VSquare/R

Transcycle Regulator

Leo Valenti
Jim Daly
May 13, 2015

The Transcycle Regulator is a system for controlling power to a load. A microcontroller responding to inputs from a user and/or feedback from the load, controls a switch to determine load power as shown in Figure 1. A special low noise soft switching method is used. Switches make and break contact when the load current is zero. This prevents voltage spikes and reduces noise.

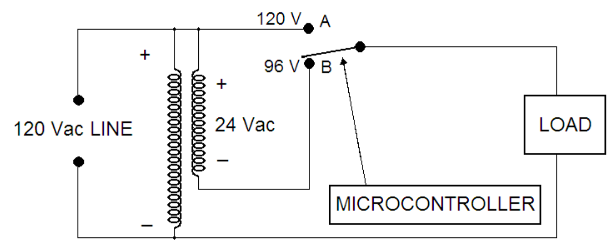

Figure 1 A microcontroller determines the timing of the Transcycle switch.

In the implementation shown in Figure 1, a buck transformer is used. When the switch is in position A, the full 120 V AC line voltage is applied to the load. When the switch is in position B, the load voltage is reduced by the voltage across the secondary of the buck transformer. If the secondary voltage is 24 V, the load voltage will be 96 Volts. This represents a 20% decrease in voltage, and since power varies as the square of voltage, 96 volts results in a 36% decrease in power delivered to the load.

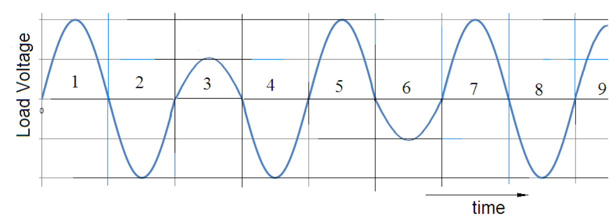

Figure 2 The load voltage is periodically reduced in half cycle increments. The voltage is shown reduced during the third and sixth half cycles.

Precise Regulation

Precise power regulation is achieved by intermittently switching between the two power levels. Power is applied to the load in half cycle increments. This allows any desired power between full power and the reduced power to be realized.

For example, when the switch is in position B, the voltage applied to the load is 120 V minus the voltage across the secondary of the transformer, 96 volts are applied to the load (120 - 24). Since power is proportional to the square of voltage, when the switch is in position B, the power is reduced to 64%, $(96/120)^2$.

Accurate regulation of load power is achieved by switching in half cycle increments as shown in Figure 2. The average load power as a function of the fraction of time at reduced power is plotted in Figure 3. The relative power is 100% when none of the half cycles are at reduced power. The average load power is 64% of the maximum when all the half cycles are at reduced power.

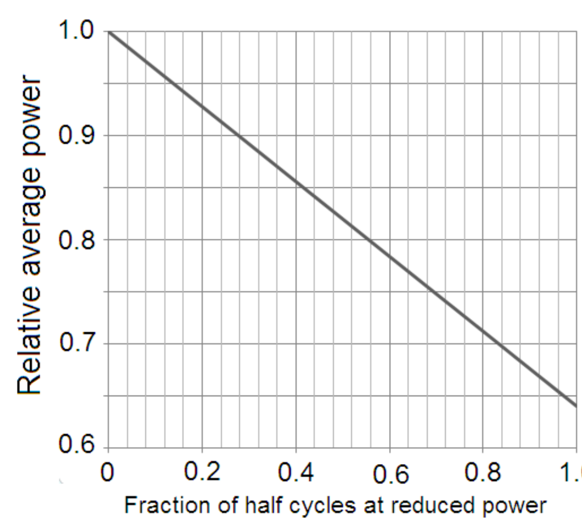

Figure 3 Reducing the load voltage in half cycle increments results in a reduced average load power. When none of the half cycles are at reduced power, the load power is 100%. When all of the half cycles are at reduced power the load power is at 64%

In this example the transformer secondary voltage is 24 volts. This results in a low applied voltage of 96 volts. If the secondary voltage were larger, more voltage would be subtracted from the line voltage when the switch is in position B. This would result in a greater reduction of power to the load.

Circuit considerations

Triacs work well switching AC power. Figure 4 shows the implementation of the single pole double throw switch (SPDT) using triacs. A triggering pulse from the microcontroller puts the triac into the conducting state. The triac remains in the conducting state until its current is zero. The SPDT switch consists of two triacs in parallel as shown in Figure 4. Care has to be taken to ensure that only one conducts at a time. If both triacs conduct, a short circuit current would flow from the high voltage to the low voltage. This short is avoided by switching when the load current is zero. In the absence of a triggering pulse, triacs turn off when their current goes to zero. Therefore, at the zeros of the load current, both triacs will be off. The appropriate triac is then triggered to provide the desired load power.

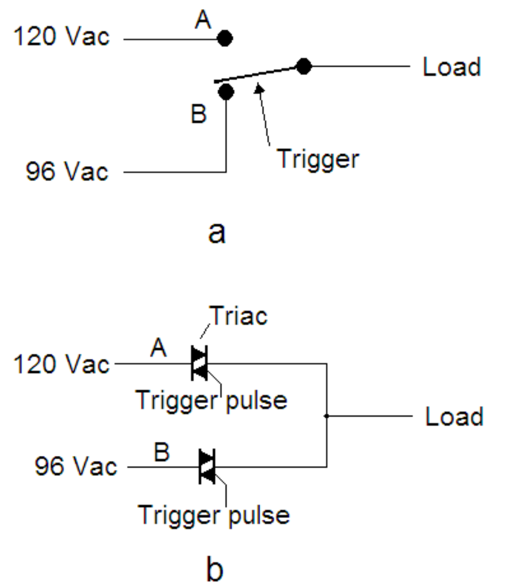

Figure 4 The single pole double throw switch, SPDT, used to regulate power is shown. In Figure 4 b the switch in implemented using two triacs.

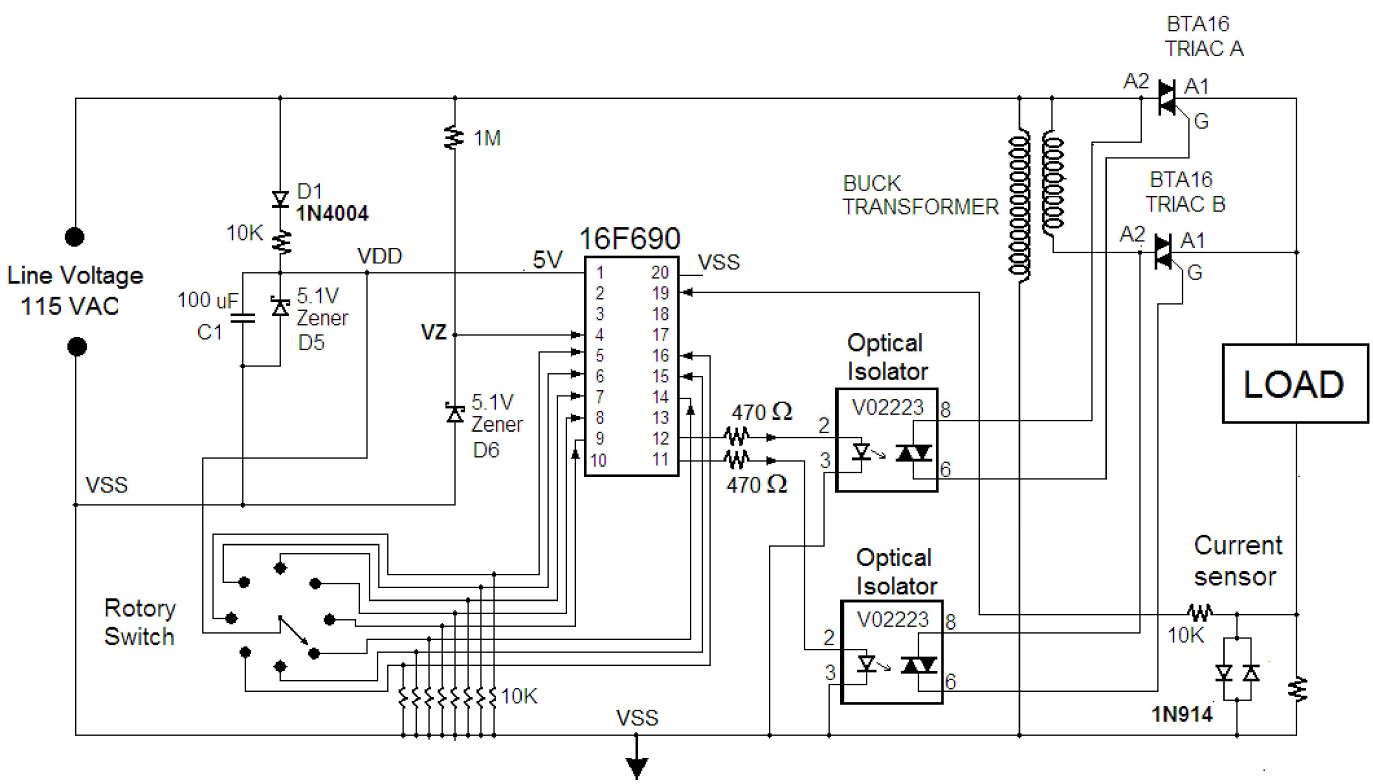

Figure 5 The 16F690 PIC microcontroller receives input from an 8 position rotary switch. Each position represents a desired power level. The controller determines the distribution of power levels needed to achieve the desired power. Optical isolators protect the microcontroller from the high load voltages and produce the signals required to trigger the switching triacs.

The distribution of power levels for the 8 different modes is shown in Figure 6. A time interval of 16 half cycles was used. A zero represents a half cycle at reduced power. A one represents a half cycle at full power. The relative power is the number of ones (full power half cycles) divided by 16. The microcontroller uses this information to generate the triac triggering pulses.

Other Implementations

An implementation using an auto transformer is shown in Figure 7. Auto transformers are used to regulate power in situations where the voltage supplied by the electric utility varies over an unacceptable range. An auto transformer can have a number of taps, each providing a different voltage. The desired voltage is achieved by selecting the appropriate tap.

The Transcycle Regulator principle can be applied to the auto transformer regulator to provide a precise power level. Electronic switches, (for example, triacs or transistors) can be used to seamlessly switch power in half cycle intervals. Having a number of voltage levels available from the auto transformer allows greater flexibility in regulating the power in situations where the available line voltage is not reliable.

Summary

The Transcycle Regulator is capable of producing a wide variety of power levels. Power is controlled by switching between source voltage levels. Levels are switched when the current is zero. This switching technique eliminates voltage spikes and radio frequency interference. One possible switch element is a triac. It naturally opens when its current is zero. A microcontroller accepts input from a variety of possible sources. It determines switching times needed to achieve the desired average power. Switching in short intervals (half cycle) results in the smooth delivery of precise load power.

Mode	Power Distribution	P/Po
7	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	16/16
6	0 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1	14/16
5	0 1 1 0 1 1 1 1 0 1 1 0 1 1 1 1	12/16
4	0 1 1 0 1 1 0 1 1 0 1 1 0 1 1 0	10/16
3	0 0 1 1 0 0 1 1 0 0 1 1 0 0 1 1	8/16
2	1 0 0 1 0 0 1 0 0 1 0 0 1 0 0 1	6/16
1	1 0 0 0 0 1 0 0 1 0 0 0 0 1 0 0	4/16
0	1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0	2/16

Time →

Figure 6 Power distributions as a function of time for the 8 different modes is shown. A one represents a full power half cycle. A zero represents a half cycle at reduced power. P/Po is the relative power.

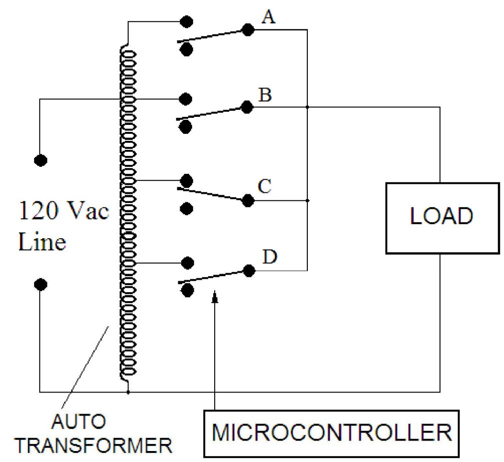

Figure 7 In this implementation power levels are switched between a number of levels provided by an auto transformer. One switch conducts at a time. Switch C is shown conducting. This results in a load voltage that is less than 120 Volts.