# FUTURE DEVELOPMENTS IN OSCILLOSCOPE CALIBRATION

**Peter Dack**
**Fluke Precision Measurements**
**Hurricane Way**
**Norwich, Norfolk NR6 6JB**
**+44 1603 256686**
**peter.dack@fluke.com**

***Abstract - The pushing forward of communications systems bandwidths and frequencies is forcing greater demands on the test equipment used in its development, testing, and support. The humble oscilloscope has become a sophisticated measuring instrument, with capabilities extending far beyond a simple display device, at bandwidths and sampling rates well into the GHz region. There is no sign of the trend letting up, and these increasingly critical scope applications are bringing with them greater need for oscilloscope calibration and increasing the technical complexity of providing the required calibration. Recent developments have introduced dedicated oscilloscope calibrators enabling those demands to easily be met in a cost effective manner. This paper presents a view of the future requirements for oscilloscope calibration and how they might be met.***

## INTRODUCTION

The market for Oscilloscope calibrators is not constrained to calibration laboratories alone. Product features and specifications are often tailored to cover a much broader market that encompasses requirements of the oscilloscope manufacture. Here demands on scope calibrator performance can be more stringent and may differ between various departments. For example oscilloscope design engineers are generally less interested in the fact that calibrators have multi-channel features but will place greater emphasis on jitter or inter-channel skew specification. On the other hand, scope Manufacturing test will have requirements for fast throughput where multi-channel and delay specifications are more critical parameters. Similarly associated Service departments and Calibration labs have their own specific requirements.

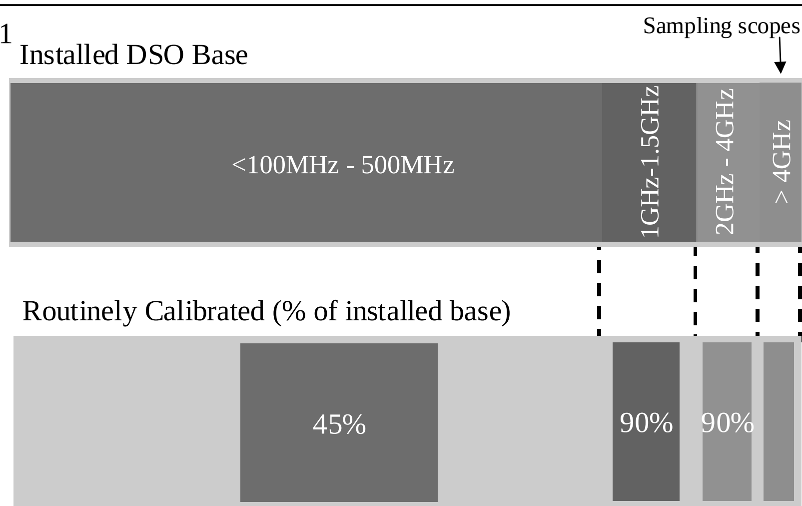
As a leading supplier of scope calibration hardware and associated control software it is important we understand the needs of each of the markets described above to ensure that we maintain pace with current trends. Most oscilloscopes on the design table today will require routine calibration at some point in the near future.

## MARKET INFLUENCES

The two main influences in oscilloscope design improvement during the past ten years are telecommunications and digital signal processing. Furthermore competition between scope manufacturers and the availability of improved technology scope design has evolved from the simple capture and display of signals to instrument that perform similar to complex signal analyzer.

From a calibration perspective general purpose oscilloscopes are historically used as visual indicators with little emphasis on accuracy, calibration or traceability. Our research indicates that scope accuracy has and will continue to improve. Increasing number of customers are investing in scope calibration equipment, to support this National laboratories are taking a keen interest in providing traceability for oscilloscope parameters. A familiar perspective is that of the oscilloscope installed base by bandwidth versus the percentage of each that might be routinely calibrated. It can be seen from figure 1 that the largest installed base of oscilloscopes fall into the <500MHz bandwidth. However only 45% of this class of oscilloscope is routinely calibrated.

Fig.1




## SCOPE TECHNOLOGY

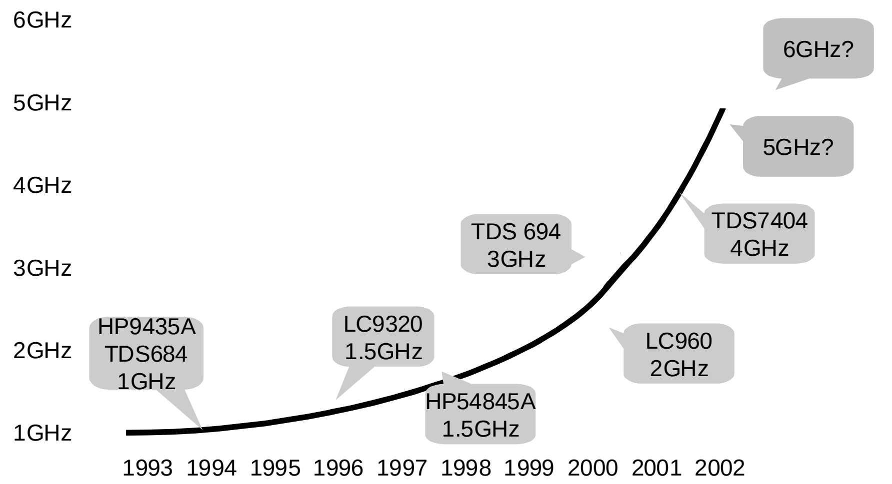
As clock speeds increase and timing margins decrease, engineers in the telecommunication and semiconductor industries have a greater need to measure critical signal characteristics. The demands placed on measuring instruments for this task have often been found lacking in performance and in some cases will contribute to the signal error.

Oscilloscope designers have benefited from the same technology that drives demand. This not only helps maintain pace with market but improves the performance of today's oscilloscopes. The key areas of improvements are:

- Sample rates/Bandwidth.
- Connectivity/Probes
- Trigger qualification.
- Long memory and Post signal processing.

Increased sample rates in the order of 20GS/s and bandwidths ranging from 1- 4GHz for mainstream scopes will increase demands calibration equipment. Figure 2 shows the introduction of oscilloscopes from leading manufacturers over the last ten years. If trends continue over the next two to three years 5 – 10GHz bandwidth scopes will be common place.

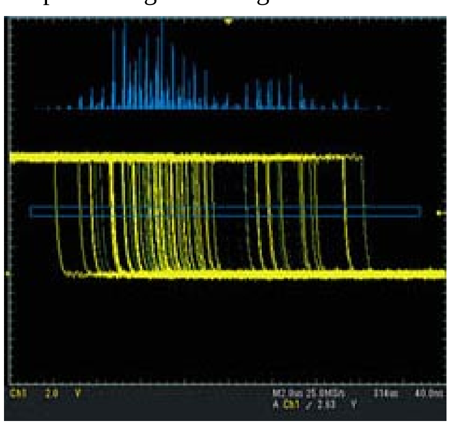
Fig.2




The overall measurement accuracy of scopes achieved by users will depend on a number of error contributions, scope design, probes and the ability to test or calibrate both scope and probe. The performance of high bandwidth scopes can be severely restricted if the wrong type of probe interface is used. It is for this reason scope manufacturers recommend the use of specialist probes. High bandwidth probes have low input capacitance (typically 0.5-0.7pf) to minimize UUT loading. Increasing bandwidth is often compromised by the probes dynamic range with peak to peak inputs rated at ±8V (<2.5GHz), reducing to ±1.75V (4GHz) as bandwidth increases. The same compromise impact calibrator design where the calibrated source signals pk-pk amplitude will reduce as bandwidth increase. There’s no point in designing a ±5V leveled sine signal to 4GHz if the calibration workload does not need it.

A challenge when using oscilloscopes as diagnostics tools within semiconductor test applications is to capture and thoroughly analyze large streams of data at greater speeds. There are techniques currently being employed by oscilloscopes today to achieve this. One technique is the use of large blocks of internal memory that stores results from a number of A/D conversions. This memory will allow the scope to sample signals over a longer period of time. Once captured in memory it’s possible to perform mathematical equations on the stored data to represent signal information to the display in a different format. An example might be to present jitter information using histograms to quantify the distribution of jitter. Figure 3 represents signal information being analyzed and presented in this manner.

Fig.3 Post processing of raw signal data.



It is for these reasons t esign to ensure high signal integrity during attenu

# NEED FOR CALIBRATION

The advent of more stringent quality standards bringing insistence on traceability for qualifying measurement systems emphasizes the need to calibrate oscilloscopes. Despite the burgeoning increase in oscilloscope functionality, the essential features of faithful and accurate representation remain few:

- Vertical Deflection
- Horizontal time
- Frequency response
- Trigger response

Added to these are additional sub-parameters normally associated with factoryadjustment:

- Inter-channel delay
- Jitter characteristics

Techniques and procedures for calibration must measure these parameters, while coping with the functional conditions that surround them. Good metrological practice must be used to ensure that the oscilloscope performance at the time of use is comparable with that observed and measured during calibration. This will provide confidence in certificates of traceability and documentation that result from calibration.

The following paragraphs review future trends by parameter to help gain better understanding of changing requirements placed on the calibration laboratory from a procedure or equipment perspective.

## Processes

Generally calibration procedures are clearly documented within the oscilloscopes support documentation. The documented calibration routines are sometimes supplemented with additional factory set parameters, however it's common practice with some scope suppliers to withhold this information. It is my understanding that most factory-set parameters generally don't change with time or temperature unless components or sub-assemblies are replace, this moves the responsibility to the Service operation.

In addition the ability to adjust often remains with the manufacturer of the oscilloscope, which in most cases are performed automatically using the oscilloscopes communications interface. I question if this trend will remain the soul responsibility of the supplier as oscilloscope vertical deflection accuracy's improve and bandwidths increase.

## Connectivity

Cables and probes used to interface with oscilloscopes bring with them their own error contributions. Not a big problem when dealing with low cost, low bandwidth scopes. However as scope performance improves probe and cable errors can dominate. Similarly calibration hardware used to test/calibrate the oscilloscope will have to improve to maintain adequate test margins. As a consequence it is recommended that use of specialist probes should be considered part of the measurement equipment and included during the calibration process.

Note: Some oscilloscopes use self-adjustment techniques to remove probe offset error contributions. If this process requires operator intervention then it should be completed prior to any calibration.

## Vertical Deflection

Oscilloscope trends indicate that single and two channel scopes were once the commonplace, we now find for scopes with bandwidths of 1GHz and above two or four channels minimum. Furthermore channel gain accuracy’s have improved from what was typically 1% to 0.3%. These trends will place greater demands on the calibration laboratory and as a consequence lengthen calibration times and reduce test margins between the scope and the calibrator.

## Rise-time/Aberration

Viewing the rise-time and associated aberrations of a pulse fast edge is one of the two complementary methods of measuring the response of the vertical channel to pulsed inputs (the amplifier’s bandwidth should also be measured). As scopes continue to increase in bandwidth greater emphasis will be placed on edge traceability to determine bandwidth. Not only is the use of known rising and falling edge faster than alternative test methods, it is also a better proves the scope ability to handle real-world digital signals.

Traditionally edge traceability and uncertainty was associated with edge speed alone, however as oscilloscope aberration specifications continue to improve greater knowledge of the calibrators edge characteristic is required. NIST is currently the only National Laboratory that has the ability (Note: The UK NPL are investing money to provide this service) to de-convolute a rising or falling edge to provide improved uncertainty for not only edge speed but also it’s aberrations. This knowledge is valuable when used to calibrate high bandwidth scopes.

## Trigger

Signal processing applications and associated increased bit rates drive improvement in oscilloscope trigger circuit design. Use of correct trigger technique enable test applications to run faster as well as provide better diagnostics information. Glitch, Slew and Runt trigger techniques are associated with the ability to filter signal data to present the operator with out of tolerance information much faster than before. These scope features will drive oscilloscope calibrator design to provide more versatile trigger sources. Furthermore the trigger jitter specification of your oscilloscope determines the amount of jitter you can expect the scopes triggering system to add to the device under test. It is therefore important that oscilloscope calibrators minimize jitter contribution (see Jitter Analysis).

## Jitter Analysis

As clock speeds increase and timing margins decrease, engineers in the communications and semi-conductor industries have greater need to measure jitter within their system. Jitter in a digital system may violate timing margins causing circuits to fail. Careful characterization of jitter will determine how close the system is to failing. The device under test and the oscilloscope will contribute to Jitter error, the key is knowing what is systematic to the scope design. Therefore knowledge of the scopes jitter performance is important. The scope specification can be broken down into systematic and random jitter. The robustness of scope design to jitter should be determined using a very stable oscilloscope calibrator. It could be argued that oscilloscope jitter characteristics would not change with time or temperature and is therefore a factory set-up. If scope jitter specification continue to improve future routine jitter verification will be a requirement.

## Inter-channel delay

Increased signal processing speeds continually challenge oscilloscope inter-channel delay specifications. Typical scopes are specified in the region of 10's of nanoseconds, with newer high bandwidth scopes, around the 100's of picoseconds. To achieve these specifications it's critical that transmission line lengths are matched, and that calibrated cable lengths and probes are used.

Just as critical is the ability to minimize or remove transmission line mismatch between one or more test/calibration signal sources. A common technique is to place the calibrated edge generator as close as possible to the scope input thus minimizing transmission line length. This technique can be further enhanced through the use of internal delay compensation within the scope or the calibrated source, this is often known as de-skew.

Calibration times will increase as a direct result of having more oscilloscope channels. Y deflection characterization on the whole is performed sequentially. In some areas such as inter-channel delay it would be advantageous to generate four or more calibrated/de-skewed signals simultaneously.

## Conclusions

Market demands will drive oscilloscope bandwidths higher with timing and amplitude characteristics continuing to improve. This will result in increasing demands on the calibration laboratory, not only to handle a greater workload and increasing number test parameters but must also maintain calibration equipment with adequate test margins.

High speed semi-conductor and signal processing applications will require improved measurement performance and better value oscilloscope design. Improvements in scope accuracy will reach a point where changes in external operating conditions will begin to affect performance. With this follows improvements in the supporting calibration equipment and traceability. We're already beginning to see greater investment within National laboratories to provide the necessary traceability, we would wish for this will continue.

As a leading supplier of oscilloscope calibrators it is our business to gain a better understanding of what drives the oscilloscope market. We must continue to work closely with leading scope manufacturers to ensure that the technical challenge that face them will also help us to provide the right support platform.

## References

[1] Developments in fully automated oscilloscope calibration to 3.2GHz – Paul Roberts/Mark Ashcroft, Fluke Precision Measurement.

[2] Oscilloscope connectivity made easy – Tektronix.

[3] Fully automated true bandwidth testing of high bandwidth scopes – Leveled Sine or Edge. Paul Roberts, Fluke Precision Measurement.