SGS-THOMSON MICROELECTRONICS

APPLICATION NOTE

COMPARISON OF MOSFET AND IGBT TRANSISTORS IN MOTOR DRIVE APPLICATIONS

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1. INTRODUCTION

The increase of the switching frequency and the reduction of the power transistors losses are always important issues for the designer of power conversion systems. In recent years these issues have drawn attention to the comparison between IGBTs and Power MOSFETs.

In practice there is no single solution, and the choice will depend on the intrinsic transistor characteristics and the requirements of the application. These main characteristics can be summarised as:

- The ruggedness of the device (i.e., its ability to withstand surge voltages from the AC line input), and
- Its total losses, particularly at turn off and in conduction.

2. VOLTAGE RUGGEDNESS

This is the ability of the transistors to withstand pulses of energy in avalanche breakdown.

The MOSFET has high avalanche capability: for instance ST's IRF840 is specified at 510mJ single pulse avalanche energy.

The IGBT has a lower clamping capability than the equivalent MOSFET because of the junction temperature is more limited. This device usually requires external clamping protection.

3. COMPARISON OF DRIVE TOPOLOGIES

The comparison involves usually PWM switched transistors, with frequencies above the audible range (>20kHz). The cross-over point between the use of MOSFETs and IGBTs is not generally definable. The topology of the inverter and the DC input voltage will affect the choice.

For the purposes of this paper, we shall split the types of application into two categories:

- the single transistor chopper, the symetric half bridge, the asymetric half bridge topologies; and
- 120V RMS AC (200V DC), and 277V RMS AC (450V DC) mains supplies.

3.1 Single Transistor Chopper

This topology is usually used for brush DC motor drives. Its basic layout is shown in figure 1.

A single transistor chopper application was tested using two similar transistors with the same voltage capability: the IRF840 MOSFET and then the STGP10N50 IGBT.

The switching frequency was fixed at 17kHz with a 50% duty cycle with an applied voltage of 400V. An STTA806 TURBOSWITCH was used as the freewheeling diode. Figure 2 compares the losses of the two types of transistor. It can be seen that the MOSFET has the lower losses below 5A peak current, and the IGBT above.

3.2 Asymmetric Half Bridge

See figure 3. In this topology the motor coil current is unidirectional. It is suited for use with the switched reluctance motor.

The above comparison also applies to the asymmetric half bridge topology.

Figure 1. Single Transistor Chopper

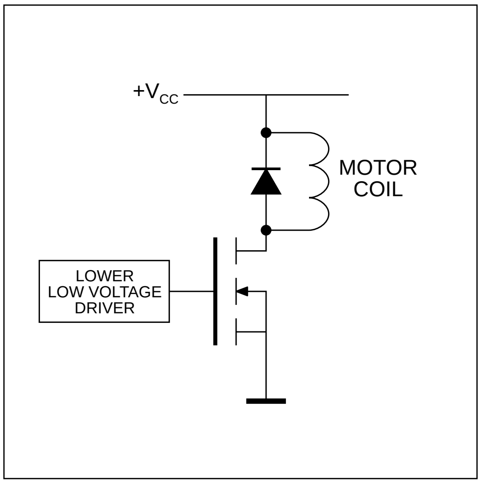
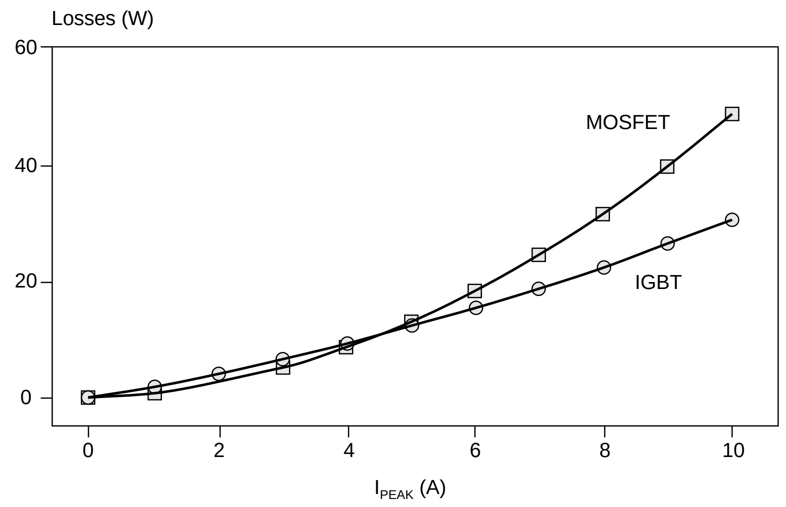


Figure 2. Comparison of 500V IGBT and MOSFET in a single transistor chopper



3.3 Symmetrical Half Bridge

This topology can generate bidirectional current. It can be used with induction motors and brushless permanent magnet DC motors. Figure 4 shows the basic configuration.

MOSFETs are less suited to this application, as the

Figure 3. Asymmetric Half Bridge

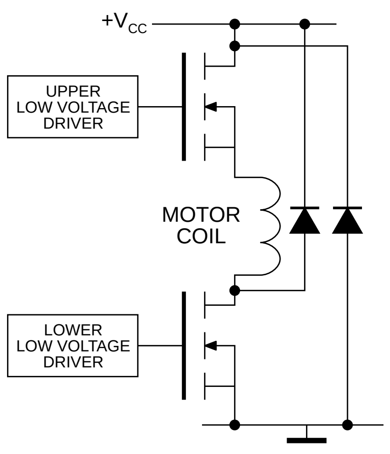
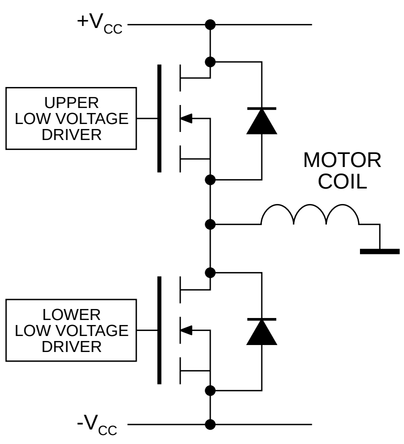


Figure 4. Symmetrical Half Bridge



intrinsic body diode has poor switching characteristics, and their use leads to higher losses. The turn-off speed of the MOSFET (its maximum dI/dt) is limited to reduce the reverse recovery of the diode. The crossover point between the 500V MOSFET and the IGBT is lower, around 3-4A.

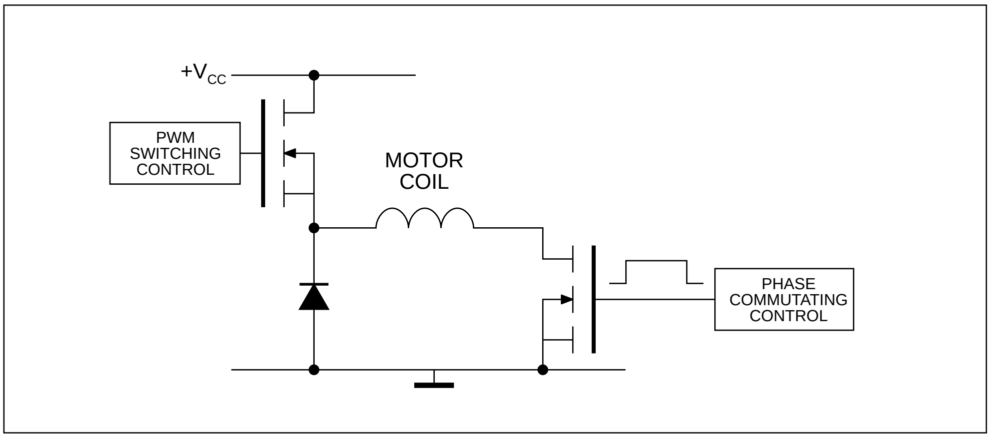
In low frequency operation (<5kHz) IGBTs perform better, as conduction losses dominate. The phase commutating transistor used in a symmetrical or asymmetric half bridge (see figure 5) corresponds to this case.

Home Appliance Electric Motors

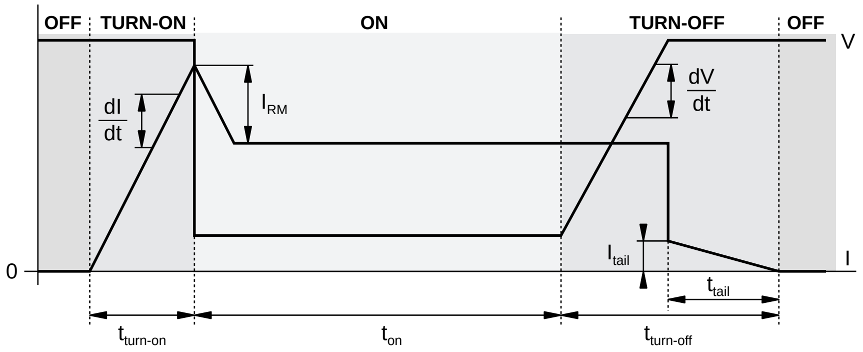
These applications usually involve a speed drive power of less than 600W. With a three-phase inverter the transferred power per phase is around 200W, and the transistor RMS current is around 3A. Such applications will require the MOSFET at least as a PWM switching transistor.

Additionally, when operating from a mains supply voltage of 120V AC, the MOSFET is the better choice. This is because 250V MOSFETs have a better $R_{DS(on)}$ / BV_{DSS} (breakdown voltage) ratio and therefore lower conduction losses .

Figure 5. Half bridge showing phase commutating transistor



APPENDIX 1. FORMULÆ FOR THE CALCULATION OF SWITCHING LOSSES IN MOTOR DRIVE APPLICATIONS



AT TURN-ON: $P_{turn-on} = 0.55 \times V \times (I + I_{RM})^2 \times f_{SW} \times (dI/dt)^{-1}$

IN THE ON PHASE: $P_{on} = [\,(E_O \times I) + (R_D \times I^2)\,] \times \delta$

AT TURN-OFF: $P_{turn-off} = [\,(V^2 \times I \times (dV/dt)^{-1}) + (I_{tail} \times t_{tail} \times V)\,] \times \frac{f_{SW}}{2}$

WHERE:

f_{SW} = Switching frequency

δ = duty cycle = $t_{on} \times f_{SW}$

E_O = ON-state threshold voltage (Zero for MOSFET)

R_D = ON-state resistance