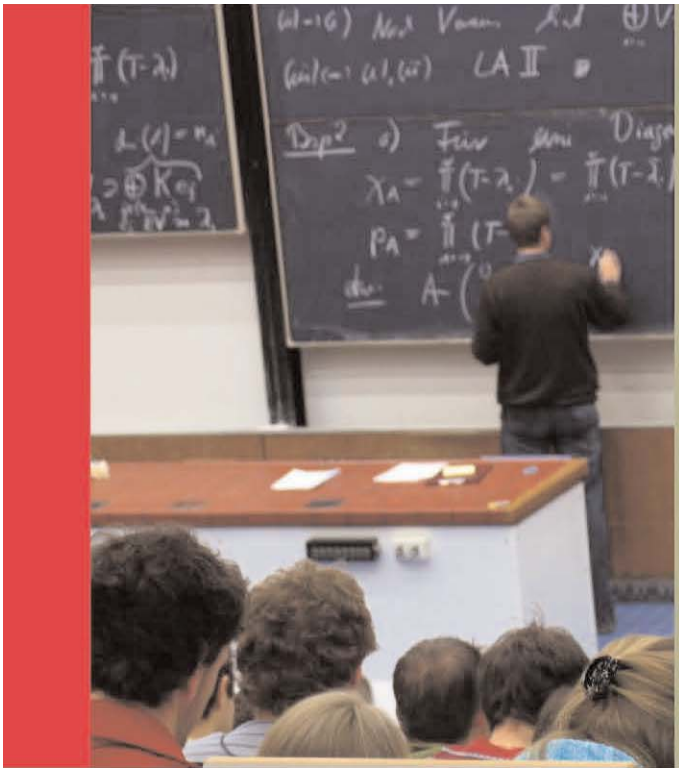

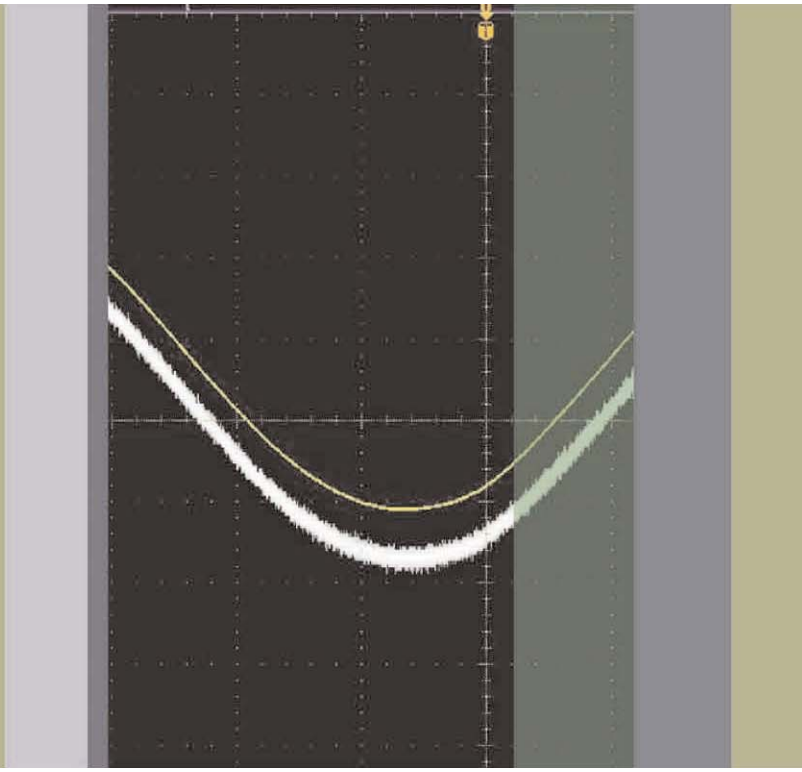

Oscilloscope Fundamentals

Tektronix®

PI 2009
Semiconductor Components v. Power Integrations
IPR2016-01600

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Introduction

Nature moves in the form of a sine wave, be it an ocean wave, earthquake, sonic boom, explosion, sound through air, or the natural frequency of a body in motion. Energy, vibrating particles and other invisible forces pervade our physical universe. Even light – part particle, part wave – has a fundamental frequency, which can be observed as color.

Sensors can convert these forces into electrical signals that you can observe and study with an oscilloscope. Oscilloscopes enable scientists, engineers, technicians, educators and others to "see" events that change over time.

Oscilloscopes are indispensable tools for anyone designing, manufacturing or repairing electronic equipment. In today's fast-paced world, engineers need the best tools available to solve their measurement challenges quickly and accurately. As the eyes of the engineer, oscilloscopes are the key to meeting today's demanding measurement challenges.

The usefulness of an oscilloscope is not limited to the world of electronics. With the proper **sensor**, an oscilloscope can measure all kinds of phenomena. A sensor is a device that creates an electrical signal in response to physical stimuli, such as sound, mechanical stress, pressure, light, or heat. A microphone is a sensor that converts sound into an electrical signal. Figure 1 shows an example of scientific data that can be gathered by an oscilloscope.

Oscilloscopes are used by everyone from physicists to television repair technicians. An automotive engineer uses an oscilloscope to correlate analog data from sensors with serial data from the engine control unit. A medical researcher uses an oscilloscope to measure brain waves. The possibilities are endless.

The concepts presented in this primer will provide you with a good starting point in understanding oscilloscope basics and operation.

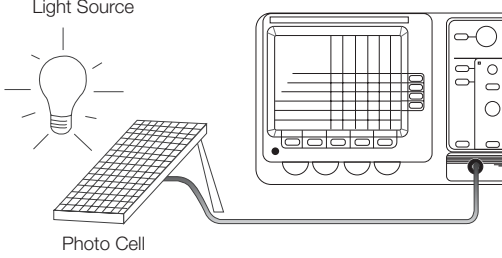

Figure 1. An example of scientific data gathered by an oscilloscope.

The glossary in the back of this primer will give you of unfamiliar terms. The vocabulary and multiple-ch written exercises on oscilloscope theory and contr this primer a useful classroom aid. No mathematica tronics knowledge is necessary.

After reading this primer, you will be able to:

- Describe how oscilloscopes work
- Describe the differences between analog, digital digital phosphor, and digital sampling oscilloscop
- Describe electrical waveform types
- Understand basic oscilloscope controls
- Take simple measurements

The manual provided with your oscilloscope will giv more specific information about how to use the osc in your work. Some oscilloscope manufacturers als a multitude of application notes to help you optimiz oscilloscope for your application-specific measurem

Should you need additional assistance, or have any comments or questions about the material in this p simply contact your Tektronix representative, or visi **www.tektronix.com**.

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The Significance of Signal Integrity

The key to any good oscilloscope system is its ability to accurately reconstruct a waveform – referred to as **signal integrity**. An oscilloscope is analogous to a camera that captures signal images that we can then observe and interpret. Two key issues lie at the heart of signal integrity.

- When you take a picture, is it an accurate picture of what actually happened?
- Is the picture clear or fuzzy?
- How many of those accurate pictures can you take per second?

Taken together, the different systems and performance capabilities of an oscilloscope contribute to its ability to deliver the highest signal integrity possible. Probes also affect the signal integrity of a measurement system.

Signal integrity impacts many electronic design disciplines. But until a few years ago, it wasn't much of a problem for digital designers. They could rely on their logic designs to act like the Boolean circuits they were. Noisy, indeterminate signals were something that occurred in high-speed designs – something for RF designers to worry about. Digital systems switched slowly and signals stabilized predictably.

Processor clock rates have since multiplied by orders of magnitude. Computer applications such as 3D graphics, video and server I/O demand vast bandwidth. Much of today's telecommunications equipment is digitally based, and similarly requires massive bandwidth. So too does digital high-definition TV. The current crop of microprocessor devices handles data at rates up to 2, 3 and even 5 GS/s (gigasamples per second), while some DDR3 memory devices use clocks in excess of 2 GHz as well as data signals with 35-ps rise times.

Importantly, speed increases have trickled down to the common IC devices used in automobiles, VCRs, and machine controllers, to name just a few applications. A processor running at a 20-MHz clock rate may well have signals with rise times similar to those of an 800-MHz processor. Designers have crossed a performance threshold that means, in effect, almost every design is a high-speed design.

Without some precautionary measures, high-speed problems can creep into otherwise conventional digital designs. If a circuit is experiencing intermittent failures, or if it encounters errors at voltage and temperature extremes, chances are there are some hidden signal integrity problems. These can affect time-to-market, product reliability, EMI compliance, and more. These high speed problems can also impact the integrity of a serial data stream in a system, requiring some method of correlating specific patterns in the data with the observed characteristics of high-speed waveforms.

Why is Signal Integrity a Problem?

Let's look at some of the specific causes of signal degradation in today's digital designs. Why are these problems so much more prevalent today than in years past?

The answer is speed. In the "slow old days," maintaining acceptable digital signal integrity meant paying attention to details like clock distribution, signal path design, noise margins, loading effects, transmission line effects, bus termination, decoupling and power distribution. All of these rules still apply, but…

Bus cycle times are up to a thousand times faster than they were 20 years ago! Transactions that once took microseconds are now measured in nanoseconds. To achieve this improvement, edge speeds too have accelerated: they are up to 100 times faster than those of two decades ago.

This is all well and good; however, certain physical realities have kept circuit board technology from keeping up the pace. The propagation time of inter-chip buses has remained almost unchanged over the decades. Geometries have shrunk, certainly, but there is still a need to provide circuit board real estate for IC devices, connectors, passive components, and of course, the bus traces themselves. This real estate adds up to distance, and distance means time – the enemy of speed.

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