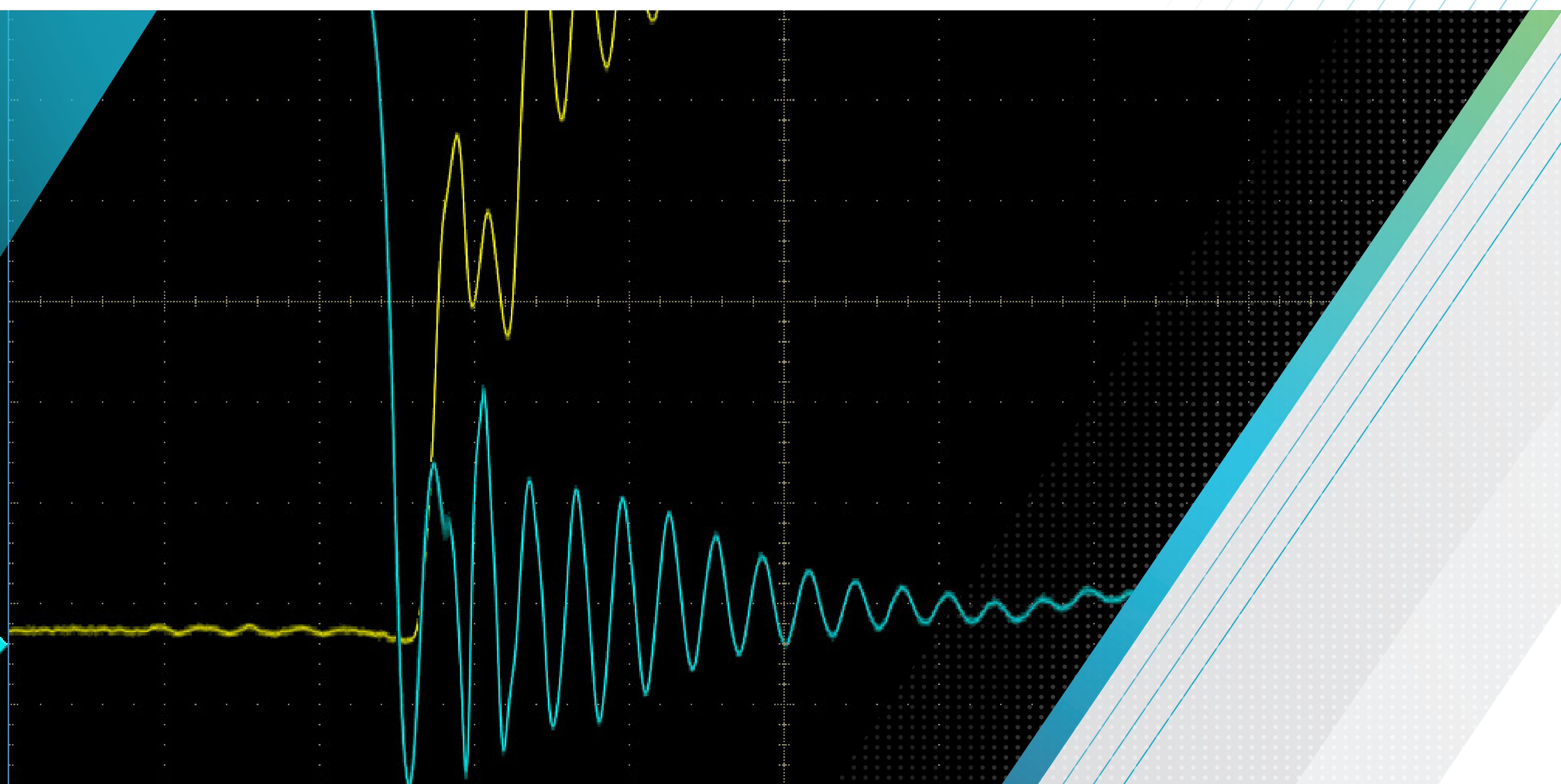
Measuring Vgs on Wide Bandgap Semiconductors

APPLICATION NOTE



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This application note focuses on accurate high-side V_{GS} measurements using the IsoVu measurement system. The measurements described in this application note are shown on a half-bridge configuration with eGaN FETs on both the high-side and low-side switches. While high-side gate measurements are the focus of this application note, the low-side gate will also be examined.

This application note addresses measurements during the following events:

1. High-side Turn-on
2. Hide-side Turn-off / Low-side Turn-on

Introduction

Components used in topologies such as the half-bridge have greatly evolved leading to advancements in efficiencies, densities, and reliability. An example half-bridge configuration is shown in Figure 1.

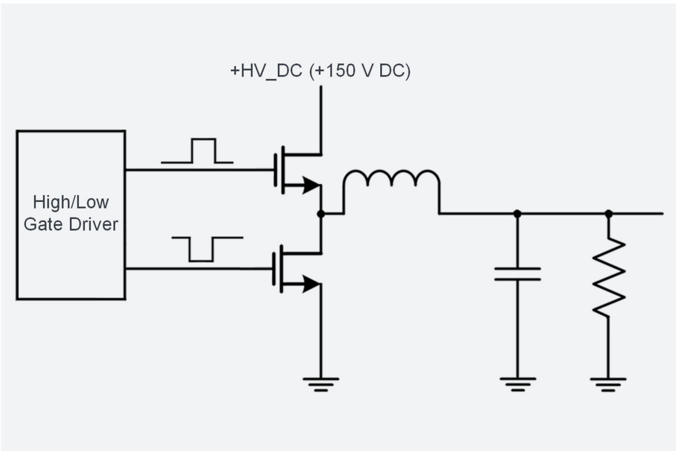

FIGURE 1. Half-Bridge Configuration.

The advancement of power conversion components and more stringent design requirements have far outpaced the ability to accurately measure and characterize these designs. At present, there is no test and measurement equipment capable of accurately making measurements such as the high-side gate-source voltage. In fact, most differential signals in the presence of today's higher frequency common mode voltages cannot be measured accurately. To make sense of what is happening in these environments, users have been forced to use alternative methods such as extensive simulation, measuring the low-side ("ground" referenced) switch and inferring the results to the high-side switch, examining thermal characteristics, EMI proximity probing, or trial and error methods.

The benefits of a design such as a half-bridge circuit can only be achieved when the half-bridge circuit, the gate drive circuit, and layout, are all properly designed and optimized. It's impossible to tune and optimize this circuit if you cannot measure it. Completing this design requirement involves characterizing the waveforms shown in the ideal case in Figure 2.

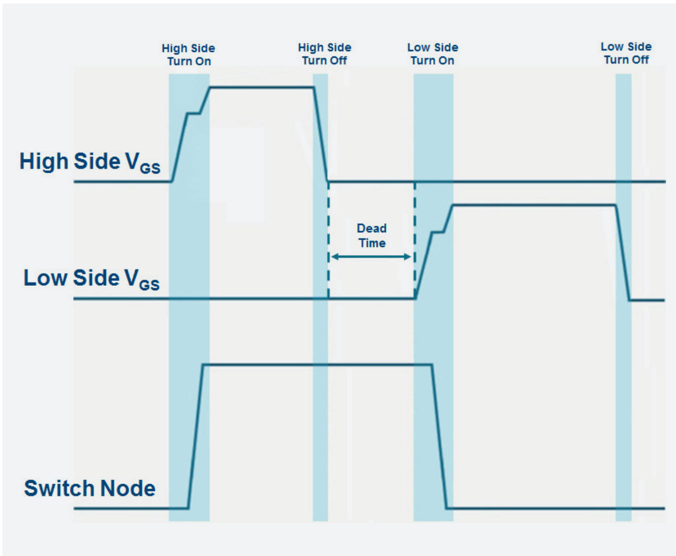

FIGURE 2. Example Ideal Half-Bridge Switching Waveforms.

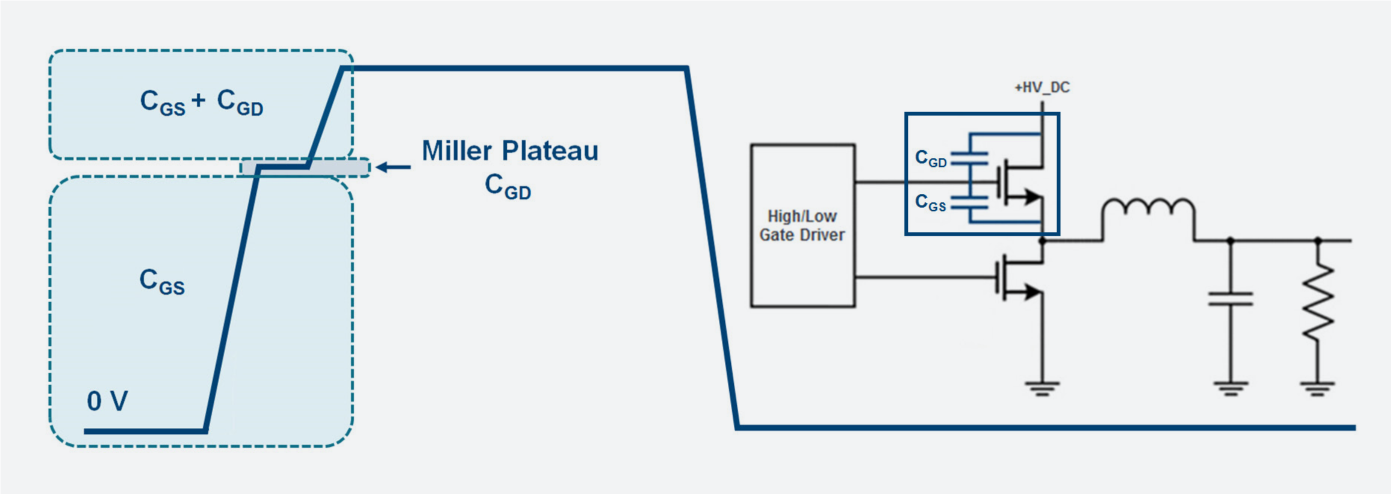

FIGURE 3. High-Side Turn On Characteristics.

1. High-side Turn-on Characteristics

In general there are three characteristic regions of the turn on waveform that are of interest. The first region is the C_{GS} charge time. This is followed by the Miller Plateau which is the time required to charge the gate-drain Miller capacitance (C_{GD}), and is V_{DS} dependent. This charge time increases as V_{DS} increases. Once the channel is in conduction, the gate will charge up to its final value. The ideal representation of these regions is shown in Figure 3.

The high-side V_{GS} is riding on top of the switch node voltage which is switching between "ground" and the input supply voltage. Because of this rapidly changing common mode voltage, the gate-source voltage is impossible to measure without adequate common mode rejection.

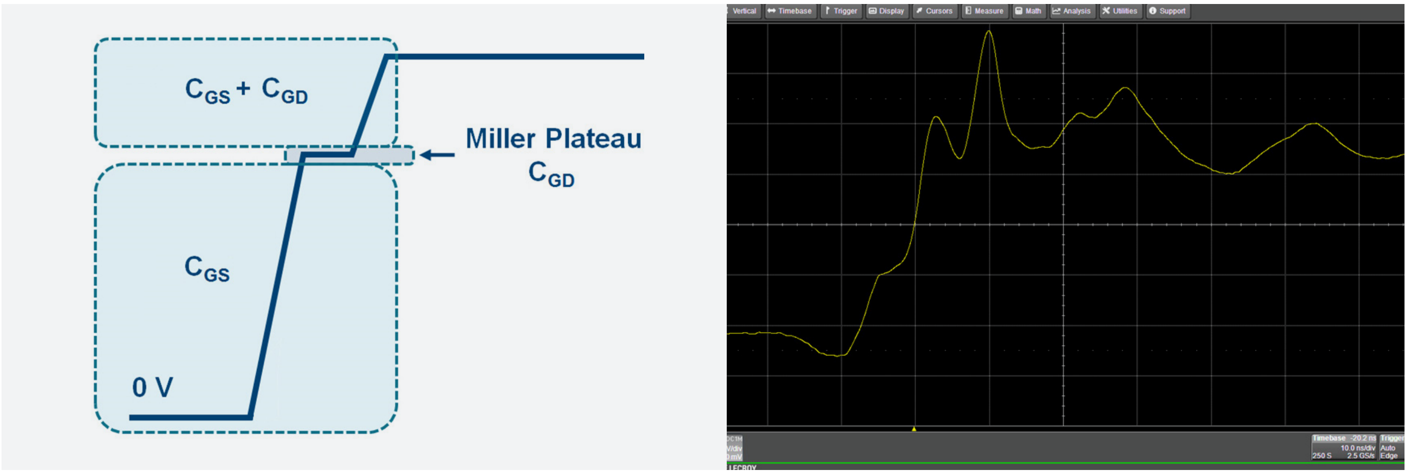

FIGURE 4. Comparison of LeCroy's DA1855A High-Side V_{GS} Output to Ideal.

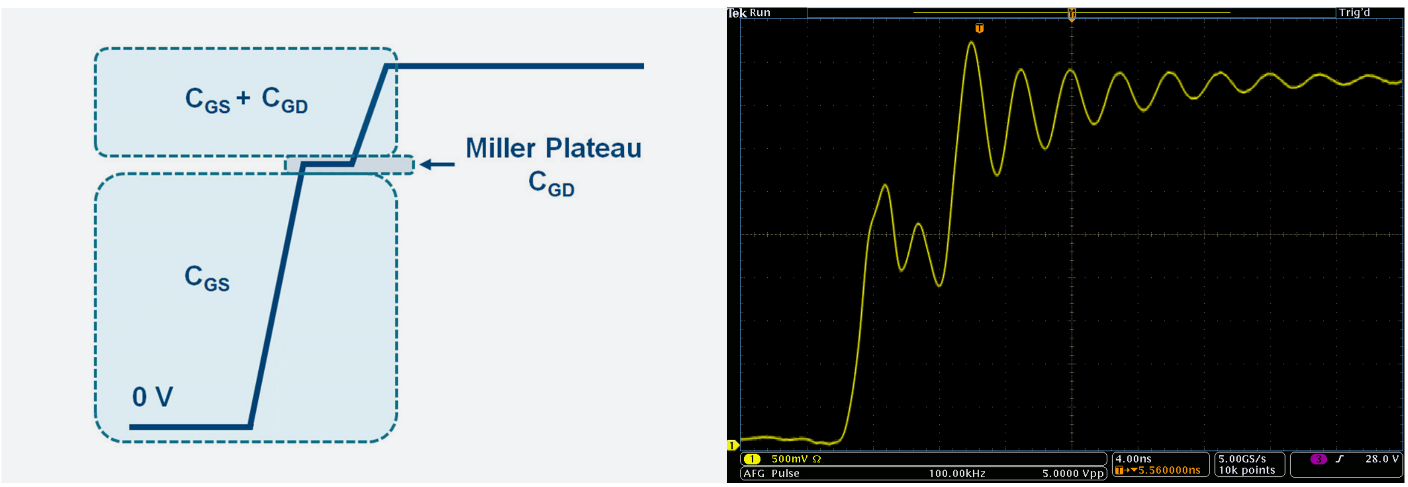

FIGURE 5. Comparison of the Tektronix IsoVu High-Side V_{GS} Output to Ideal.

You may have tried making the high-side V_{GS} measurement and gotten a waveform similar to the output of the DA1855A on a LeCroy scope shown in Figure 4. Comparing this actual output to the ideal transition, it's difficult to extract any meaningful details regarding what is happening in each of the regions referenced above and make design decisions based on this measurement. It's worth noting that the waveform shown below changes dramatically based upon position of the probe's input leads making a repeatable measurement impossible.

However, the IsoVu measurement system shows the details of what is occurring in the design and the measurement is stable and repeatable. This waveform clearly shows resonances and signal details previously hidden.

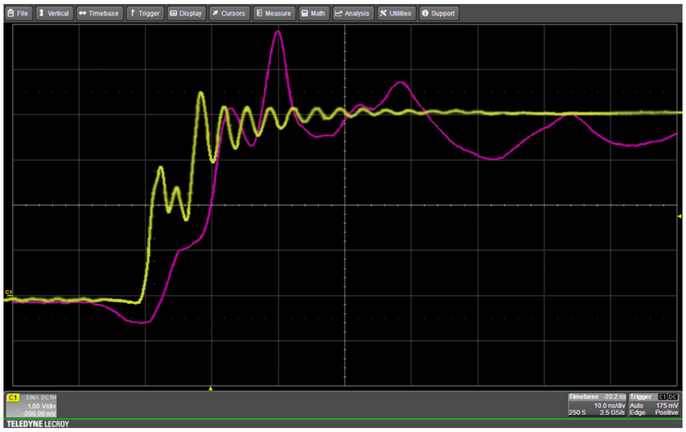

FIGURE 6. Comparison of Waveforms on a LeCroy Oscilloscope with IsoVu Waveform Overlaid.

Until now, the LeCroy DA1855A with a 12-bit oscilloscope has offered the most insight into these kinds of measurements. With this measurement system, the user may have been tempted to optimize their design based on the waveform information. After all, it does seem to show some of the expected characteristics. However, the IsoVu system tells a very different story. Figure 6 shows a comparison of these two measurement systems and reveals how optimizing based on a measurement system with limited CMRR and bandwidth can cause users to severely mis-tune their design.

IsoVu offers users the resolution and repeatability required to optimize the performance of their designs. As you can see in Figure 7, there is clear correlation between the Miller plateau and the switch node transition.

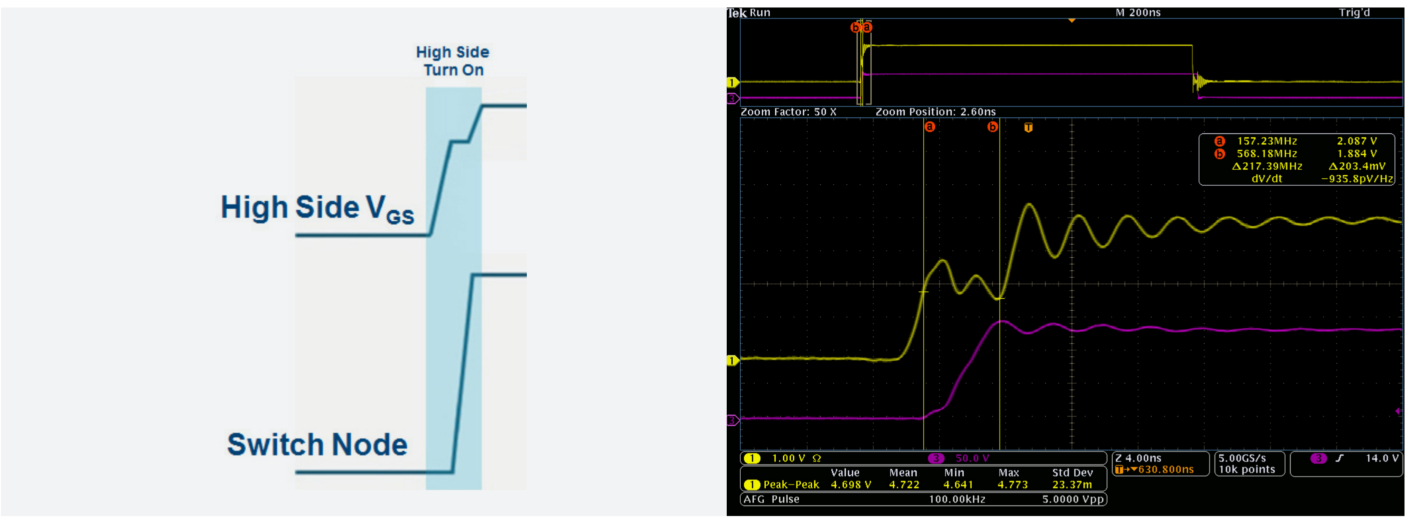

FIGURE 7. High-Side V_{GS} Turn On and Switch Node Compared to Ideal.

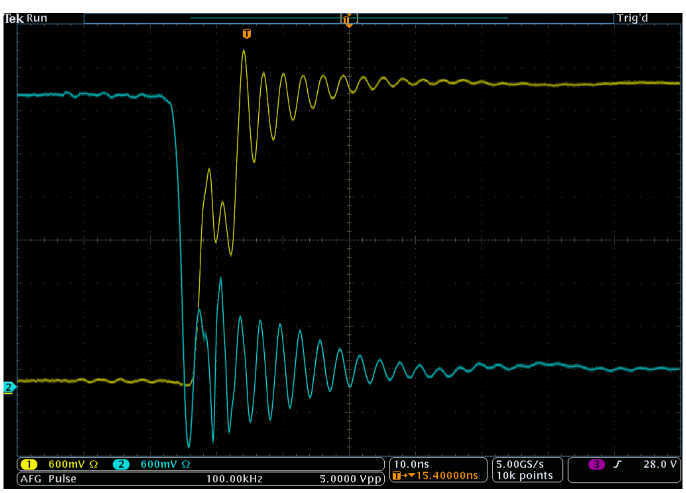

FIGURE 8. Interaction of the High-Side and Low-side Switches.

Although the low-side switch is supposed to be "ground" referenced, it's interesting to see the actual waveform and how it may affect the high-side performance. Figure 8 shows that the low-side switch has ringing due to parasitic coupling between the low-side switch, the high-side gate and the switch node.

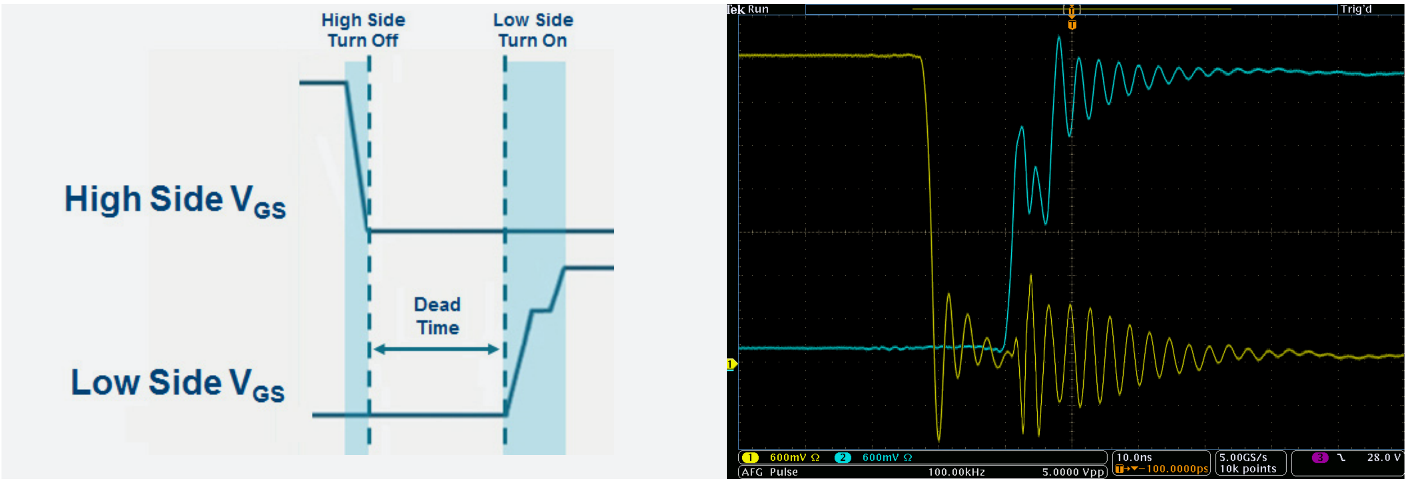

FIGURE 9. High-Side Turn Off, Low-Side Turn On, and Dead Time.

2. High–side Turn–off / Low–side Turn–on Characteristics

Many of the same characteristics are apparent during the high-side turn-off/low-side turn on transitions. As shown in Figure 9, the Miller plateau on the low-side V_{GS} is clearly visible. The coupling due to parasitics between the switch node and the high and low-side FETs is apparent, and the IsoVu measurement system has more than adequate bandwidth to measure the dead time.

Accurate measurement of the time aligned high-side and low-side events is critical to avoid simultaneous conduction of the two FETs which can lead to excess switch loss, efficiency loss and device degradation.

Conclusion

To accurately make difficult measurements such as the high-side V_{GS} measurement, you need a measurement system which combines high bandwidth, high common mode voltage, and high common mode rejection. Along with its complete galvanic isolation, the Tektronix IsoVu system offers 1 GHz bandwidth, 2000 V common mode voltage and 1 Million to 1 (120 dB) common mode rejection ratio. It's the combination of these specifications which makes these kinds of difficult measurements possible.

Contact Information:

Australia* 1 800 709 465

Austria 00800 2255 4835

Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777

Belgium* 00800 2255 4835

Brazil +55 (11) 3759 7627

Canada 1 800 833 9200

Central East Europe / Baltics +41 52 675 3777

Central Europe / Greece +41 52 675 3777

Denmark +45 80 88 1401

Finland +41 52 675 3777

France* 00800 2255 4835

Germany* 00800 2255 4835

Hong Kong 400 820 5835

India 000 800 650 1835

Indonesia 007 803 601 5249

Italy 00800 2255 4835

Japan 81 (3) 6714 3010

Luxembourg +41 52 675 3777

Malaysia 1 800 22 55835

Mexico, Central/South America and Caribbean 52 (55) 56 04 50 90

Middle East, Asia, and North Africa +41 52 675 3777

The Netherlands* 00800 2255 4835

New Zealand 0800 800 238

Norway 800 16098

People's Republic of China 400 820 5835

Philippines 1 800 1601 0077

Poland +41 52 675 3777

Portugal 80 08 12370

Republic of Korea +82 2 6917 5000

Russia / CIS +7 (495) 6647564

Singapore 800 6011 473

South Africa +41 52 675 3777

Spain* 00800 2255 4835

Sweden* 00800 2255 4835

Switzerland* 00800 2255 4835

Taiwan 886 (2) 2656 6688

Thailand 1 800 011 931

United Kingdom / Ireland* 00800 2255 4835

USA 1 800 833 9200

Vietnam 12060128

*** European toll-free number. If not accessible, call:** +41 52 675 3777

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