Tektronix

Application Note

Oscilloscope and High-Voltage Probe Facilitate Motor Drive Design

TDS 360 Digital Real-Time Oscilloscope (top); P5100 High-Voltage Probe (right).

High-voltage measurements are a common requirement during the design of switching power supplies, motor controllers, power distribution systems, and more. Many general-purpose oscilloscopes, when equipped with suitable probes, are well qualified to handle high-voltage measurements. The Tektronix TDS 360 is a cost-effective 200 MHz Digital Real-Time scope aimed at design, manufacturing, and service applications. This application note explains the use of the TDS 360 and the P5100 High-Voltage Passive Probe in designing a motor drive cell. The Unit-Under-Test (UUT) is part of a motor drive system from Robicon, Inc., a leading provider of conventional and harmonic drives for high-power AC electric motors. The drives are widely used in oil derrick and liquid waste pumping systems, air conditioning equipment, etc.

The Importance of High-Voltage Probes

For the purposes of this discussion, "high voltage" denotes any voltage that exceeds the maximum input voltage range of a conventional DSO equipped with a 10X passive probe. For the TDS 360, the maximum allowable input voltage is 300 V RMS or 424 V DC + peak AC when using the standard P6111B Probe.

Many measurement applications exceed these maximum ratings, yet require the signal to be positioned vertically such that the entire signal amplitude is visible within the eight vertical divisions on the scope display. On the TDS 360, signals exceeding the 424 V DC + peak AC limit should be attenuated with the Tektronix P5100 High-Voltage Passive Probe. The probe's 100X attenuation raises the TDS 360's effective range to 2500 V. The P5100 is the tool of choice for safe ground-referenced measurements of high voltages. It's UL 3111-1 and IEC 1010 certified for voltages up to 2500 V DC + peak AC.

The P5100's high bandwidth (up to 250 MHz) ensures that transients and fast signal edges will be captured intact. Moreover, the P5100 offers the rugged physical construction needed for power measurements. Its special retractable hook tip provides a positive connection on test points up to 6.5 mm in diameter.

The Measurement Objective

A Robicon motor drive system may consist of many modular power cells, depending on the needs of the current application. The cells use Insulated Gate Bipolar Transistor (IGBT) devices to deliver power to the load. These IGBTs are controlled by logic circuits on a separate board mounted within the module. Figure 1 is a simplified schematic of the power section in a Robicon cell.

In designing the cells, and the system as a whole, care must be taken to minimize the inductance of the power buses connected to the cell output. Excessive inductance can cause "kickback" voltages to occur when an IGBT is rapidly switched off. Even though the effective DC supply voltage for the IGBTs in this cell is approximately 600 volts, kickback effects can produce transient signals of more than 1300 volts. Since the IGBT's breakdown voltage is rated at 1200 V, it's essential to control these transients. One solution is a "snubber" circuit (a simple

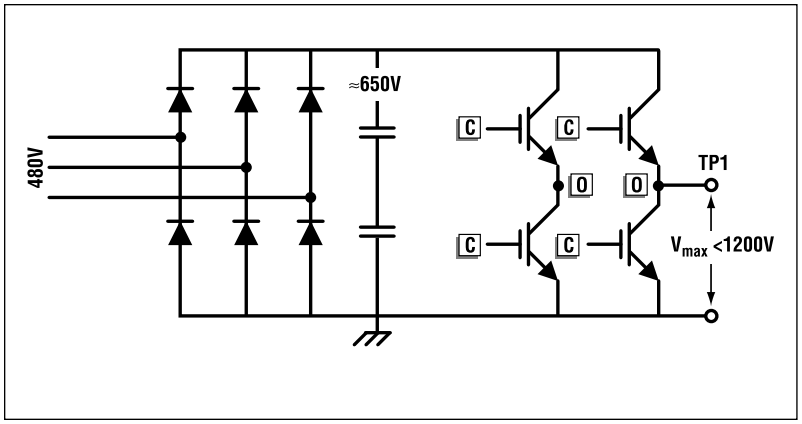

Figure 1. The IGBT power output circuit. "C" is a control signal from the Logic Board; "O" is the output. Kickback voltage V_{max} must not exceed 1200 V.

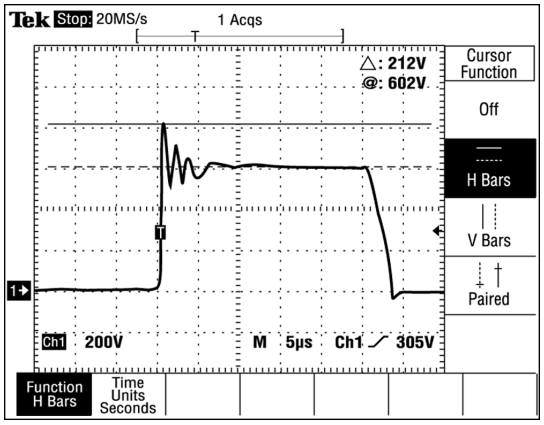

Figure 2. The IGBT waveform. The transient peak voltage is 212 V above nominal, well within the design tolerance.

resistance/capacitance network to damp out the transients) installed across the collector-emitter elements of the IGBT. Unfortunately, these waste precious power and add complexity to the circuit. The preferred means of dealing with the problem is to keep bus lengths as short as possible, and physically arrange them for minimum inductance (empirically determined).

The oscilloscope can guide the designer in making these system layout decisions. Using the TDS 360 and the P5100 High-Voltage Passive Probe, Test Point 1 (TP1 in Figure 1) is used to monitor the voltage as the IGBT switches on and off. Note that the emitter of the device is connected to ground, a requirement for safe measurements with any passive probe.

Robicon 454 GT Variable Frequency AC drive (photo courtesy of Robicon, Inc.).

As shown in Figure 2, the P5100's attenuation (100X) keeps the waveform amplitude within the viewable graticule area discussed earlier. Note that the scope senses the probe type and scales its readings accordingly. Thus the scope's 2 V/Div setting becomes 200 V/Div. The cursors also recognize the scaling. Here the cursors are set to measure the voltage level of the initial transient – that's 212 volts above nominal. If it's necessary to measure the nominal voltage (the stable, flatter portion after the transient), the cursors can be moved to bracket that part of the waveform. In this instance, the voltage would be 602 volts. Both of these values are well within the tolerance of the IGBT breakdown voltage specification and easily within the limits of the TDS 360/P5100 measurement system.

Floating Measurement Solutions

Many power circuits don't provide an appropriate earth ground point for the passive probe ground lead. For example, when the circuit discussed above is used in a system such as Robicon's Perfect Harmony motor drives, the IGBT junctions are not referenced to earth ground. This is known as a "floating" circuit. Line-powered scopes with passive probes offer no safe means of measuring voltage across the device in this situation.

There are two safe solutions for this problem. Line-powered scopes can be fitted with an isolating differential probe such as the Tektronix P5200 High-Voltage Differential Probe. Neither lead is fixed at earth ground. The probe measures the difference voltage across the two terminals, ignoring the common-mode offset voltage.

The second choice is a fully-isolated, battery-powered scope such as the handheld Tektronix THS 720P. Again, neither probe lead is fixed at earth ground, and the instrument itself is not connected to ground.

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