



LOW-COST POWER SUPPLY FOR HOME APPLIANCES

INTRODUCTION

In most non-battery applications, the power to the microcontroller is supplied by using a step-down transformer, which is then rectified, filtered and regulated. However, in many smaller low-cost applications, the cost of the transformer becomes the key factor in the system. Under these circumstances, the step-down transformer is normally not used in order to reduce the cost as well as the size. The power supply is a simple one-way rectifier with very few components. The output voltage is regulated by using a 5.6V zener diode. Despite its simplicity and low cost, it is still able to deliver enough current to the microcontroller and application circuits.

The purpose of this application note is to present the basic principle and cost analysis of the various power supply circuits for home appliance applications.

1 BASIC CIRCUITS

1.1 TRANSFORMER POWER SUPPLY

Figure 1. Transformer Power Supply Diagram

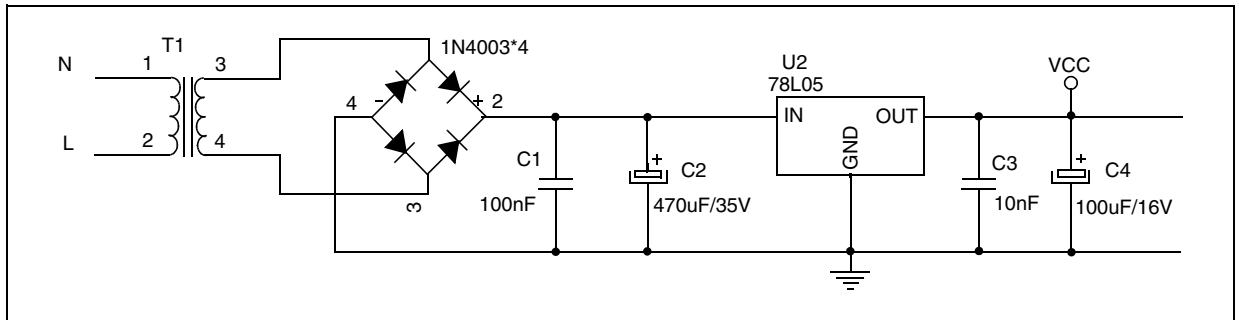


Figure 1. describes how to obtain a 5V DC voltage from the AC power line. In this circuit, the AC voltage drops down on the transformer’s secondary winding. A rectifier bridge with 4 diodes is used to convert the alternating AC voltage to a continuous DC voltage supply. A filter capacitor is added after the rectifier bridge in order to decrease the DC voltage ripple. The 78L05 triple terminal voltage regulator provides a very stable output and high current.

The advantages of this solution are:

- Power Supply is isolated from the AC line voltage,
- Power Supply can deliver high current (up to 100 mA for 78L05),
- The ripple of DC voltage will be small.

However, the disadvantages of this solution are also obvious:

- Much more expensive than transformerless power supplies,
- Power supply size is bigger due to the transformer and other components.

1.2 CAPACITIVE POWER SUPPLY

Figure 2. Capacitive Power Supply Diagram

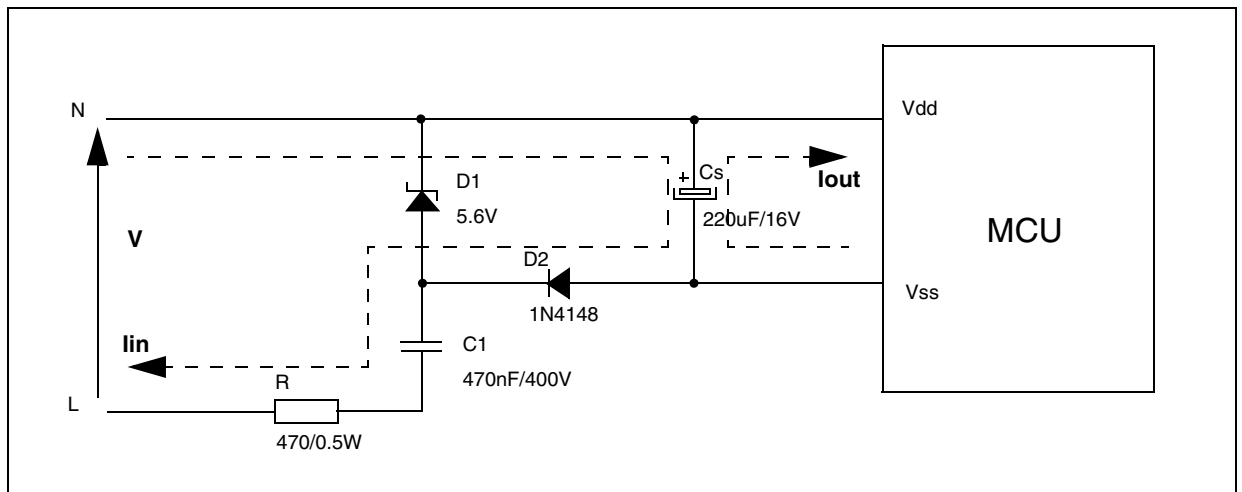


Figure 2. describes the capacitive power supply. In order to have a constant voltage across capacitor C_s , the average value of the input current (I_{IN}) must be equal to the average value of the output current (I_{OUT}). Current through this capacitor (C_s) flows during only the positive half cycle of the supply and during the negative half cycle it flows through the zener diode. Input current (I_{IN}) is a half-wave current, whose value is given by the following equation (R and C_s can be disregarded as the impedance offered by these is negligible in comparison to C_1):

$$I_{IN_{avg}} = \frac{V_{peak} \cdot 2\pi f \cdot C_1}{\pi}$$

Here V_{peak}/π = Average(dc equivalent) voltage in one cycle.

$2 \cdot \pi \cdot f \cdot C_1$ = impedance offered (neglecting R and C_s) . The voltage rating of C_1 should be greater than V_{peak} as it is charged up to V_{peak} .

Resistance and Capacitance(C_s) significance:

C_s has to be charged upto 5.6 V. So the voltage rating should be more than 5.6V. This capacitor reduces ripples from the output supply. As one tries to withdraw more and more current, the ripples will be increased. The high value of C_s would reduce the ripples from the supply up to a certain limit.

Resistance(R) limits the current through the zener diode. The value of R should be such that V_{peak}/R is more than the current limit of the zener.

To ensure the delivery of enough current in the worst conditions (V_{peak} , f and C at minimum), the average output current, sunk by the MCU, must match the following conditions (capacitor

value has $\pm 20\%$ accuracy), for a 220V / 50Hz supply:

$$I_{OUT_{av}} < \sqrt{2} \cdot 200_{(V)} \cdot 98_{(Hz)} \cdot 0.8 C_{(F)}$$

Note: For a 110V/60Hz calculation, replace 200V and 98Hz with 100V and 118Hz respectively.

The advantages of this solution are:

- The transformer is removed and the cost is significantly reduced.
- Power Supply size is smaller
- Maximum output current values are proportional with the AC capacitor values.

Removing the transformer optimizes the cost. As a result, the power supply is not isolated from the AC line voltage and the microcontroller is powered directly from the AC line.

In a capacitive power supply, the input current is mainly determined by the capacitor value on the AC line. The energy is stored in capacitor C on the positive half-wave cycle and can be re-stored on the other half-wave cycle. In order to obtain a higher minimum output current, increase the capacitor value on the AC line.

[Table 1](#) gives the maximum average output current values in relation to the various AC capacitor values.

Table 1 Maximum MCU Average Current Values for a 220V / 50Hz supply

| AC Capacitor Value | Max. MCU Average Current Value |
|--------------------|--------------------------------|
| 220 nF | 4.9 mA |
| 330 nF | 7.3 mA |
| 470 nF | 10.4 mA |
| 680 nF | 15 mA |
| 1 μ F | 22.1 mA |

1.3 RESISTIVE POWER SUPPLY

Figure 3. Resistive Power Supply Diagram

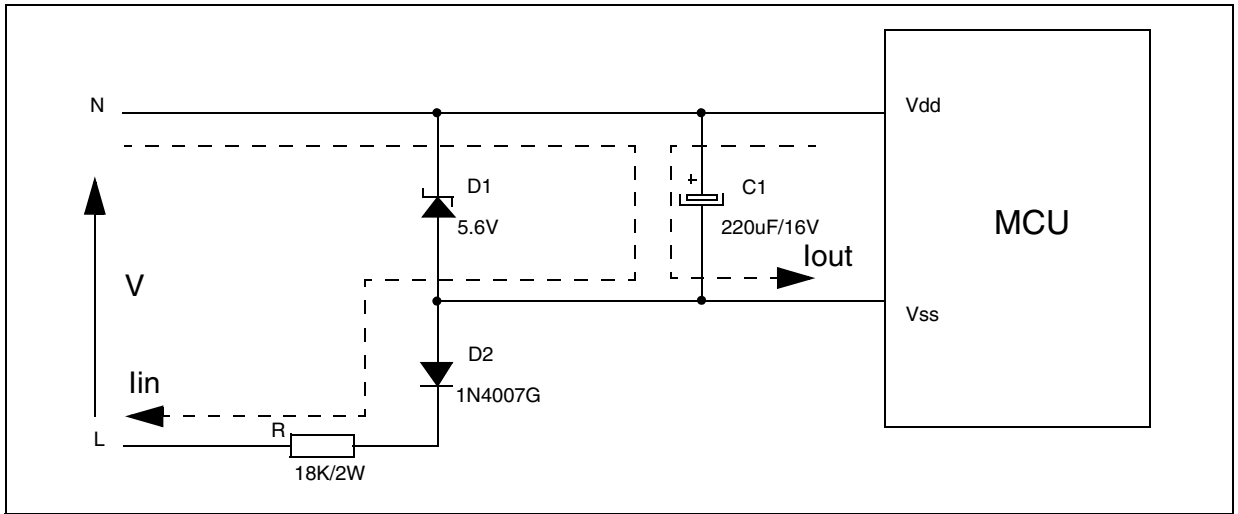


Figure 3. describes the resistive power supply. As shown in the diagram, the current passing through resistor R in the conductive half cycle is mainly dependent on the value of the resistor because the reactance of the capacitors is much less than that of the resistors. The value of the current through resistor R is therefore given by the following equation:

$$I = \frac{V}{R}$$

The current through resistor R is a half-wave current, the average current value is given by the following equation:

$$I_{INav} = \frac{V_{peak}}{R \times \pi}$$

In order to have a constant current through capacitor C1, the input current must be equal to output current. In the worst conditions (V_{PEAK} at minimum and R at maximum), the average output current, sunk by the MCU, must match the following conditions:

$$I_{OUTav} < \frac{200_{(V)} \cdot \sqrt{2}}{3.14 \cdot 1.1 \cdot 18_{(k\Omega)}} = 4.5mA$$

The advantages of this solution are:

- As with the capacitive power supply, the transformer is removed and the cost is significantly reduced.

- The circuit is very simple and the cost is even less expensive than the capacitive power supply.

In the resistive power supply, the input current is determined by the resistor value on the AC line. Therefore, the power consumption of this resistor is very high. In order to reduce the power consumption on this resistor, it is better to increase the resistor value. But the maximum output current will be decreased accordingly.

The disadvantages of resistive power supply are:

- Maximum average output current is limited and can not be adjusted easily.
- Power consumption on the resistor is high.
- Power supply is not isolated from the AC line.

2 COST ANALYSIS OF A POWER SUPPLY WITH/WITHOUT TRANSFORMER

2.1 COST ANALYSIS

Table 2 Cost Analysis of a Power Supply with/without Transformer

| Components | Unit Price ¹⁾ | Qty | Transformer Power Supply | Qty | Capacitive Power Supply | Qty | Resistive Power Supply |
|--------------------|--------------------------|-----|--------------------------|-----|-------------------------|-----|------------------------|
| 1.1 VA Transformer | 1.50 | 1 | 1.50 | 0 | - | 0 | - |
| 1N4003 Diode | 0.05 | 4 | 0.20 | 0 | - | 0 | - |
| L7805 | 0.15 | 1 | 0.15 | 0 | - | 0 | - |
| 470 μ F/35V | 0.30 | 1 | 0.30 | 0 | - | 0 | - |
| 100 μ F/16V | 0.20 | 1 | 0.20 | 0 | - | 0 | - |
| 1N4148 Diode | 0.03 | 0 | - | 1 | 0.03 | 0 | - |
| 470 nF/400 V | 0.30 | 0 | - | 1 | 0.30 | 0 | - |
| 1N4007 Diode | 0.05 | 0 | - | 0 | - | 1 | 0.05 |
| 18K/2W Resistor | 0.03 | 0 | - | 0 | - | 1 | 0.03 |
| 5.6V Zener Diode | 0.02 | 0 | - | 1 | 0.02 | 1 | 0.02 |
| 220 μ F/16V | 0.20 | 0 | - | 1 | 0.20 | 1 | 0.20 |
| Total | | | 2.35 | | 0.55 | | 0.30 |

1) Prices are listed in US dollars (year 2000). All prices are based on > 1000 unit quantities.

As shown above, the cost of the transformer power supply is much higher than without a transformer power supply.

3 CONCLUSION

To correctly design the power supply, the following conditions should be taken into account:

- The maximum currents required by the application circuits,
- Overall cost/performance evaluation.

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