalent DC voltage of a power supply design is computed as $V_{dc} = 0.636 (V_{mp} - 2V_k)$ for full wave; $V_{dc} = 0.318 (V_{mp} - V_k)$ for half-wave.
- To compute for the Filter Capacitor (FC), consider the formula: C = IT/V, where C is the capacitance (usually in μF), I is the current that flows into the capacitor (usually in mA), T (full wave = 8.33 ms; half wave = 16.64 ms); and V is the V_{ripple} ($V_{pp}/2 = 0.5/2 = 0.25V_p$).
- Vripple is the fluctuating DC filtered out from the rectifier circuit and can be expressed as $V_{pp}/2$ or V_p value which should be ideally $\leq 0.5V_{pp}$.

- It is computed by the formula: $V_{ripple} = V_{dc}\ (1 - e^{-T/RLC})$; where RL is the load resistance; T is the time element of the design; and C is the assumed capacitor value.
- Note that V_o can be V_{dc} (use $R_L = V_{dc}/I_o$) or V_{mp} ($R_L = V_{mp}/I_o$).
- Note that the formulas C=IT/V and $V_{ripple} = \Delta V = V_{max} - V_{min} \approx V_{dc}\ (1 - e^{-T/RLC})$ may not be exactly equal due to some tolerance considerations such as noise, etc., but can be used interchangeably depending on the choice of the designer.
- C is inversely proportional to V, hence, the higher the C value, the lower the voltage ripple.
- The output frequency for half wave is equal to the input ($f_i = f_o$), which is 60Hz for 220VAC; while for full wave, $f_o = 2f_i$, which is 2*60=120Hz.

- ***For Fixed Regulator IC***
  a. Check for pin configuration of the regulator IC's V_{in}, G (ground), and V_o terminals.
  b. Ensure that the $V_{mp} \geq V_{in}$ by referring on the datasheet of the regulator IC.
  c. Follow the recommended optimization circuit as stated on the datasheet of the regulator IC such as the C_1 and C_2 components and others.
  d. The output of the regulator IC indicates the V_{min} | $V_{typical}$ | V_{max} with equivalent test conditions I_{min} | $I_{typical}$ | I_{max}

- ***For Adjustable Regulator IC***
  a. Check for pin configuration of the regulator IC's V_{in}, V_{Adj} (Adjust), and V_o terminals.
  b. Ensure that the $V_{mp} \geq V_{in}$ by referring on the datasheet of the regulator IC.
  c. Follow the recommended optimization circuit as stated on the datasheet of the regulator IC such as the C_1,C_2,R_1, R_2 and others components.
  d. Output capacitors (C_2) are usually in the range of 1 μF to 1000 μF, unless stated.
  e. The output voltage (V_o) of the regulator IC indicates the V_{ref} or V_{min} ($1.25V_{typ}$)| V_{max} | I_{R2max} (100uA) also known as Adjustment Pin Current. The average output voltage of the regulator IC is computed as $V_o = V_{ref}(1 + R_2/R_1) + (I_{adj} * R_2)$
  f. Note that for negative and positive regulator circuits, same formulas can be used.

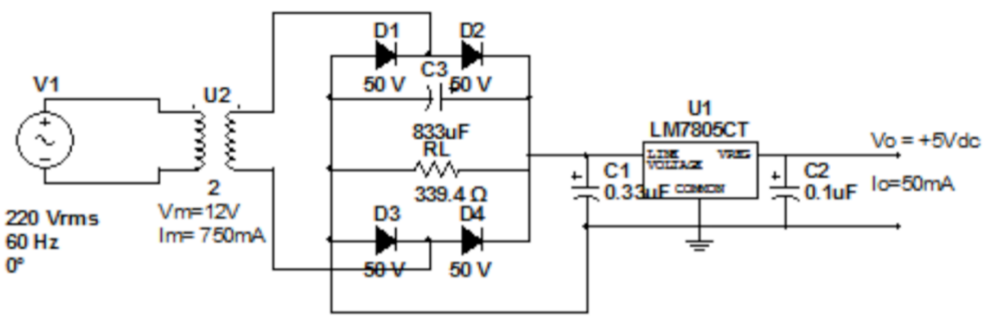
- ***For Adaptor/ Charger***
  a. The V_O and I_O of the adaptor substitute the V_m and I_m parameters of the transformer.

b. Additional half-wave or full-wave rectifier circuits can be used and follow the same design considerations as using the conventional transformer method.

III. SAMPLE DESIGN

Design a DC regulated, bridge type, full wave, power supply with $I_o \approx 50mA$, $V_o \approx 5V$, V_m = 12-0-12V (Center-tap, just use Vm = 12V), Im = 750mA, $V_k = 0.7V$, and $V_{ripple} = 0.5Vpp$.

Figure 3
Power Supply Design 1

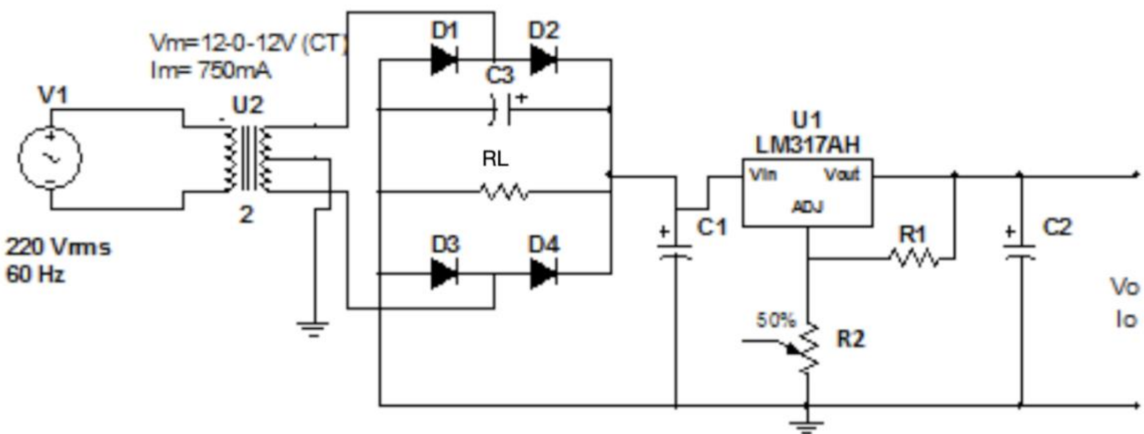


- $V_{mp}=V_m\sqrt{2}= 12\sqrt{2}=16.97V$
- $V_{dc}=0.636(V_{mp}-2V_k)=0.636[16.97-(2*0.7)]=9.90V$ (full wave)
- $C=IT/V=(50^{-3}*8.33^{-3})/0.5V_{pp}=833uF$
- $R_L=V_{dc}/I_o= 9.90/50^{-3}=198\Omega$ with $P_D = IV = 50^{-3}*9.90=0.495W$ (ideal)
- $R_L= V_{mp}/I_o= 16.97/50^{-3}=339.4\Omega$ with $P_D = IV = 50^{-3}*16.97=0.849W$ (actual)
- $V_{ripple}=Vdc(1-e^{-T/R_LC})= 9.90(1-e^{-0.00833/[198*.000833})=0.5V_{pp}$
- According to the LM7805 datasheet, V_{in} = 7V-20V, hence, V_{dc} = 9.90V is check.
- According to the LM7805 datasheet, optimization components should be C_1=0.33μF and C_2=0.1μF.
- According to the LM7805 datasheet, I_m = 750mA, I_o=5mA-1A, hence, I_o= 50mA is check.
- According to the LM7805 datasheet, V_{min} = 4.8V, V_{ave} = 5V and V_{max} = 5.2V, V_o = 5V is check.

IV. CHECKPOINT

In reference to the above concepts, design a regulated **adjustable power supply** with $I_{omax} \approx 750$ mA, $V_{ripple} = 0.10V_p$, and maximize the center-tap $V_m = 12*2 = 24V$. Use LM317A, refer to its datasheet, and complete the table below. Show solutions.

Figure 4
Power Supply Design 2



Parameter	Computed
V_m	
V_{mp}	
V_{k1}	
V_{k2}	
V_{k3}	
V_{k4}	
V_{dc}	
V_{ripple}	
V_{in} (LM317)	
R_L (ideal)	
R_L (actual)	
$P_{D\ RL}$ (ideal)	
$P_{D\ RL}$(actual)	
V_{R1}	
I_{R1}	
V_{R2min}	
I_{R2min}	
V_{R2max}	

I_{R2max}	
C_1	
C_2	
$V_{omin\ (pureDC)}$	
$V_{omax\ (pureDC)}$	
$I_{omin\ (pureDC)}$	
$I_{omax\ (pureDC)}$	
F_I	
F_O	

2. In reference to your previous proposed IPO/block model in Modules 1 and 2, design the appropriate power supply system. Present the following requirements:

- Schematic circuit design
- Computational solution/s for each electronic component, including justification if necessary.