AN392
Application note

Microcontrollers and TRIAC-based dimmers

Introduction

Today, electronics is used in home appliances for applications as widely varying as motor regulation in a washing machine, control of a vacuum cleaner, dimming of a lamp or heating in a coffee machine. This evolution has increased pace rapidly because appliances require enhanced features that are easy to build and modify while electronics-based solutions become cheaper and more sophisticated.

Within this evolution, microcontrollers (MCU) progressively replace analog controllers and discrete solutions even in low cost applications. MCUs are more flexible, often need less components and provide shorter time to market. With an analog IC, the designer is limited to a fixed function frozen inside the device. With a DIAC control, features like sensor feedback or enhanced motor drive cannot be easily implemented. With an MCU the designer can include his own ideas and test them directly using EPROM or one time programmable (OTP) versions.

The TRIAC is the least expensive power switch to operate directly on the 110/240 V mains. Thus it is the optimal switch for most of the low-cost power applications operating online. The logic level or snubberless TRIACs can operate with low gate current and can be directly triggered by the MCU.

This application note describes two different MCU based applications: a universal motor drive, and a light dimmer. They all operate with the same user interfaces and almost the same software and hardware.

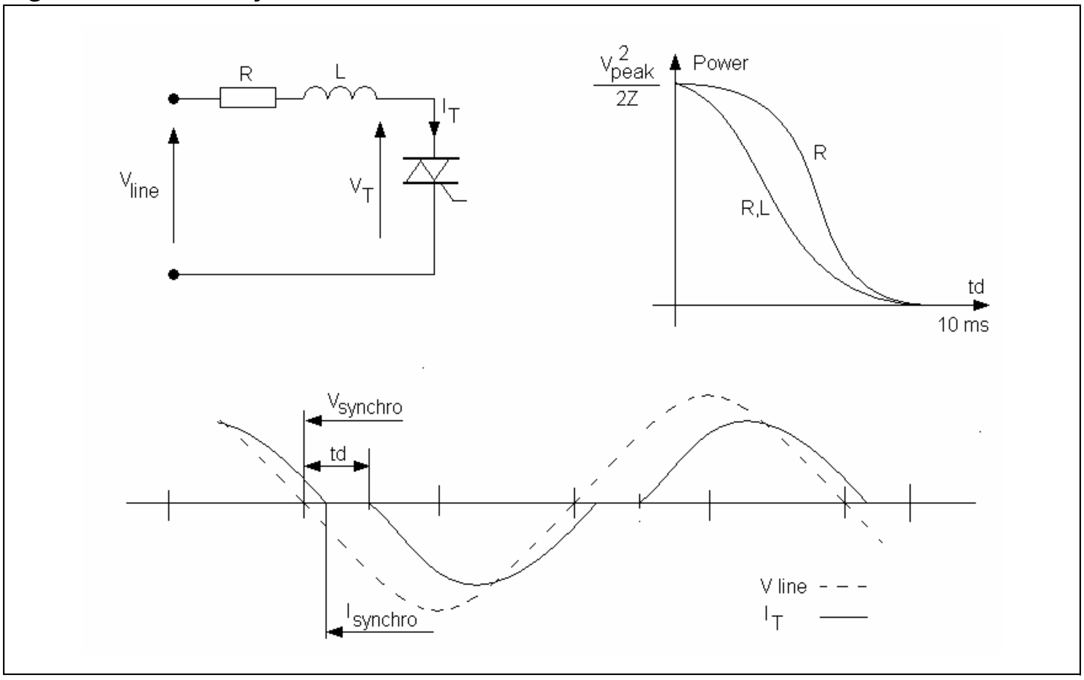
1 Universal motor drive

1.1 Power control

The power device is a TRIAC because it is the most economical online switch. In a TRIAC-based controller the output power, and, for example, the motor speed, are controlled by the phase delay of the TRIAC drive. This delay is referred to the zero crossing of the line voltage which is detected by means of a connection to the mains neutral (*Figure 1*). Changing operation from 60 Hz to 50 Hz can be achieved by making simple modifications to the MCU EPROM/ROM table defining the TRIAC conduction angle versus power level. Automatic selection of the 50 Hz/ 60 Hz tables can be implemented.

The TRIAC can be directly driven by the MCU. A very short gate current pulse (~ 100 µs) could be enough to trigger the TRIAC for rms load currents above 2 A. Such pulse control allows the low voltage MCU power supply consumption to be reduced. The snubberless TRIAC is driven in quadrants QII and QIII with a 60 mA gate current provided by three I/O bits of the ST6210 in parallel. This pulse is sufficiently long to ensure the TRIAC is latched at the end of the pulse. Pulse length can be modified if another TRIAC or motor is used.

Figure 1. Mains synchronization

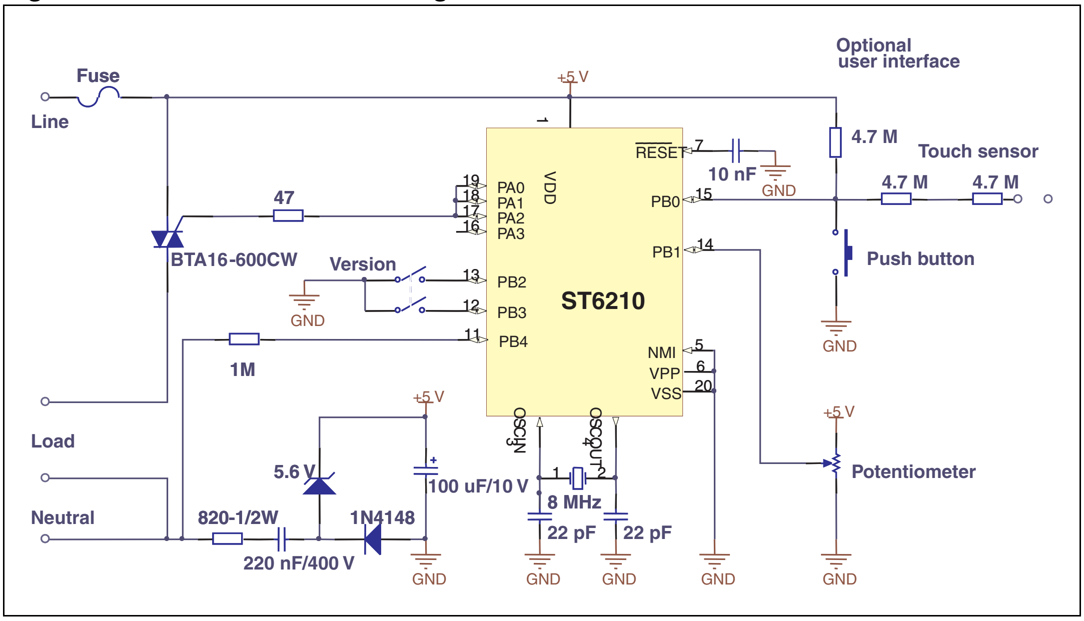


1.2 User interfaces

Different user interfaces can be implemented - a touch control, a push button or a potentiometer. The circuit diagram in *Figure 2* show that the three modes are implemented on the board to let the system designer choose the preferred user interface.

Control action is obtained when the sensor or the button is touched for more than 330 ms. If the touch duration is between 50 ms and 330 ms, the circuit is switched on or off. A contact of less than 50 ms causes no action.

Figure 2. Motor drive circuit diagram



1.3 Circuit components

The MCU chosen (ST6210) includes an 8 bit accumulator, 2 k ROM, 64 bytes RAM, an 8 bit A/D converter that can be connected to 8 different inputs, 4 I/O lines with 40 mA sink current capability and a timer. Hysteresis protection is included in series with each I/O pin. The ST6210 is packaged in DIL or SMD packages. The ports, the timer and interrupt configurations can be chosen by software, providing high flexibility. The ST6210 has been designed to operate in very disturbed environments. Each I/O line contains internal diodes which clamp the input voltage between V_{dd} and V_{ss}. These diodes are sized to withstand a continuous current of 1 mA (typ.).

The snubberless TRIAC (BTA 16-600CW) has been specially designed to drive loads which generate very strong dynamic constraints such as a vacuum cleaner motor. This TRIAC can be triggered in quadrants QI, QII or QIII with gate and latching current of 35 mA and 80 mA respectively. In this application it is driven by three I/O lines of the ST6210 in parallel. This TRIAC has high current switching capability ((dI/dt)c > 8.5 A/ ms and 5.5 A/ms for BTA10600CW), and high static dv/dt ((dV/dt) > 500 V/ms). So, in this circuit, it can operate without any snubber.

Total consumption of the board is 3 mA with an 8 MHz oscillator. The board supply comes from the mains through a simple RCD circuit. The +5 V is referred to anode 1 of the TRIAC in order to provide the negative gate current necessary to drive the TRIAC in quadrants QII and QIII. The 5 V supply capacitance is connected as near as possible to the MCU with very short interconnecting traces to maximize RFI immunity.

The touch sensor is a voltage divider between line and neutral. It works only if the +5 V supply input of the circuit is connected to the line. This connection to the mains must be ensured according to local electrical safety rules.

1.4 Software

All operating features are contained in a 700 byte program. So more than 1 byte of ROM is available for additional features.

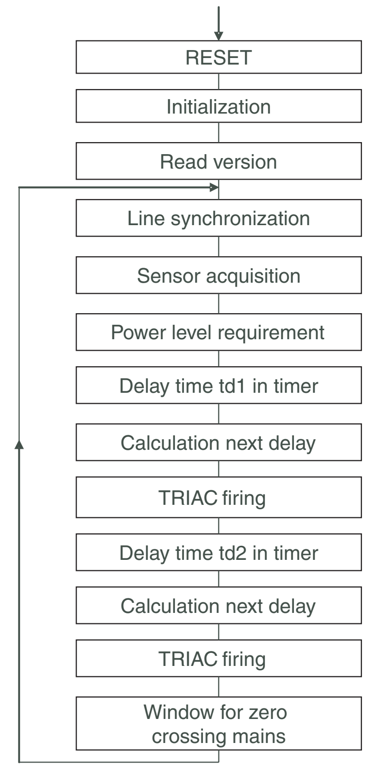
A look-up table relating delay time to the power requirement contains 64 different levels. The conduction time of the TRIAC can vary from 1.7 ms to 6.7 ms for a 60 Hz application and from 2 ms to 8 ms to a 50 Hz application. The user can easily adjust the minimum and maximum power levels because the corresponding delay times are slowly changing at the top and bottom of the table.

It is recommended that all MCU inputs be filtered so that an input is validated only if it remains constant for 15 s or more so that passive filter components can be saved. The mains supply carries disturbances (glitches, telecommand signals, ...) which could disturb the TRIAC drive. For this reason, a mains voltage zero crossing is only validated if it occurs during a window of time (1.7 ms each 16.6 ms for 60 Hz operation and 2 ms each 200 ms for 50 Hz operation) selected by the internal timer of the MCU. This block acts as a filter and again eliminates external components (*Figure 3*).

This circuit can be used in the following applications:

- Vacuum regulation in a vacuum cleaner
- Speed control in a food processor
- Speed regulation with torque limiting in a drill
- Unbalance detection in a washing machine
- Washing machine door opener with remote control

Figure 3. Major steps of the software

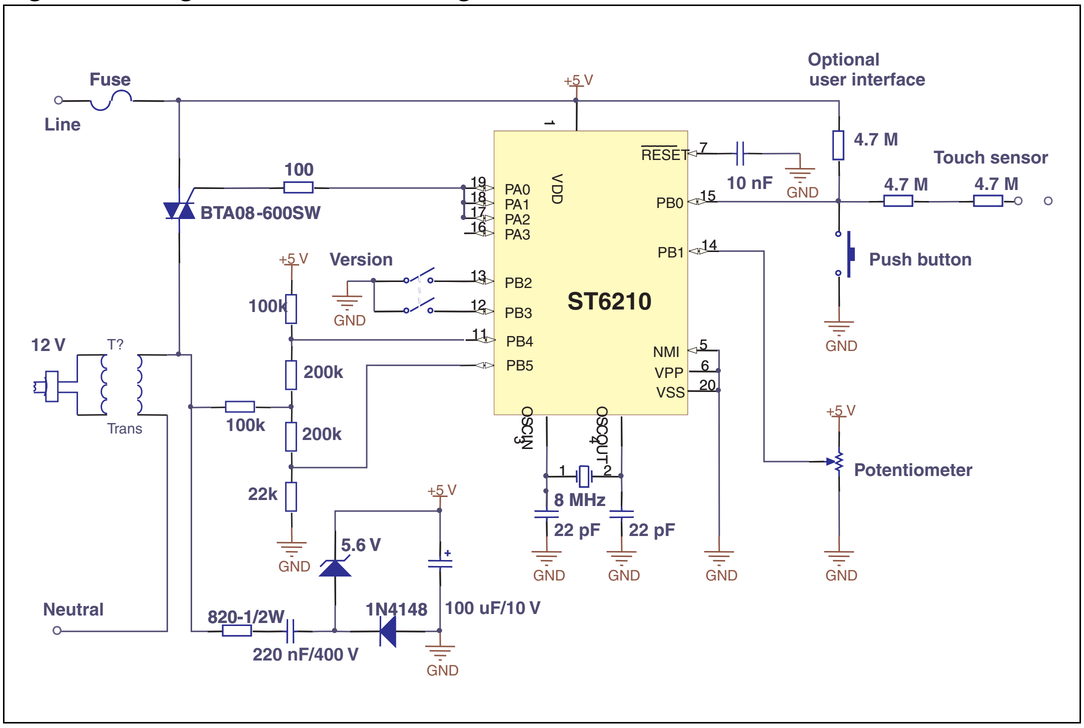


2 Light dimmer

For a light dimmer application, the board can be plugged in series with the line wire like a mechanical switch. The line synchronization and the auxiliary supply are obtained from the voltage across the TRIAC (*Figure 4*).

Figure 4 shows a schematic which can operate either on 110 V or 240 V mains. It uses an MCU ST6210 and a logic level TRIAC. This circuit drives halogen or incandescent lamps supplied directly from the mains or through a low voltage transformer. It includes soft start and protection against transformer saturation and against open load. The user interfaces are the same as previously presented.

Figure 4. Light dimmer circuit diagram



2.1 Power control

Power is controlled by the phase delay (t_d) of the TRIAC drive. In the previous design, t_d is referred to the zero crossing of the line voltage. To avoid a connection to the mains neutral as the circuit is in series with the load, the trigger delay is referred to the zero crossing of the current (see *Figure 1*). When the TRIAC anode current reaches zero, the mains voltage is reapplied across the TRIAC. Synchronization is achieved by measuring this voltage. This voltage is monitored over each half cycle with a network of resistances connected to two I/O lines of the ST6210. This allows detection of spurious open load and the retriggering of the TRIAC with multipulse operation if it is not latched after the first gate current pulse.

2.2 Operation with a transformer

Low power halogen spots use low voltage lamps (12 V typ.) usually supplied through a low voltage transformer. For good application performance, the MCU program should ensure the following:

- At start-up, the delay time between the first gate pulse and the synchronization instant is greater than 5 ms. This limits transformer coil induction and the risk of saturation with associated high peak current.
- The circuit starts on a positive line half cycle and stops on a negative one. Thus it starts with positive induction and stops after negative induction has been applied. This helps to minimize the size of the magnetic core material, and the current rating of the TRIAC.
- The timer is precisely tuned in order to obtain 8.3 ms (for 60 Hz) or 10 ms (for 50 Hz) delay between two gate pulses. As a result, the TRIAC is driven symmetrically in both half cycles so that DC voltage content is avoided across the transformer terminals. Saturation risk is then also reduced here. Otherwise, the voltage across the TRIAC is monitored to detect a spurious open load condition at the secondary of the transformer.
- The inrush current at lamp switch-on (halogen or incandescent) is also reduced due to the soft start feature of the circuit (*Figure 6*).

2.3 TRIAC drive

The TRIAC is directly driven by the MCU. The pulse driving the TRIAC lasts 50 µs. The logic level TRIAC is driven in quadrants QII and QIII with a gate current of 20 mA provided by two I/O lines of the ST6210 in parallel. The logic level TRIAC has a maximum specified gate triggering current of 10 mA at 25 °C.

The TRIAC is multi-pulse driven. Therefore, inductive loads can be driven without the use of long pulse drives. As a result, the consumption on the +5 V supply can be reduced and the supply circuit components are downsized. Before supplying the first drive pulse, the TRIAC voltage is tested. If no voltage is detected, a spurious open load or a supply disconnection is assumed to have occurred and the circuit is stopped. After the first driving pulse, the TRIAC voltage is monitored. If the TRIAC is not on, another pulse is sent. The same process can be repeated up to four times. Then, if the TRIAC is still not on, the circuit is switched off.

2.4 Circuit components

The light dimmer board (*Figure 4*) is almost the same as the motor drive board (*Figure 2*). The major differences concern the point where the voltage is measured and the TRIAC choice. When the board is dimming a resistive load, an RFI filter should be added to limit the conducted noise.

In a dimmer, because of the resistive load, dynamic constraints are lower than in a motor control, so a logic level TRIAC (BTA08-600SW) can be used. It is a sensitive TRIAC (I_{GT} < 10 mA) which can be triggered in quadrants I, II and III. This TRIAC has high switching capabilities ((dI/dt)c > 2.98 A/ms, (dV/dt)c > 10 V/ms). Thus it can also operate without any snubber across it.

The MCU board in *Figure 4* is supplied only when the TRIAC is off. A minimum off-time of the TRIAC (1.7 ms/60 Hz and 2 ms/50 Hz) is necessary to ensure a good V_{DD} level. The R_{CD} circuit is the same as the one used for the board in *Figure 2*.

2.5 Software

The software for a light dimmer can be the same as for motor drive. The major difference concerns the mains disturbances rejection in order to prevent lamp flickering. The timing is carried out internally by the MCU timer. The mains period can be calculated internally by the MCU to detect the mains frequency. But this mains frequency must not be disturbed by noise coming from the line, as the mains synchronization signal is received every cycle.

3 Practical results

Figure 5 presents the current and voltage in a TRIAC driving a universal motor.

Figure 5. Universal motor drive: TRIAC current and voltage

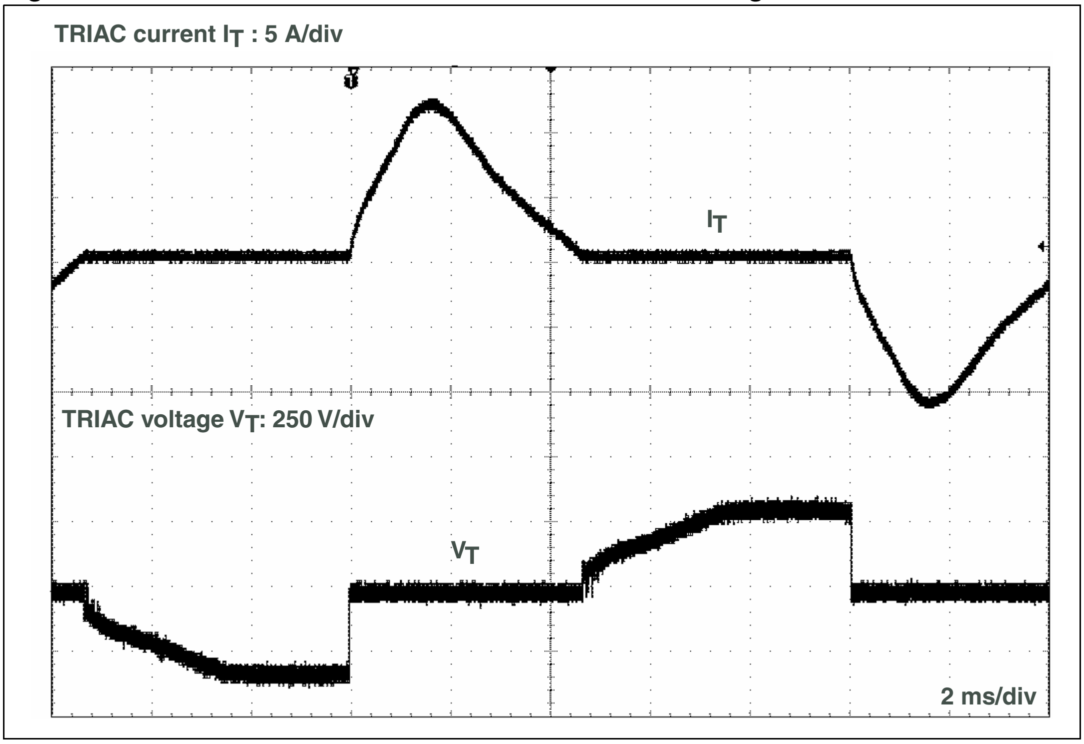
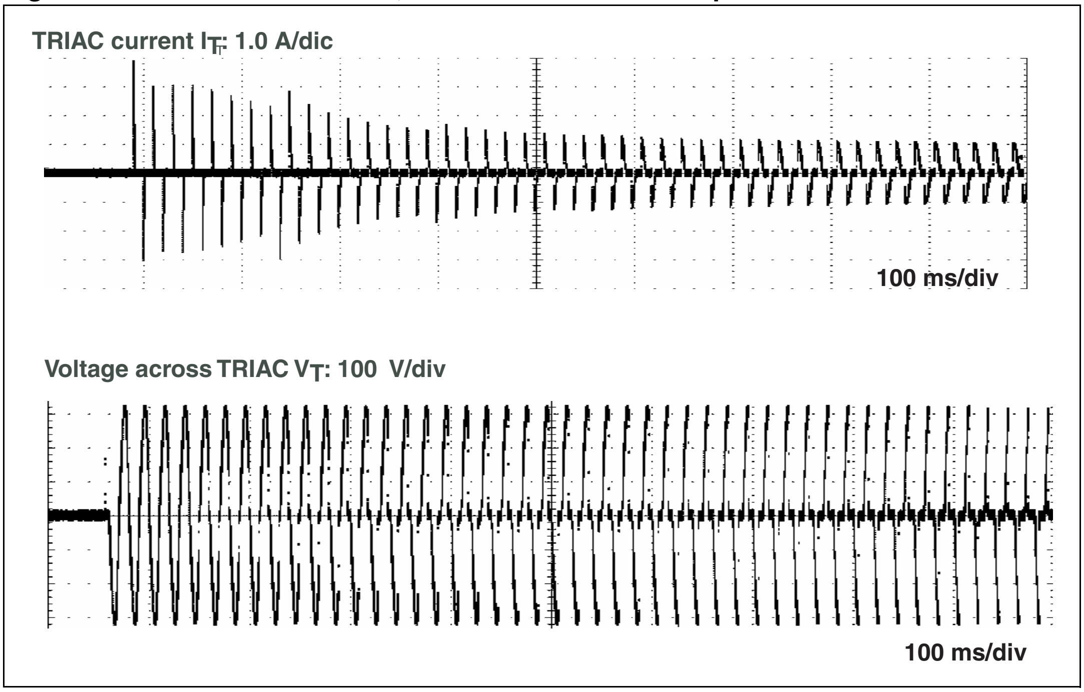


Figure 6 presents the soft start operation for an incandescent lamp rated at 150 W, 230 V.

Thanks to the embedded soft start, the peak in-rush current is about 3 times the nominal current compared with 8 to 10 times otherwise. Therefore, the lamp life time is improved.

Figure 6. Soft start for 150 W, 230 V incandescent lamp



4 Conclusion

Microcontroller units (MCU) are in common use in most areas of home appliances. The applications described in this Application note show that enhanced appliance circuits can be designed with ST6210 MCU and a snubberless or logic level TRIAC.

The presented circuits are a universal motor drive, and a light dimmer operating from the 110/240 V mains. The motor drive can be adapted, for instance, to vacuum cleaners, food processors, drills or washing machines. The light dimmer drives incandescent and halogen lamps supplied either directly from the mains or through a low voltage transformer.

Those circuits include soft start and protection features. Different user interfaces can be chosen: touch sensor, push button or potentiometer.

Such features are obtained with only few components: an ST6210 MCU in 20 pin DIL/SMD package with a logic level or snubberless TRIAC in TO-220 package and some passive components.

Additional features such as motor speed regulation, torque limitation, vacuum or unbalance control, I_R presence detection, remote control, alarm, homebus interface can also be implemented.

5 Revision history

Table 1. Document revision history

Date	Revision	Changes
Jan-1998	1	Initial release.
24-Apr-2009	2	Reformatted to current standards. Updated for current products.

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