Benefits of DSOs in Communications Testing

Overview

This technical note discusses the application of digital oscilloscopes to a variety of problems encountered in communications. Examples are given of how to use the benefits of a DSO in examining phase shift keying, frequency shift keying, full duplex signals, gaussian minimum shift keying, quadrature amplitude modulation and Ethernet LANs. Use of a persistence display and Pass/Fail testing are examined.

Introduction

The rapid evolution of communications poses new and challenging technical problems and a need for improved instrumentation. Despite the variety of communications media, there are many similarities in the problems encountered when developing, testing and debugging communication links. Testing is typically performed by transmitting and receiving known patterns of data which are most often repetitive, whereas real-life conditions often require single-shot capabilities due to the unpredictable nature of the data.

Because of their ability to display single-shot as well as repetitive events, digital oscilloscopes are ideal for the communications field. Advanced digital oscilloscopes also offer a wealth of features including sophisticated triggering, processing of data, computer control, etc. These features can be invaluable to engineers faced with the problem of capturing and analyzing communications signals.

This note presents typical applications and shows how particular features of LeCroy oscilloscopes can be beneficial.

DIGITAL OSCILLOSCOPE OVERVIEW

The transition from analog to digital technology in oscilloscopes brings several advantages which include:

- Capture of single-shot as well as repetitive events.
- Steady, non-volatile display of waveforms.
- Event archiving (computer storage and paper hardcopy).

- Viewing of pre- and post-trigger data.
- Digital control of the acquisition conditions.
- While the above features are common to most digital oscilloscopes, LeCroy oscilloscopes also provide innovative and unique features particularly valuable in communications. These are:
- Long memory per channel, up to 2 Mpoints, allow viewing of long-lasting events with very high time resolution.
- Simultaneous sampling on all channels to ensure correct phase analysis of complex waveforms.
- XY display with dedicated cursors for relative phase and amplitude measurements.
- External clock input to sample the input waveform synchronously with a user-defined clock (particularly useful for constellation displays).
- A wide choice of signal processing options, including Fast Fourier Transform (FFT) which allows the oscilloscope to act as a spectrum analyzer.
- Variable and infinite persistence display modes, for eye diagram display.
- PASS/FAIL testing with "template" waveforms and parameter limits representing popular telecom standards.
- Time-qualified trigger, where the distance between the arming condition and the actual trigger is defined in terms of time.
- State-qualified trigger, where the presence of a particular logic state, for instance on Channel 2 and/or External, is a condition for Channel 1 to trigger.
- Histogram analysis of amplitude fluctuation, edge jitter and other important signal properties.

The following examples highlight some applications of these features.

PHASE SHIFT KEYING

Phase Shift Keying (PSK) is a popular way of transmitting digital data through modems and telephone lines. It is based on the phase modulation of a continuous sine wave. While the structure of these signals is quite simple, oscilloscopes with just a threshold trigger have difficulty displaying them. The continuous change of phase results in a display with excessive jitter. A trigger which operates only when the oscilloscope senses a variation in the phase of the signal is much more effective.

LeCroy oscilloscopes are capable of sensing the width of the input pulses or, alternatively, the time distance separating successive pulses. A change of phase in a continuous sine wave can be detected as a sudden variation of the period.

Figure 1 shows such an example. The trigger occurs on Channel 2 (lower trace). The requirement is that the separation between two cycles must be smaller than the sine wave period (Interval smaller than 258 μsec). The trigger position in time is indicated by the small arrow at the bottom of the screen. As can be seen, the trigger takes place after a 180° phase change.

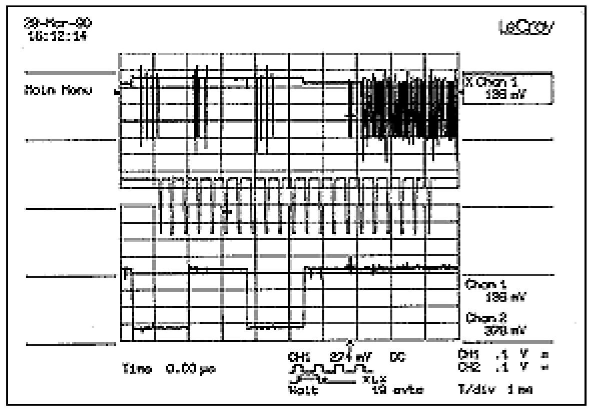

Figure 1. Interval trigger provides a stable trigger on a Phase Shift Keyed signal.

CONSTELLATION DISPLAY

The two waveforms in Figure 1 are the I (In-phase) and Q (Quadrature) components of a transmitted PSK waveform, acquired simultaneously. An XY display of these two waveforms shows their phase trajectory (Figure 2).

A constellation display can be generated by clocking the I and Q components with the system clock and showing an XY display of the sampled values. This can be easily done since LeCroy oscilloscopes can be used with an external clock.

Figure 3 shows the constellation display obtained by the two waveforms of Figure 1. The slight spread of the points in the constellation display indicates a small phase jitter between the I and Q signals.
The phase jitter can be measured exactly by locating the cross-hair cursor at the two extremes of a spot, as shown in Figures 3 and 4. The difference of the two angles seen on the right-hand side of the XY display gives the amount of jitter. In this case, delta f = 50.8° - 46.3° = 4.5°.

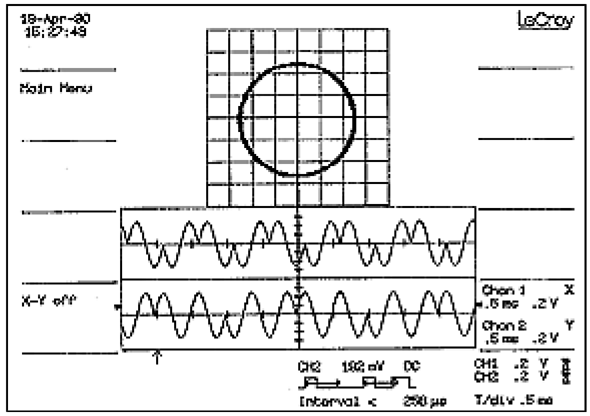

Figure 2. The phase trajectory of the I and Q components of a PSK signal.

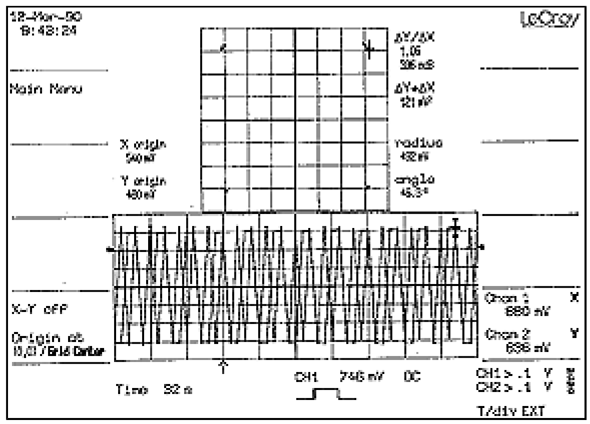

Figure 3. Constellation diagram of a PSK signal.

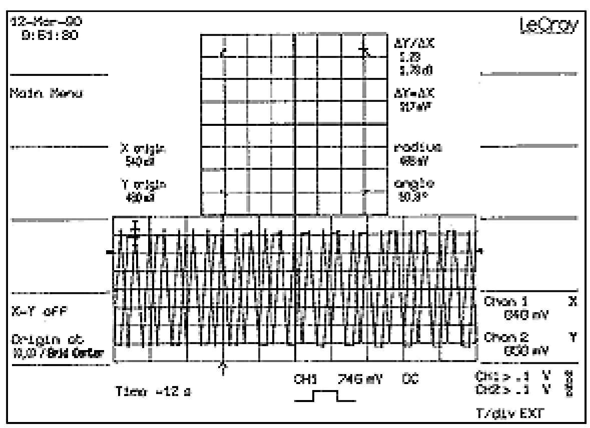

Figure 4. The same constellation diagram of a PSK signal as in Figure 3, with the crosshair cursor used to measure the phase jitter.

FREQUENCY SHIFT KEYING

Frequency Shift Keying (FSK) is another common way of transmitting digital data. It's based on modulation frequency of a carrier.
The upper waveform in Figure 5 shows an example of a binary frequency modulation. This is a relatively simple signal, but very difficult to trigger on without resulting in a jittering display. Any one of the pulses

composing the waveform can be a potential trigger. The signal in Figure 5 was captured with a LeCroy oscilloscope by setting the instrument to trigger only when a change takes place in the carrier period (pulse width less than 3 µsec). The trigger position is indicated by the arrow at the bottom of the grid.

The lower trace in Figure 5 shows another feature of LeCroy oscilloscopes; the ability to calculate the FFT of the input waveform. Two frequency peaks are clearly visible. The two cursors, set on the two peaks, measure a frequency difference of 100 kHz.

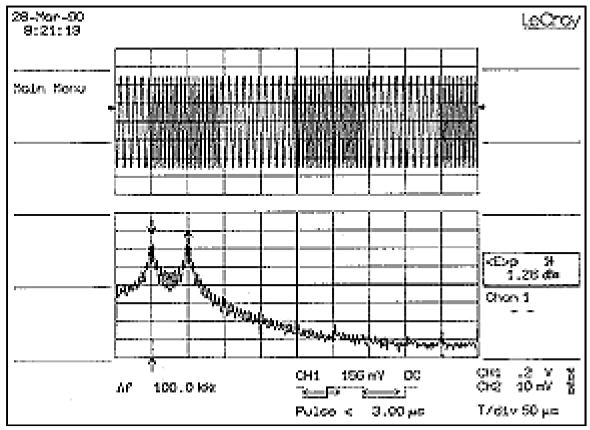

Figure 5. An FSK signal and its frequency spectrum.

FULL DUPLEX LINE

A full duplex line is a two-way link between two communication terminals, where transmission occurs in both directions simultaneously. In order to distinguish the direction of the data, carriers at two different frequencies are normally used. Each terminal isolates the carrier bringing data from the other terminal, by applying a suitable filter to the signal.
The upper trace in Figure 6 shows the data flow in a full duplex line. The bottom trace shows the FFT Power Spectrum of the same waveform. The two carriers are clearly visible. The cross-hair cursor measures the peak frequency of the first carrier (1.195 kHz) and the associated power (-8.40 dBm).

One more feature is used to provide the frequency spectrum in Figure 6. The time domain waveform is quite noisy and the FFT of a single waveform would provide a noisy FFT spectrum. This would reduce the chances of clearly identifying the two carriers. In Figure 6, the FFT spectrum shown was obtained by averaging individual spectra (244 times). Random noise effects are dramatically reduced, making the two frequency components clearly visible.

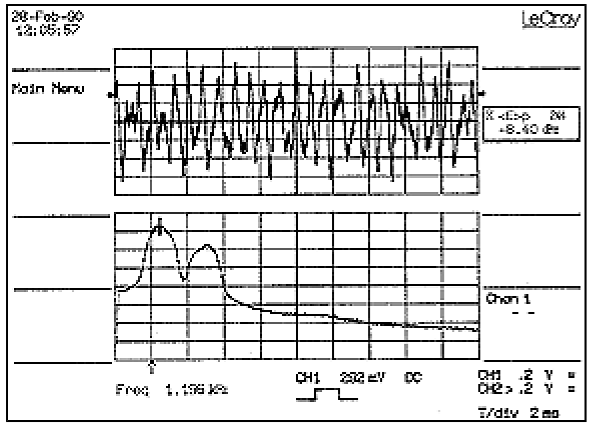

Figure 6. Signal captured on a full duplex line and its corresponding frequency spectrum.

GAUSSIAN MINIMUM SHIFT KEYING

Gaussian Minimum Shift Keying (GMSK) is a type of modulation typically used in digital mobile telephones. The upper trace in Figure 7 shows one of the components of a GMSK signal. Again, the sophisticated trigger capabilities of the LeCroy oscilloscopes are employed. Triggering at the beginning of individual data streams can be obtained by requiring a pulse separation greater than the longest separation expected in the data stream (150 µsec in this case). The deep acquisition memory (up to 2 MBytes/channel) also allows the user to catch a long data stream and to zoom in to see the fine details of the waveform. The lower trace in Figure 7 is a 20 times expansion of the upper trace.

The two waveforms at the bottom of Figure 8 are the I and Q components of a GMSK signal taken with a LeCroy oscilloscope, simultaneously acquired as they came out from a transmitter. The XY display at the top shows the corresponding phase trajectory. The asymmetry in the circle at the point of the upward arrow is indicative of a saturation effect. This effect is also visible in the time domain on the Q component (lower trace), but not as clearly as in the XY display. The possibility of positioning a cursor in the XY display, as well as on the waveform in the time domain, facilitates the use of the XY display to identify the problem in the time domain.
In Figure 9 the GMSK signal has been transmitted, then received and decomposed again into its I and Q components (lower two traces). The XY display clearly shows the degradation of the signal due to noise and to the non-ideal characteristics of the receiver.

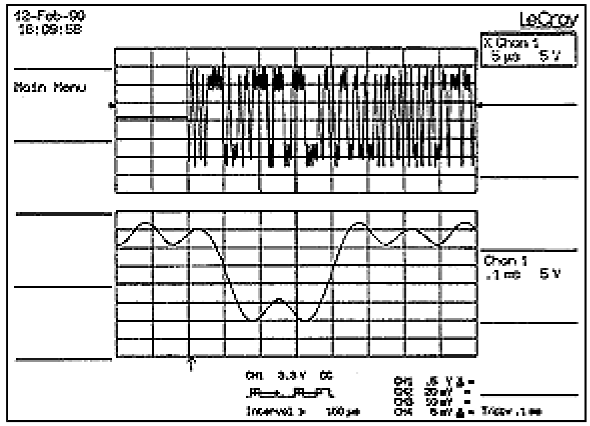

Figure 7. Interval trigger used to capture a GMSK signal.

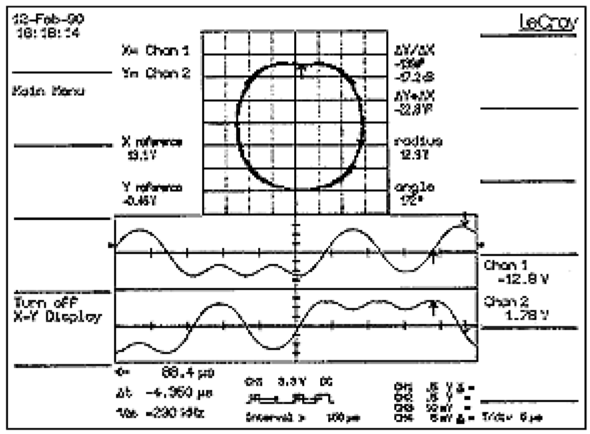

Figure 8. Phase trajectory of the I and Q components of a transmitted GMSK signal.

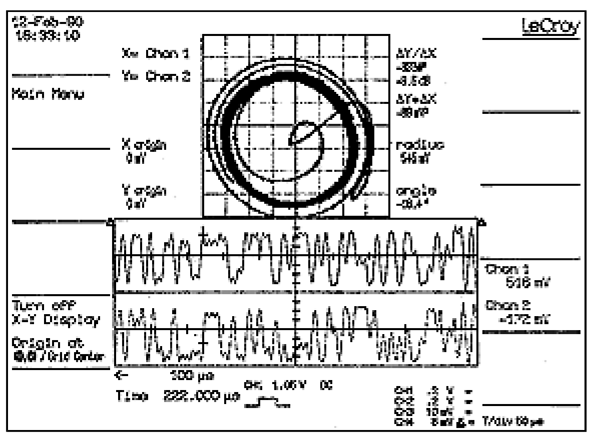

Figure 9. Phase trajectory of the I and Q components of a received GMSK signal.

QUADRATURE AMPLITUDE MODULATION

Quadrature Amplitude Modulation (QAM) is another well-known modulation technique for achieving more efficient use of the available bandwidth. It consists of two amplitude-modulated carriers summed in quadrature and, therefore, it can also be viewed as a combination of amplitude and phase modulation. If, for instance, the amplitude of each carrier is allowed to have four different states, each carrier will transmit

two bits per baud. The total waveform will, therefore, carry a total of four bits and the constellation diagram would then contain 16 points arranged in a rectangular constellation (16-QAM). This is exactly what can be seen in Figure 10 showing the XY display of the I and Q components of a 16-QAM signal. The two signals have been simultaneously sampled by the system clock sent to the external clock input of the oscilloscope.
The 16 possible states are clearly shown. By using voltage cursors (not shown) it is possible to verify the symmetry of the states. The cross-hair cursor shown provides the relative phase of the I and Q signals (45.1 degrees), the distance from the center of the grid (1.416 V), and the ratio of the I and Q amplitudes (in this case equal to 1).

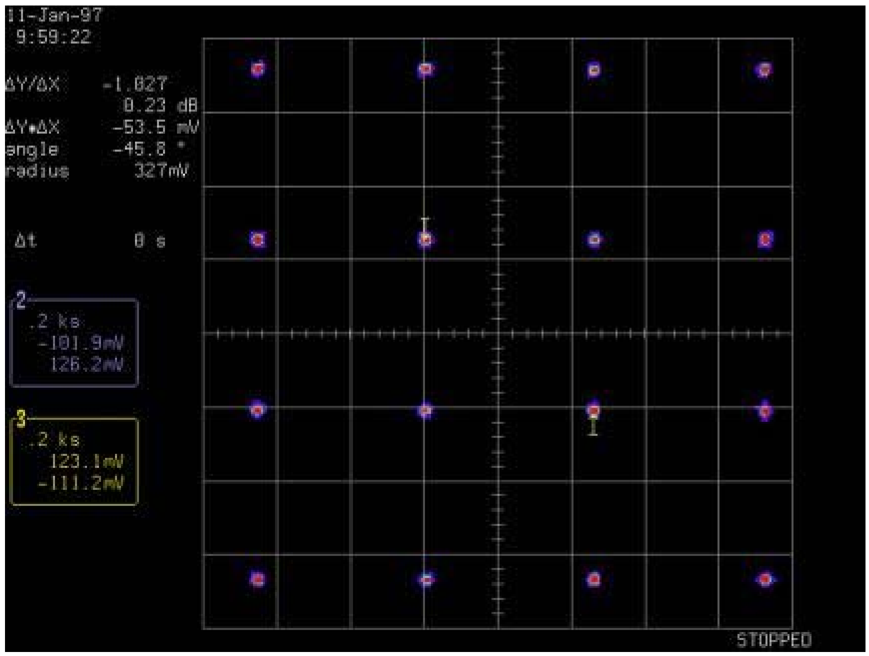

Figure 10. Constellation display of a 16-QAM signal.

VARIABLE PERSISTENCE

The variable persistence feature allows accumulation of successive events on display, so that the user can estimate the evolution in time of a given phenomenon. In communications this feature is useful to build up eye diagrams, showing the time or amplitude jitter in a given bit stream. Figure 11 shows an example of such an eye diagram: the two vertical time cursors offer an easy way of measuring the opening of the eye over time. Two similar horizontal voltage cursors allow measurement of the opening of the eye in amplitude.

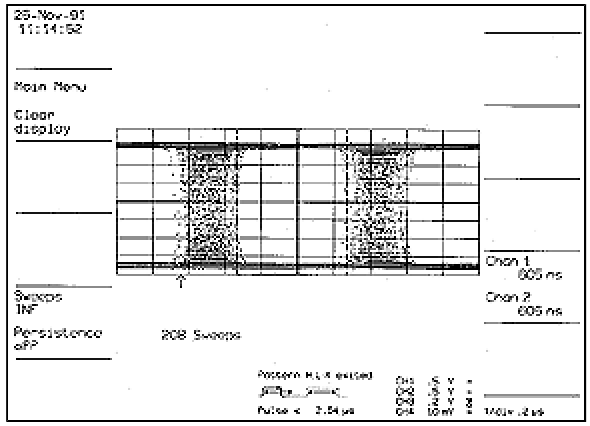

Figure 11. Example of an eye diagram using variable persistence.

PASS/FAIL TESTING

The PASS/FAIL package, standard in all LeCroy oscilloscopes, permits multiple tests on an acquired waveform.

The tests can be executed both on pulse parameters and/or against a tolerance mask. The tolerance mask can be defined by the user, or down-loaded from either the optional memory card , portable PCMCIA hard drive (9300 family) or the built-in floppy disk (9300 families) or an external computer.

LeCroy offers an optional memory card or floppy disk which is preloaded with 23 telecom templates taken from the following standards: ANSI T1.102, ANSI T1.403, CCITT G.703, and CCITT1.430 (ISDN).
Figure 12 shows one such telecom template PASS/FAIL test being executed.

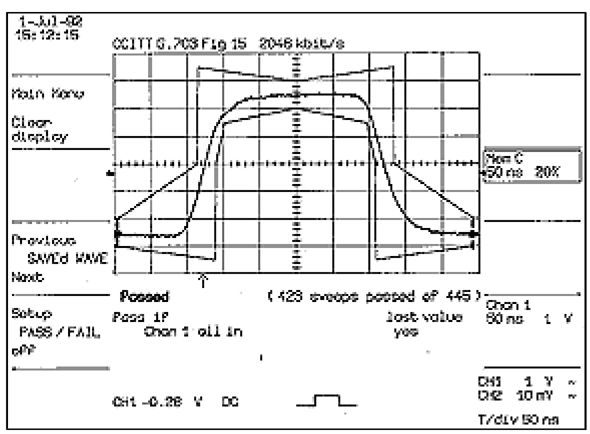

Figure 12. Automatic PASS/FAIL testing against a telecom template.

TESTING AN ETHERNET LAN

Ethernet is a local area network which works on the assumption that each local user can sense the state of a common broadcast line before attempting to use it.

A data packet can have a maximum size of 1526 bytes, that is 12,208 bits. With a bit lasting 100 nsec, this means that a packet can have a maximum length of 1,220.8 μsec. A digital oscilloscope sampling at 100 MS/sec allows capture of the individual 100 nsec long bit, but capture of a full packet requires up to 122,080 words of memory.

The 9300 series scopes offer models with up to 2 Mword of memory per channel.

The 2 Mword memory can also be sliced in segments (up to 2,000) and each segment can be used to acquire a new event. Figure 13 shows this feature applied to the unattended monitoring of "collisions" happening on the Ethernet bus. The upper trace shows a compacted display of a sequence of 12 such collisions. A collision is defined at the trigger level by requesting a separation between two successive packets varying between 125 nsec and 9.6 μsec (the trigger conditions at the bottom of the display). The lower trace is the expanded view of one of these events, where the "illegal" gap between two packets is visible. The two cursor arrows measure a gap width of 9.45 μsec.

Figure 14 shows the time stamps associated with each individual collision. The instrument provides both the absolute trigger time, with resolution of one second, and the time relative to the first trigger, with nanosecond resolution.

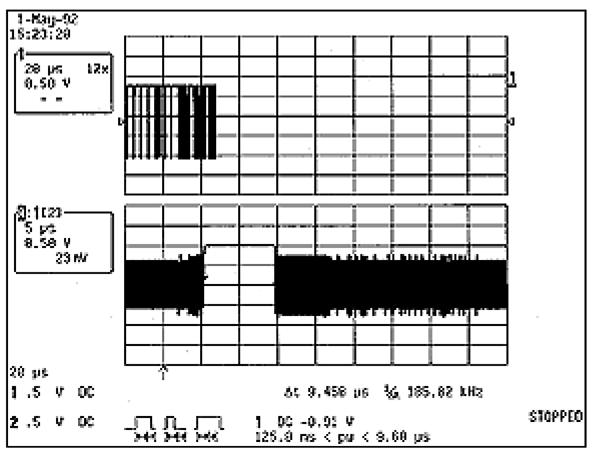

Figure 13. Capture of collisions on a Ethernet bus.

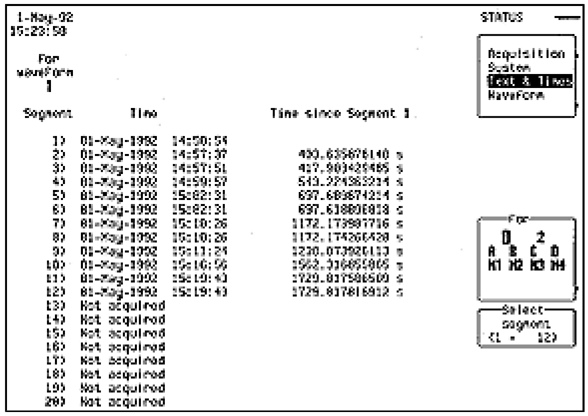

Figure 14. Time stamps associated with the collisions of Figure 13.

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