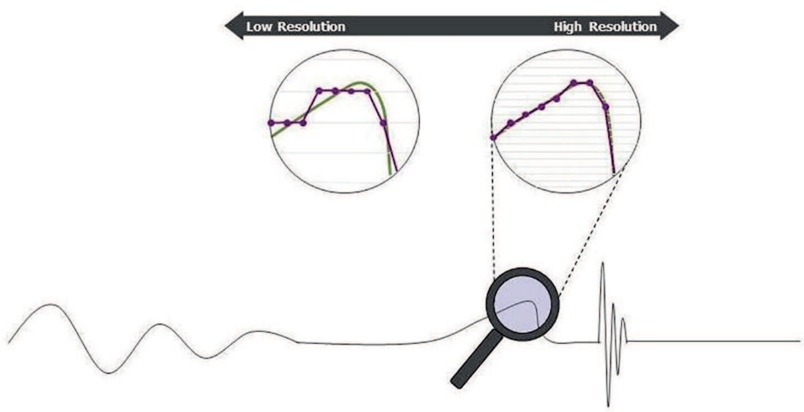
Achieving better resolution, accuracy and signal clarity with an oscilloscope

By Clive Davis, Marketing Manager, Yokogawa Test & Measurement Europe & Africa

Oscilloscopes and related measuring instruments are often selected on the basis of their specified resolution but, as this article shows, there are a number of other factors that need to be taken into account to achieve the optimum results in terms of accuracy and signal clarity.

Typically a general-purpose oscilloscope has an 8-bit analogue to digital converter (ADC), which provides 256 quantisation levels (2n, where n is the number of bits). In practice this means that the maximum resolution on a 1 V per division range, for example, is between 31.25 mV and 40 mV. depending on how the oscilloscope manages the ADC range and the displayed divisions. A 12-bit ADC has 4096 quantisation levels and a 16-bit ADC has 65536. Some potential benefits of more bits are easily apparent as more detail is available when the signal is expanded or zoomed and small disturbances on much bigger signals can be analysed in detail (Fig.1). The effects of noise, accuracy and common-mode voltage, however, also need to be considered to understand if an increase in resolution alone adds value to the measurement.

Fig.1. The effects of higher resolution



‘Normal’ oscilloscopes have single-ended grounded inputs and have a DC voltage accuracy of 2 or 3%. There is a trend for these 8-bit units to move towards 12-bit resolution. Some use actual 12-bit ADCs while others use oversampling and averaging techniques with 8-bit ADCs to increase the resolution. Indeed this basic technique has been available as a “high-resolution mode” in most instruments for some years, and is useful when the frequency of the input signal is much lower than the maximum bandwidth and sample rate of the oscilloscope. In both cases, the signal to noise ratio (SNR) of the input channel needs to be considered, as the noise may extend over the improved lower bits of the ADC and thus no improvement in actual resolution can be seen. An improved resolution also does not help to increase the accuracy of voltage measurements.

Differential inputs

The terms “isolated inputs” and “differential inputs” are sometimes used interchangeably. However, it is important to be aware of the differences. All voltage

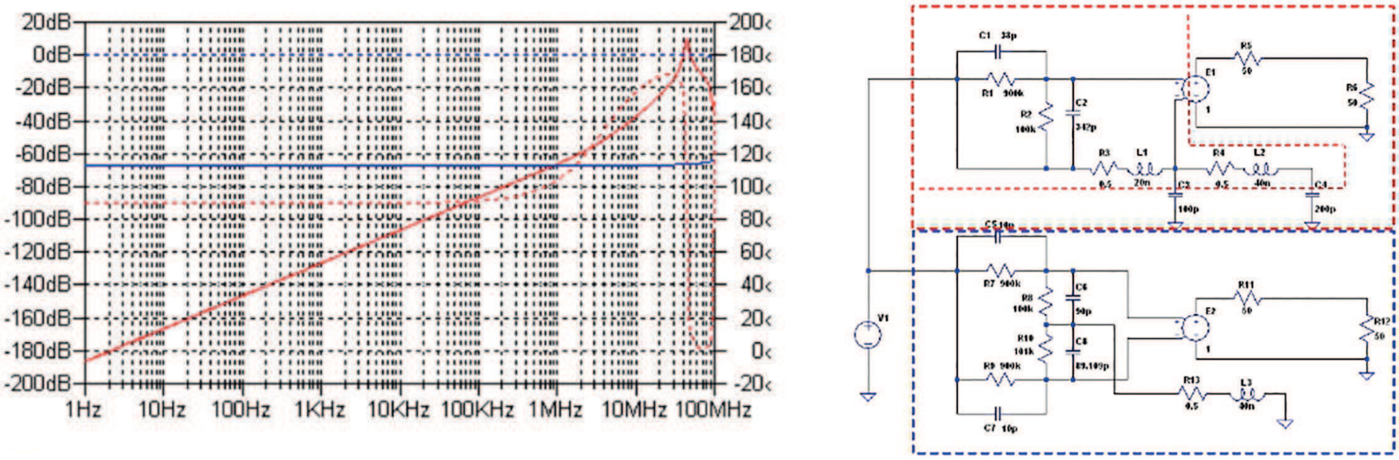


Fig.2. Comparison graphs of common-mode rejection ratios for both isolated and differential inputs using simple simulation models

measurements between two points are differential whether one is earthed or not. The two terms are used to describe the technique or design of the circuit used. Both measuring systems provide isolation in order to enable safe measurements on floating signals to be carried out or to measure at different points of the circuit with multiple channels where the grounds are at different potentials without creating crosstalk and large earth currents. A key difference is their effectiveness at different frequencies, and hence this is a determining factor in their selection. Common-mode signals will appear as additional high-frequency noise in the displayed signal, and thus the ability to reject this signal - the common mode rejection ratio (CMRR) - is critical. As can be seen from the graphs in Fig.2, an isolated input design is more suitable for lower frequencies as the CMRR is very high and decreases as the frequency increases. At higher frequencies (above 10 MHz), a differential design becomes more effective.

Grounded inputs

Accordingly, to test high-speed 3-phase inverter circuits which also feature high voltages, an eight-channel oscilloscope and specialised differential probes with a high CMRR are the better solution (Fig.3). These differential probes are balanced and a supplementary ground reference connection is not required when they are used with an oscilloscope with grounded inputs. The solution is therefore easy to configure, but the user must also remember that the accuracies (or rather inaccuracies) of both the oscilloscope and the probe contribute to the overall accuracy of the measurement.

Flexible acquisition

For measuring signals with frequency components up to 10MHz or 20MHz, an isolated design is better, and it is also convenient to install it in the instrument. Fig.4 shows an instrument which shares many of the characteristics of an oscilloscope, but also has the large data capture and analysis capabilities of a data acquisition system.

Resolution Improvements

The ScopeCorder offers a flexible approach as the inputs are modular, and provides the ability for the user to select the ADC, sample rate and the resolution according to the measurement requirement. One type of module, for example, incorporates a 16-bit ADC to provide a measurement resolution of approximately half a millivolt using a 1 V per division range. At first sight this does not seem to be offering the expected resolution improvements over that of an oscilloscope with an 8-bit ADC; however, the measuring range of the ScopeCorder

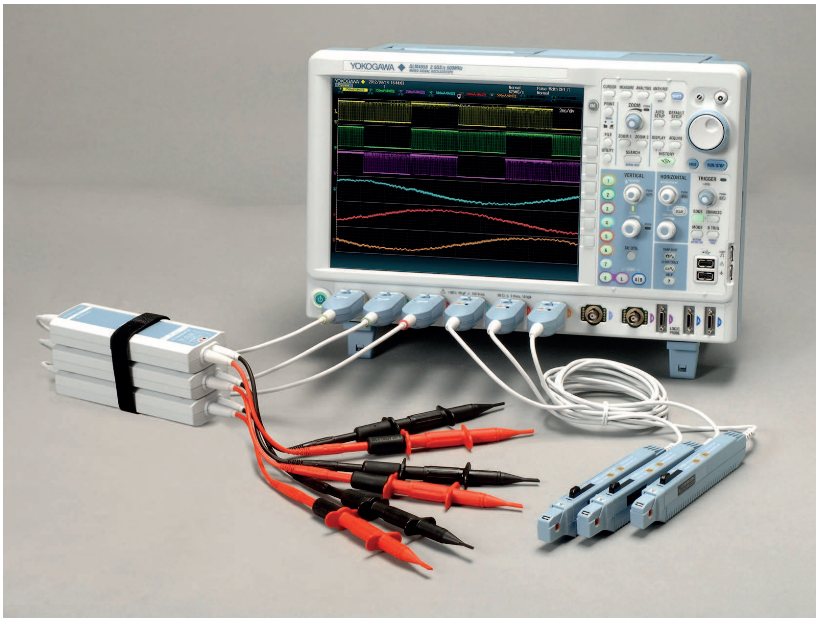


Fig.3. Eight-channel mixed-signal oscilloscope (Yokogawa DLM4000 with 701927 differential probe)

is over 20 divisions compared to the 8 or 10 divisions of a conventional oscilloscope. The module also provides built-in isolation, with the corresponding improvements in noise performance, and improved accuracy down to 0.25%.

Large voltage range

This instrument therefore provides the ability to capture a complete waveform with a large voltage range, along with the ability to examine and analyse very small variations or disturbances on parts of the waveform accurately.

The user needs to consider not only the resolution of the actual measurement but also how the oscilloscope or ScopeCorder presents multiple-channel waveforms. Traditionally, in order to show multiple channels on the display without overlapping them, each channel needs to be offset and the displayed amplitude reduced. For example, for four channels, each waveform in an 8-bit oscilloscope would need to occupy a quarter of the display and would therefore use a maximum of 64 quantisation levels or an equivalent of 6 bits.

The ability to split the display either automatically or manually enables the full range of the ADC to be maintained for each channel regardless of whether 2, 3, 4, 6, 8 or 16 waveforms etc. need to be viewed. The benefits of using a larger 10- or 12-inch high-resolution colour display can then be maximised and appreciated.

Conclusion

It is important for users to consider not only the stated resolution of the ADC when selecting a measuring instrument but also factors like noise, which is affected by the type of input as well as the residual noise in the instrument, how multiple channels are displayed, and the accuracy of the measuring instrument – all of which can nullify the proposed benefits of an increase in resolution.

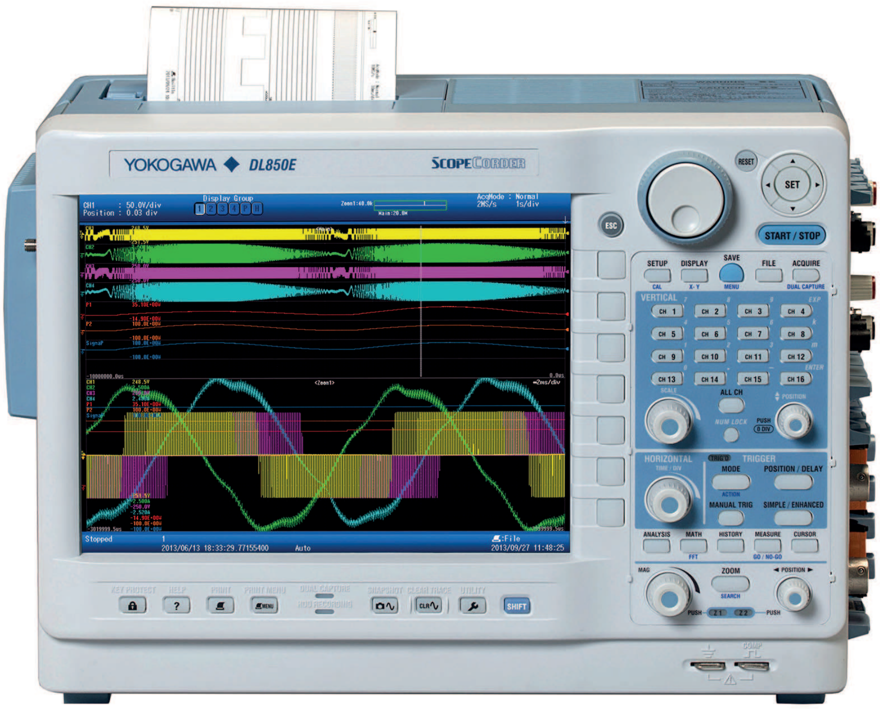


Fig.4. The Yokogawa DL850E ScopeCorder combines features of an oscilloscope and a data-acquisition system, featuring high-speed multi-channel capabilities plus long memory and isolated input channels