AN5058
Application note

Low-cost STM8 / STM32 power supply from mains

Introduction

In most non-battery applications, power is supplied to the microcontroller (MCU) using a step-down transformer, the output of which is 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 use of a step-down transformer is generally avoided in order to reduce the cost and size of the system. The power supply is instead a simple one-way rectifier with very few components. The output voltage is regulated by a zener diode. Despite its simplicity and low cost, it can still deliver enough current to power a microcontroller and application circuits.

This application presents the basic principles of various power supply circuits for home appliance applications.

1 Basic circuits

1.1 Transformer power supply

Figure 1. Transformer power supply diagram

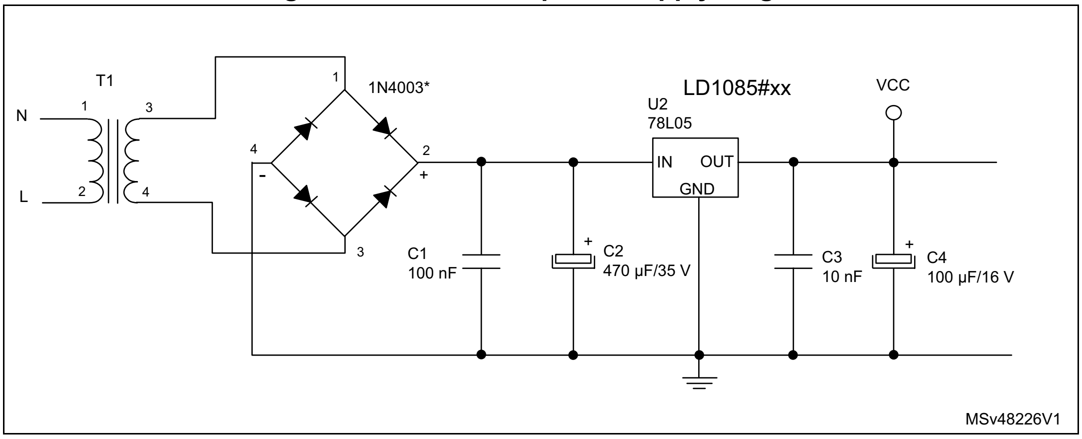

Figure 1 shows how to obtain a 5 V or 3.3 V DC voltage from the AC power line. In this circuit, the AC voltage is stepped down on the transformer's secondary winding. A rectifier bridge with 4 diodes converts the alternating AC voltage to a continuous DC voltage supply. A filter capacitor is added after the rectifier bridge to decrease the DC voltage ripple. The LD1085 triple-terminal voltage regulator provides a very stable output and high current. LD1085 #33 reference should be used for the 3.3 V supply and LD1085#50 for the 5 V supply.

The advantages of this solution are:

- the power supply is isolated from the AC line voltage
- the power supply can deliver high current (up to 3 A for an LD1085 in D²PAK package)
- small DC ripple voltage.

However, the disadvantages of this solution are also obvious:

- it is much more expensive than a transformer-less power supply
- the power supply is bigger due to the transformer and other components.

1.2 Capacitive power supply

Figure 2. Capacitive power supply diagram

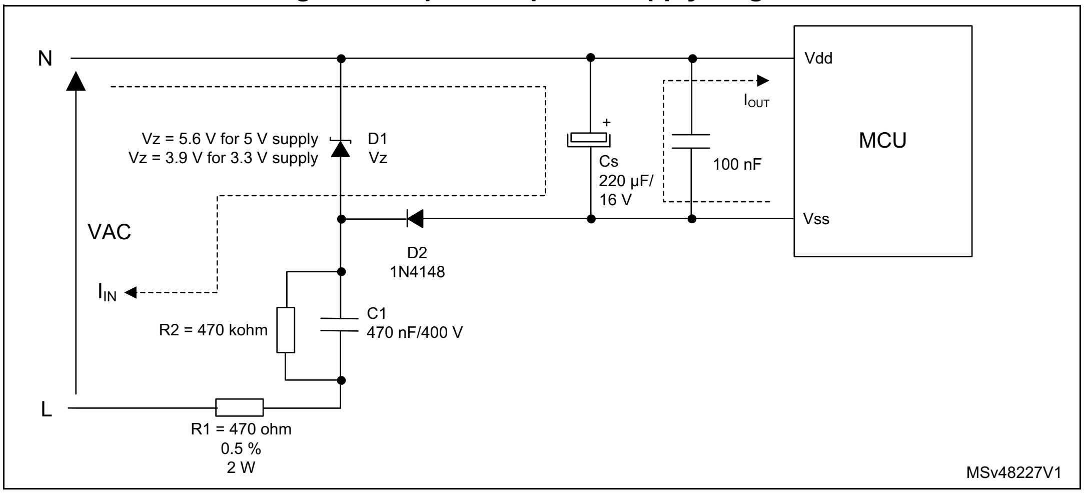

Figure 2 shows the capacitive power supply. In order to have a constant voltage across capacitor Cs, the average value of the input current (IIN) must be equal to the average value of the output current (IOUT). Current only flows through this capacitor (Cs) during the positive half cycle of the AC line voltage during the negative half cycle it flows through the zener diode.

The input current (IIN) is the half-wave current of the AC line

Significance of components Cs and R1

Capacitor Cs reduces the output-supply ripple. As more and more current is drawn, the ripple increases. The high value of Cs reduces the supply ripple within certain limits.

Resistance (R1) limits the current through the zener diode. The value of R1 should be such that Vpeak/R1 is more than the current limit of the zener diode.

To ensure sufficient current delivery under worst-case conditions (Vpeak, F and C1 at minimum) the value of C1 must correspond to the following equation:

$$C1 = \frac{1}{2 \times \pi \times F_{min}} \times \frac{1}{\sqrt{\left(\frac{\frac{\sqrt{2}}{\pi} \times VAC_{min}}{I_{OUT}}\right)^2 - R1^2}} \times \frac{1}{1 - \frac{AC}{100}}$$

In this formula:

- C1 = supply capacitor (F)
- R1 = Inrush current liminting resistor (ohms)
- VAC_{min} = Mains minimal voltage, (V RMS)
- F_{min} = Mains minimal frequency (Hz)
- AC = C1 capacitor accuracy (%)
- C1 is a class X2 capacitor

The advantages of this solution are:

- the transformer is removed and the cost is significantly reduced
- the power supply size is smaller
- maximum output current values are proportional to 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 Cs on the positive half-wave cycle and can be re-stored on the negative half-wave cycle. A higher minimum output current can be obtained by increasing the C1 capacitor value on the AC line.

Table 1 gives the maximum average output current values in relation to the various AC capacitor values. Calculations are performed with the following values :

VAC_{min} = 195 V RMS (230 V RMS – 15%), C1 accuracy = 10%, R = 470 ohms, f_{min} = 49.5 Hz (accuracy 1%).

Table 1. Maximum output current (Iout) supplied by the low-cost power supply

C1	Iout
220 nF	5.4 mA
330 nF	8.1 mA
470 nF	12 mA
680 nF	17 mA
1 µF	24 mA

1.3 Resistive power supply

Figure 3. Resistive power supply diagram

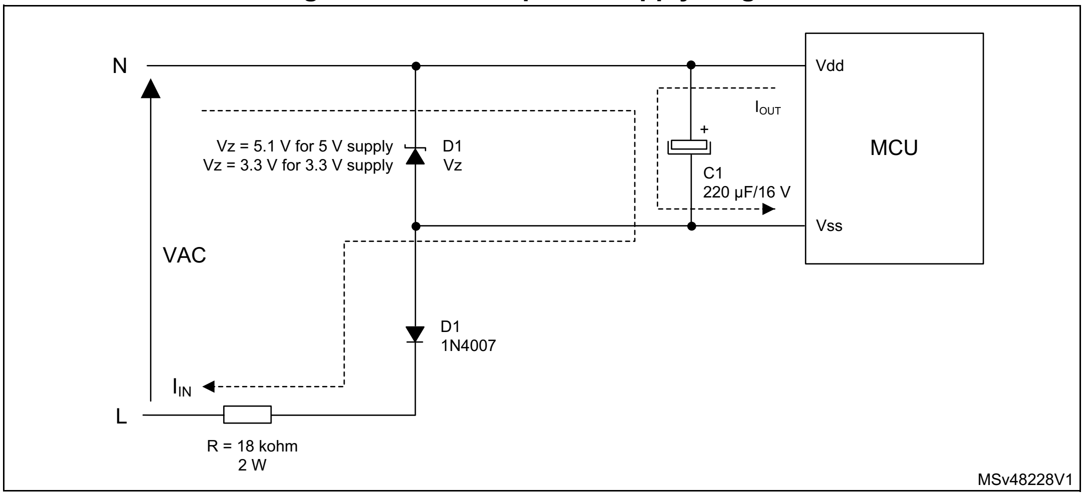

Figure 3 shows the resistive power supply. As shown in the diagram, the current passing through resistor R in the conductive half cycle is mainly dependent on the value of the resistor because the reactance of the capacitors is much less than that of the resistor. The value of the resistor R is therefore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

$$R = \frac{VAC_{min}}{I_{OUT}} \times \frac{\sqrt{2}}{\pi}$$

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 More information available in AN3168

The application note presents the basic principle of the various power supply circuits for home appliance applications. More details are available in AN3168 at chapter 3 : “Examples of negative power supplies”.

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.

4 Revision history

Table 2. Document revision history

Date	Revision	Changes
27-Mar-2018	1	Initial release.