



LOW-COST POWER SUPPLY FOR HOME APPLIANCES

by Microcontroller Division Application Team

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

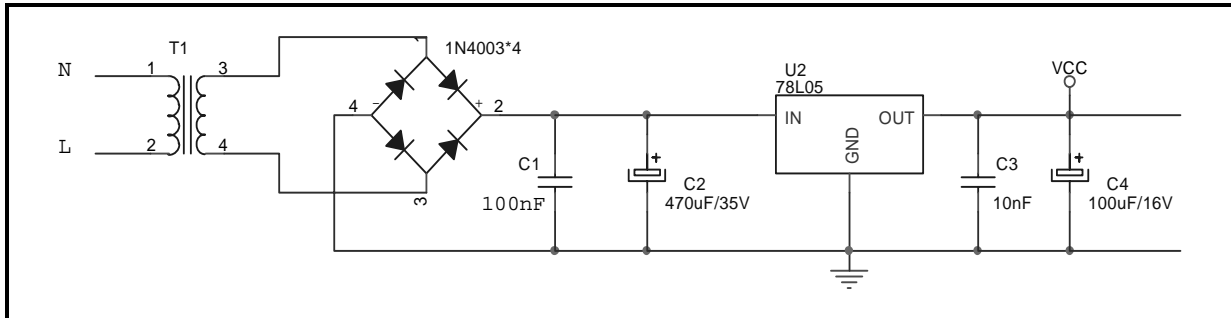


Figure 1. describes how to obtain a 5V DC voltage from the AC power line. In this circuit, the AC voltage drops down on the transformer's secondary winding. A rectifier bridge with 4 diodes is used to convert the alternating AC voltage to a continuous DC voltage supply. A filter capacitor is added after 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

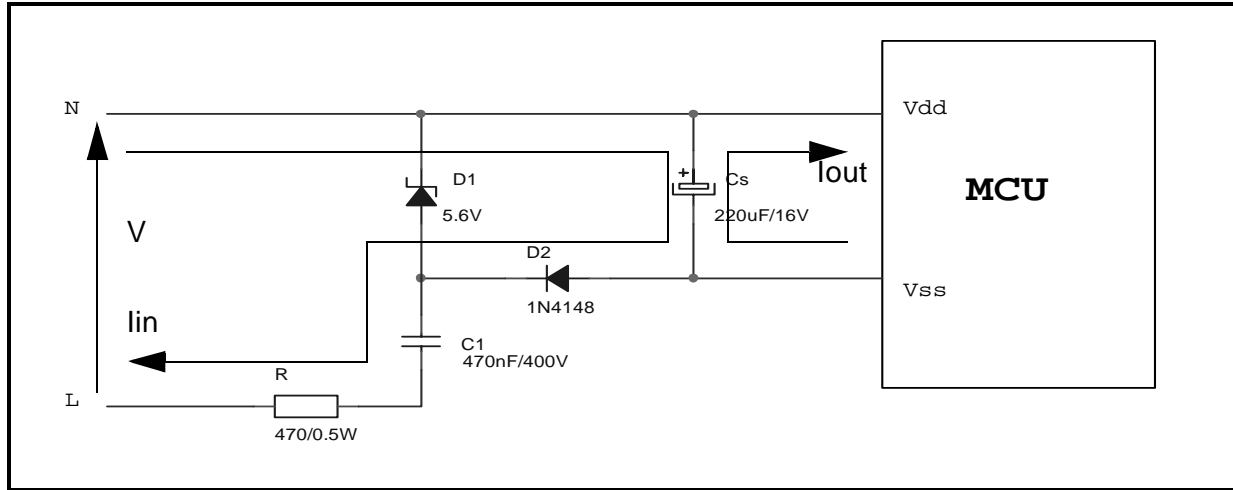


Figure 2. describes the capacitive power supply. In order to have a constant voltage across capacitor C_s , the average value of the input current (I_{IN}) must be equal to the average value of the output current (I_{OUT}). Input current (I_{IN}) is a half-wave current, whose value is given by the following equation (R can be disregarded):

$$I_{INav} = \frac{V_{peak} \cdot 2\pi f \cdot C}{\pi}$$

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):

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

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-

LOW-COST POWER SUPPLY FOR HOME APPLIANCES

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

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

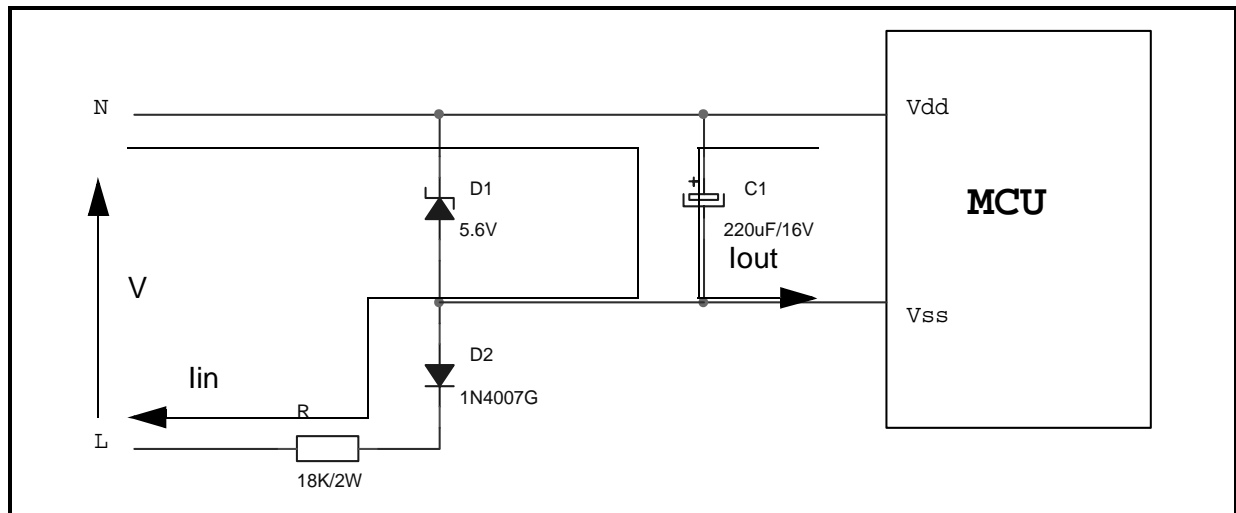


Figure 3. describes the resistive power supply. As shown in the diagram, the current passing through resistor R in the conductive half cycle is mainly dependent on the value of the resistor because the reactance of the capacitors is much less than that of the resistors. The value of the current through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

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

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 Price¹⁾	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 µF/35V	0.30	1	0.30	0	-	0	-
100 µF/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 µF/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.

LOW-COST POWER SUPPLY FOR HOME APPLIANCES

“THE PRESENT NOTE WHICH IS FOR GUIDANCE ONLY AIMS AT PROVIDING CUSTOMERS WITH INFORMATION REGARDING THEIR PRODUCTS IN ORDER FOR THEM TO SAVE TIME. AS A RESULT, STMICROELECTRONICS SHALL NOT BE HELD LIABLE FOR ANY DIRECT, INDIRECT OR CONSEQUENTIAL DAMAGES WITH RESPECT TO ANY CLAIMS ARISING FROM THE CONTENT OF SUCH A NOTE AND/OR THE USE MADE BY CUSTOMERS OF THE INFORMATION CONTAINED HEREIN IN CONNEXION WITH THEIR PRODUCTS.”

Information furnished is believed to be accurate and reliable. However, STMicroelectronics assumes no responsibility for the consequences of use of such information nor for any infringement of patents or other rights of third parties which may result from its use. No license is granted by implication or otherwise under any patent or patent rights of STMicroelectronics. Specifications mentioned in this publication are subject to change without notice. This publication supersedes and replaces all information previously supplied. STMicroelectronics products are not authorized for use as critical components in life support devices or systems without the express written approval of STMicroelectronics.

The ST logo is a registered trademark of STMicroelectronics

©2001 STMicroelectronics - All Rights Reserved.

Purchase of I²C Components by STMicroelectronics conveys a license under the Philips I²C Patent. Rights to use these components in an I²C system is granted provided that the system conforms to the I²C Standard Specification as defined by Philips.

STMicroelectronics Group of Companies

Australia - Brazil - Canada - China - Finland - France - Germany - Hong Kong - India - Israel - Italy - Japan
Malaysia - Malta - Morocco - Singapore - Spain - Sweden - Switzerland - United Kingdom - U.S.A.

<http://www.st.com>