SGS-THOMSON MICROELECTRONICS

APPLICATION NOTE

Improved Universal Motor Drive

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INTRODUCTION

Universal motors are mostly operated in AC current mode and are controlled by means of TRIACS. This widespread solution leads to a cheap electronic controller board but has some drawbacks. In particular the high peak to peak current gives poor motor efficiency and the consequential high brush temperature leads to limited motor lifetime.

When operating in DC mode, significant improvements are obtained. The RMS and peak to peak current of the motor are smaller, reducing Iron losses and brush temperature.
Operating in DC mode enables shrinking of the motor size, and increasing the motor lifetime. Furthermore, magnetic constriction of motor core and torque ripple decrease; the 100Hz noise is further reduced.

This technical note presents three solutions for motor operation in AC and DC mode, based on phase control. Motor current and motor efficiency are compared in AC and DC mode. Component selection is proposed for each case, enabling the design of a cost effective solution.

1 CIRCUIT TOPOLOGIES

Three different topologies for control of universal motors are shown in figures 1a, 1b, 1c:

- a conventional AC drive using a TRIAC
- a DC drive using a TRIAC and a rectifier bridge
- a DC drive using an IGBT and a rectifier bridge

Each is controlled with a low cost microcontroller, ST6. The difference between the control software concerns the output signal of the microcontroller, which is either adapted to TRIACs or to IGBTs.

A and B topologies are operated with a "SNUBBERLESS" TRIAC. Topology C is operated with a slow IGBT, taking advantage of its low drop voltage.

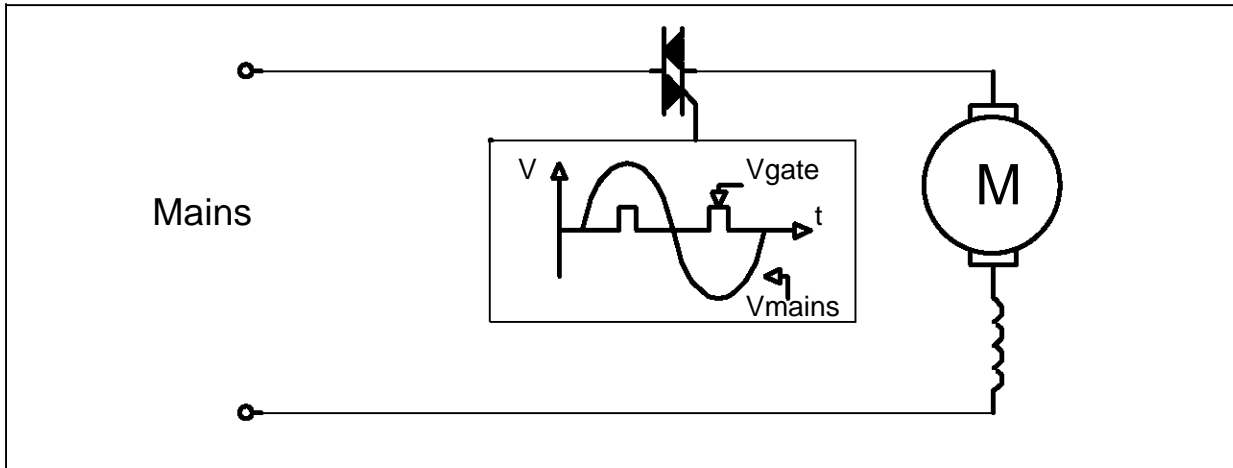Figure 1a. Universal motor drive topologies - Topology A: AC mode

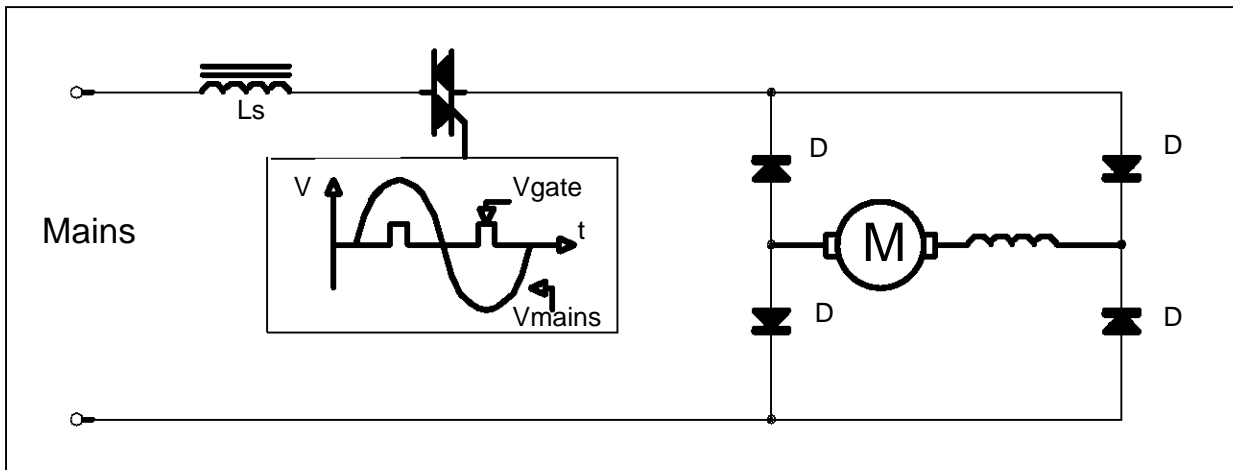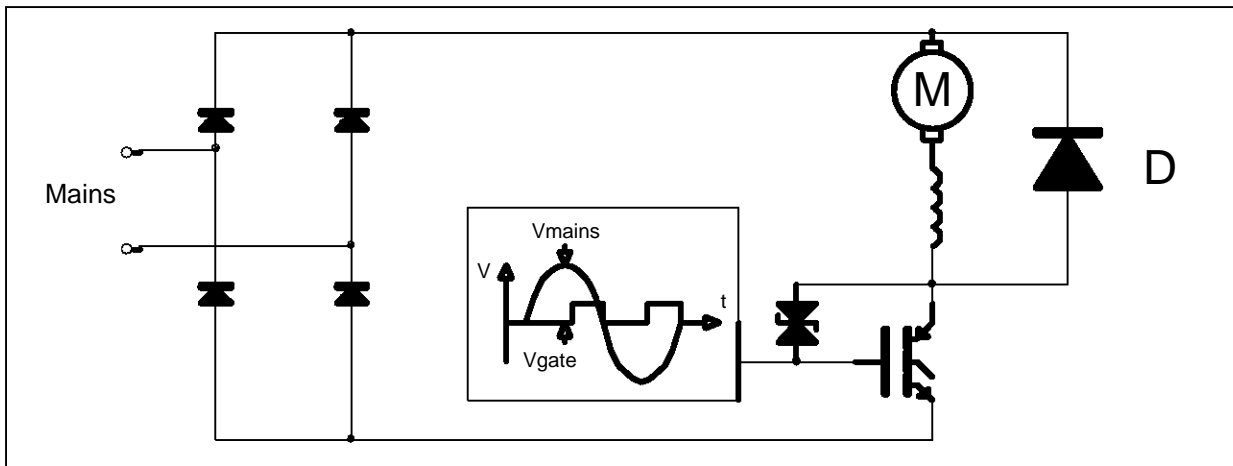Figure 1b. Universal motor drive topologies - Topology B: DC mode

Figure 1c. Universal motor drive topologies - Topology C: DC mode

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2 MOTOR CURRENT AND THERMAL BEHAVIOUR

The following figures show two examples of motor current waveforms with the same operating and load conditions, i.e. low speed and high torque. Figure 2 corresponds to the AC topology where the motor current is the same as the TRIAC's current. So, motor voltage and motor current are AC and the motor current has no DC component. Figure 3 corresponds to the DC topology where the motor current is freewheeling through diodes D while the power switch is off. The motor current has a DC component reducing its RMS and its peak to peak current. Due to this fact, magnetic and copper losses are reduced thus improving motor efficiency.

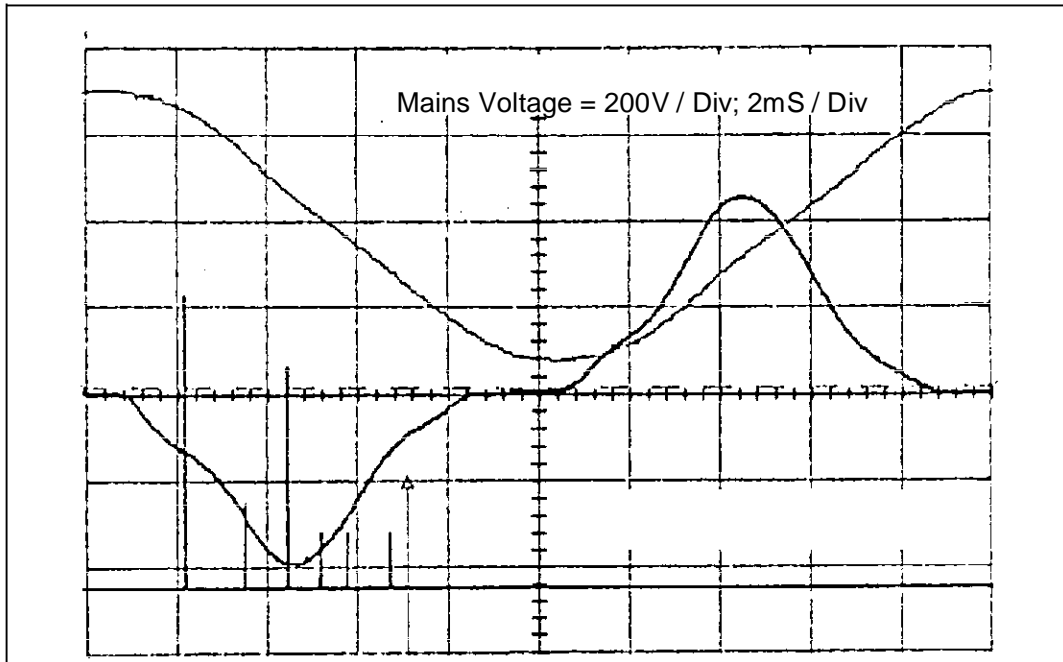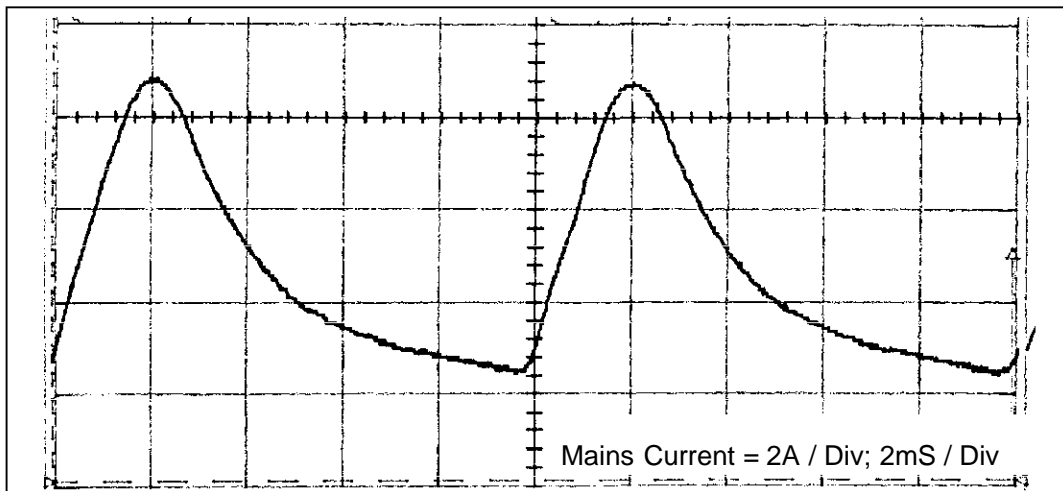Figure 2. Motor current with AC topology

Mains Voltage = 200V / Div; 2mS / Div

Figure 3. Motor current with DC topologies

Mains Current = 2A / Div; 2mS / Div

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2.1 MOTOR CURRENT

In this test the Universal motor has to deliver high torque at low speed. The following table compares RMS, DC and peak to peak current in the motor depending on the topology. The measurements are carried out with the same load, the conduction angle being adjusted to deliver the same torque and speed.

	TOPOLOGY 2.1 AC mode with TRIAC	TOPOLOGY 2.2 & 2.3 DC mode with TRIAC or IGBT
RMS motor current	5.5A	5A
DC motor current	0	4.6A
peak to peak motor current	26A	6A

In DC mode, major improvements are obtained thanks to the smaller RMS and peak to peak current:

- Reduced brush current and brush temperature, resulting in increased motor lifetime.
- Reduced current ripple and torque ripple of the motor resulting in reduced 100Hz noise of the motor.
- Reduced Iron and Copper losses as shown in the table below:

2.2 THERMAL BEHAVIOUR

		TOPOLOGY 2.1 AC mode with TRIAC	TOPOLOGY 2.2 & 2.3 DC mode with TRIAC or IGBT
Temperature rise K°	Copper Stator	73	50
	Iron Stator	46	29
	Rotor	77	47

3 PROPOSED SOLUTIONS

Today, low cost microcontrollers are the most advantageous solution for a flexible and specific motor drive control circuit. Moreover, the software approach maintains confidentiality of the application. Thus, the three circuits described in this paper take advantage of the ST6 microcontroller family. These microcontrollers have an 8-bit architecture, enabling 8-bit and 1-bit data manipulation and a low power consumption.

A large choice of peripheral interface functions are available such as LCD driver, digital watchdog timer, internal comparator device, A/D converter and pulse counter. These enable the easy implementation of features such as motor speed or torque control, sensor monitoring, display control and soft start as well as protection.
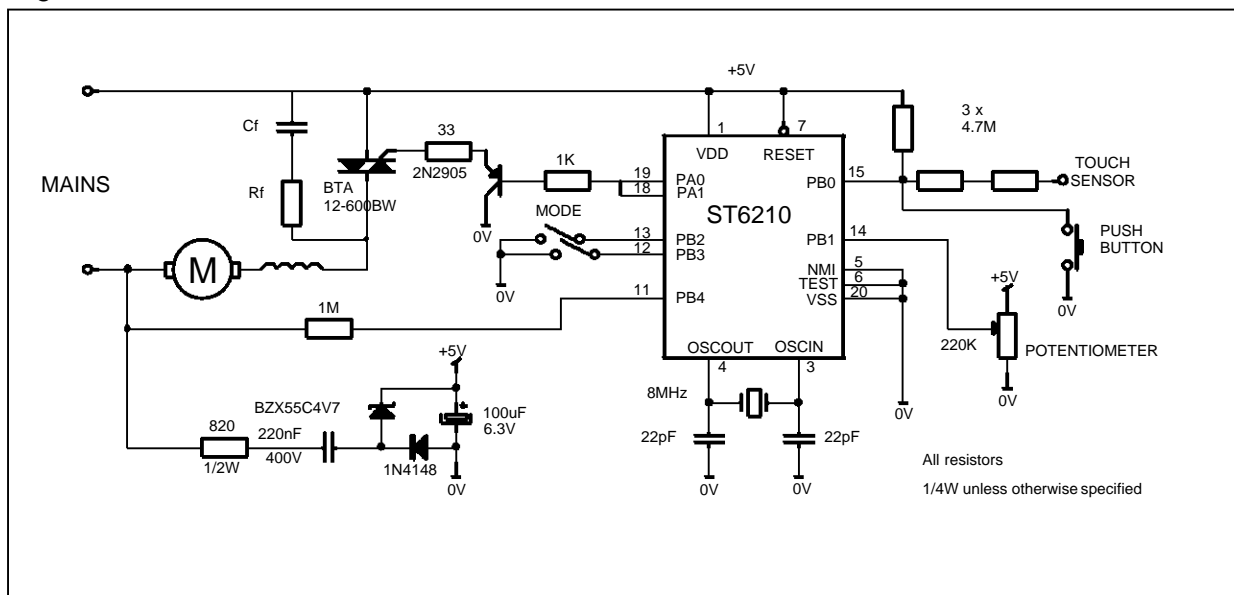
3.1 AC DRIVE WITH TRIAC

Figure 4 shows an AC drive for Universal motor suitable for a large range of applications. The power switch is a "SNUBBERLESS" TRIAC BTA 12-600BW with a maximum specified gate trigger current of 50mA at 25°C. This TRIAC is pulse driven; A small signal transistor interfaces the microcontroller and the "SNUBBERLESS" TRIAC. Although no snubber is needed in nominal operations, a small filter RfCf should be implemented if spurious triggering is prohibited in case of mains pertubations.

There are three different user interfaces: a touch control, push button or a potentiometer. In this example four operating modes are defined in hardware, selected by the interpretation of the user interface by the microcontroller.

Zero voltage detection across the mains is used for synchronization.

Changing operation from 50Hz to 60Hz is obtained by changing the EPROM/ROM table defining TRIAC conduction angle versus power level. It can be hardware programmed, or self-adapted by software.

Figure 4. TRIAC controlled AC mode Universal motor drive

3.2 DC DRIVE WITH TRIAC

Figure 5 shows a DC drive for a Universal motor. A diode bridge has been added to the previous circuit in order to supply DC current to the motor. So, after the TRIAC current crosses zero, the motor current freewheels through the diode bridge.

An inductance in series with the TRIAC is required to limit the rate of fall of the current as defined in the TRIAC specifications (12A/msec for BTA 12-600BW requiring 3mH in series). However, a larger value may be mandatory due to the standards limiting harmonic content of mains current. This serial inductance should be advantageously used as a part of the EMI filter. In normal operation, no snubber is needed. However, the small filter RfCf should be implemented to avoid spurious triggering if large mains disturbances occur.

Figure 5. TRIAC controlled DC mode Universal motor drive

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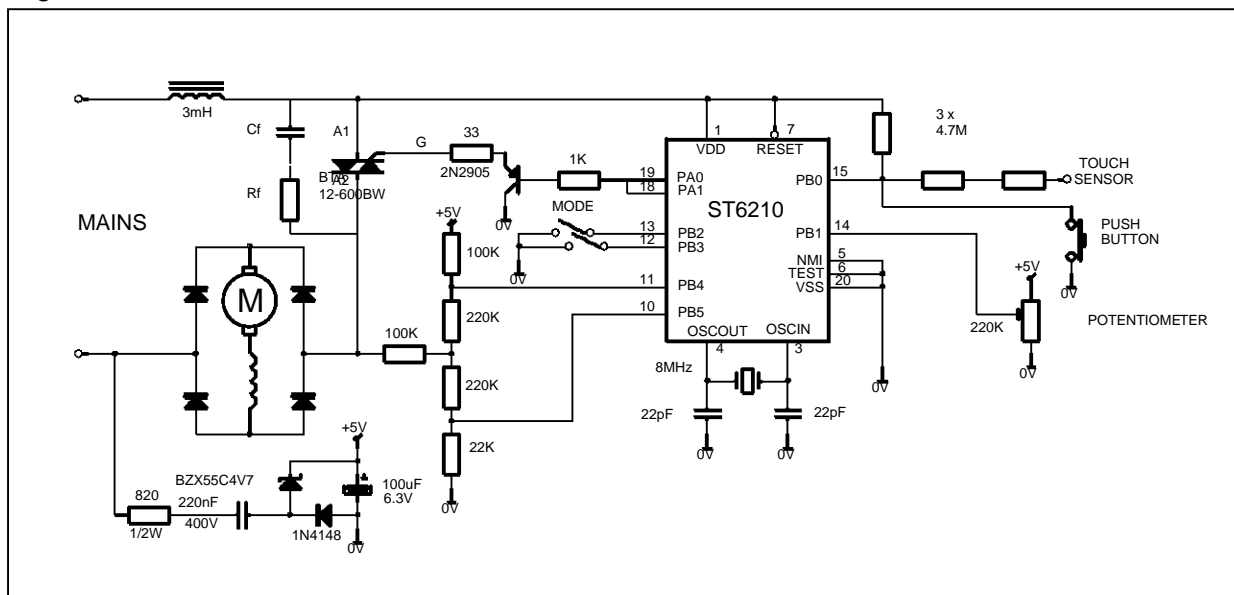
3.3 DC DRIVE WITH IGBT

Switching behaviour of IGBTs can be controlled by means of the gate drive. Controlled slow or "soft" switching can be obtained (Figure 7), leading to reducing high frequency interference and thus reducing filter cost.

Figure 6 shows a DC drive for Universal motor taking advantage of soft commutation with IGBT.

The same ST6 controller with the same software as the DC drive with Triac can be used, the only difference being the output pulse width: the signal must be held at the high state until zero current is detected in the mains. Only a few instructions have to be changed, and zero current detection is implemented, as shown as an example in Figure 6.

Figure 6. IGBT controlled DC Universal motor drive.
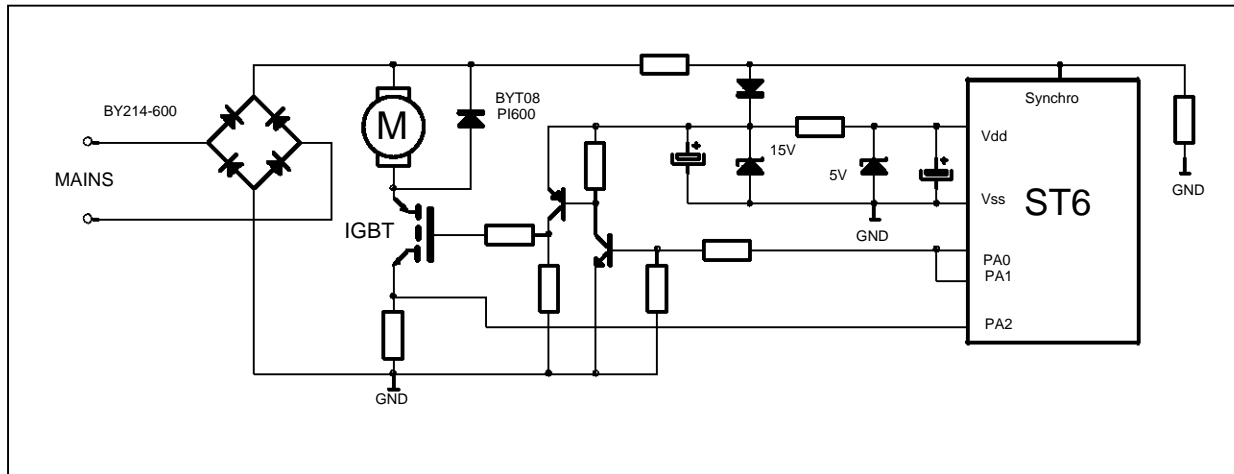
Figure 7a. Control of IGBT Switching behaviour
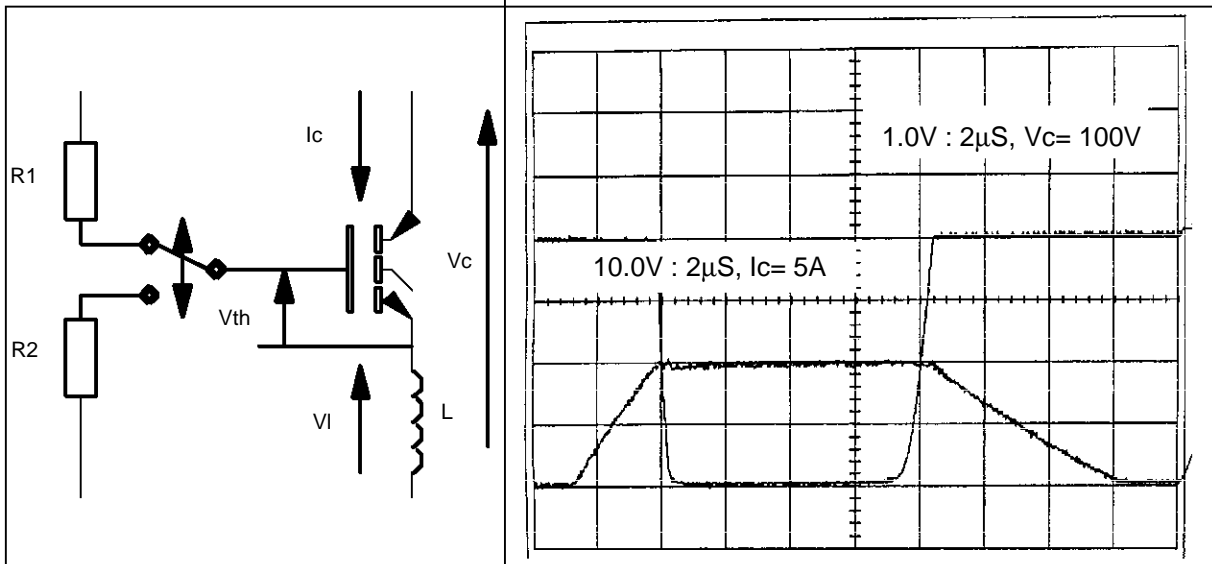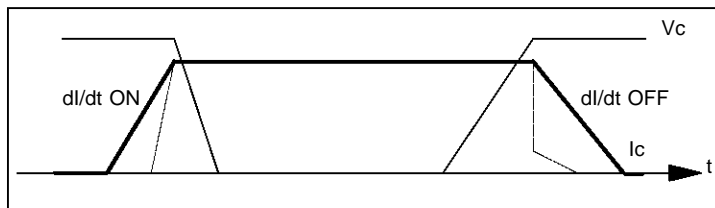MILLER effect limits dV/dt and dI/dt during turn-on and turn-off dependingon R_1- R_2 and
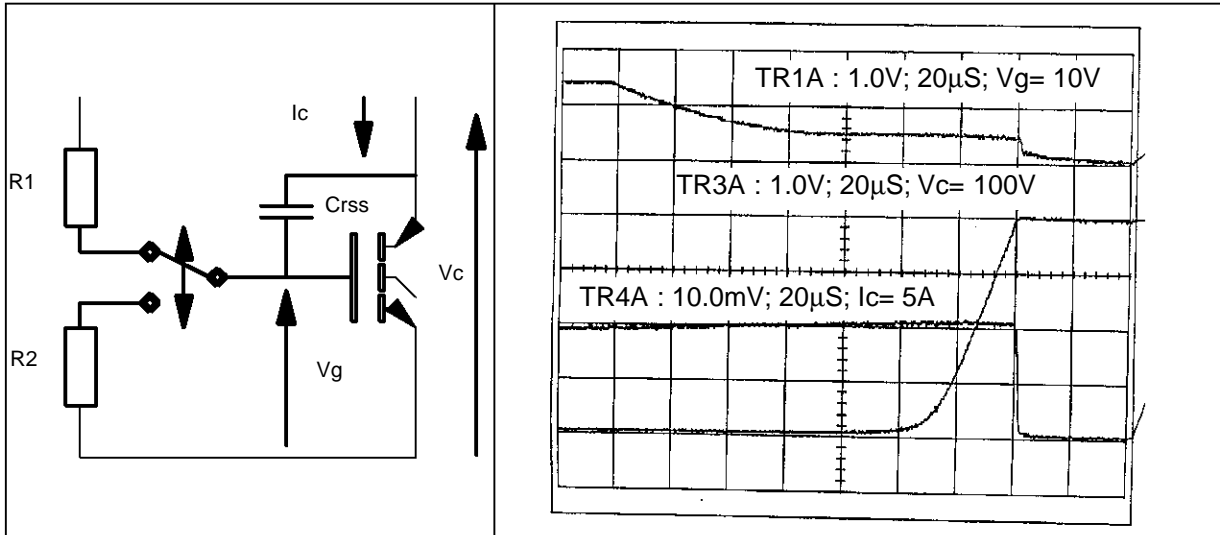
Figure 7b. Control of IGBT Switching behaviour

Inductance L limits dI/dt at turn-on and turn-off
$V_L = L\ dI/dt \simeq 15V - V_{th}$ at turn-on
$\simeq V_{th}$ at turn-off

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4 CONCLUSION

In many applications, Universal motors can be shrunk if used in DC current mode instead of AC current mode. In addition to reducing the size and the weight of the motor, operating in DC current mode increases motor lifetime and decreases motor noise.

This note proposes a flexible solution based on using a low cost 8-bit ST6 micro-controller. Depending upon hardware configuration, the ST6 micro-controller provides a DC or AC current motor drive with a large choice of user interfaces. It enables the implementation of features such as motor speed or torque control, sensor monitoring, display control or soft start as well as protection.
From both DC mode solutions, the IGBT solution reduces RFI and filter cost due to the IGBT soft commutations. So, the same ST6 microcontroller provides a flexible solution for many different universal motor drives, directly suited for each application.

References
[1] - Microcontrollers and Triacs on the 110/240V Mains
       AN 392 - Ph. RABIER and L. PERIER (SGS-THOMSON Microelectronics)

[2] - Improvement in Triac Commutation
       Application Note - P. RAULT (SGS-THOMSON Microelectronics)
[3] - New Triacs: is a snubber necessary?
       Application Note - T. CASTAGNET (SGS-THOMSON Microelectronics)

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