Debugging Microcontroller-Based Designs

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Improving Hardware & Software Debug of Digital Systems Symposium

Abstract

If you design products based on 8- and 16-bit microcontrollers, this presentation will help you get your designs to market faster. This workshop includes extensive hands-on training using the latest tools and techniques to debug mixed analog and digital designs commonly found in microcontroller-based systems.

During the presentation, you will learn how to quickly capture and characterize mixed analog and digital signals using a mixed signal oscilloscope and an advance logic probe.

Even if you do not own (or plan to own) the products you will be using, we believe that this workshop will benefit you with tips on using your current scope and logic analyzers to ***debug microcontroller-based designs***.

Authors/Speakers

Johnnie Hancock

Current Activities:

Johnnie Hancock is a Marketing Program Manager for Hewlett-Packard's Electronic Measurements Division. He began his career with Hewlett-Packard in 1979 as an embedded hardware designer, and holds a patent for digital oscilloscope triggering. Johnnie has since held various positions in marketing including an international assignment to market oscilloscopes and logic analyzers in Asia. In his current position as program manager, Johnnie is responsible for developing sales of test instruments into the emerging mixed-signal, microcontroller-based design market.

Author Background:

Johnnie graduated from the University of South Florida with a degree in electrical engineering. In his spare time, he enjoys cross-country running and restoring his 19th century Victorian home.

Slide #01

Debugging Microcontroller-Based Designs

A hands-on waveform measurements workshop for designers of microcontroller-based systems.

Presented by: Hewlett-Packard Company
Electronic Measurements Division

Slide #02

Debugging MCU-Based Designs

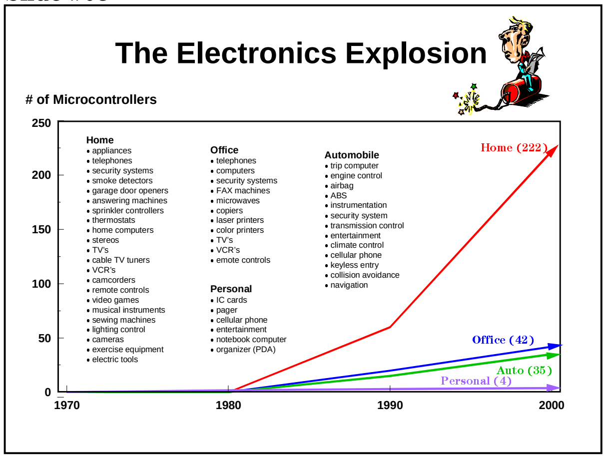
- The Electronic Explosion of the 90's
- Understanding the Measurement Needs of the Microcontroller-based System Designer
- MCU-Based Design Debug Labs
  - Lab #1: First-Level Hardware Debug
  - Lab #2: Monitoring MCU I/O Signals
  - Lab #3: Analyzing the PWM Output
  - Lab #4: Measuring the Power-Up Reset
  - Lab #5: Using FFT to Discover More about the Clock (Optional Lab)
  - Lab #6: Take the Challenge!
- Wrap-Up

Debugging Micocontroller-Based Designs

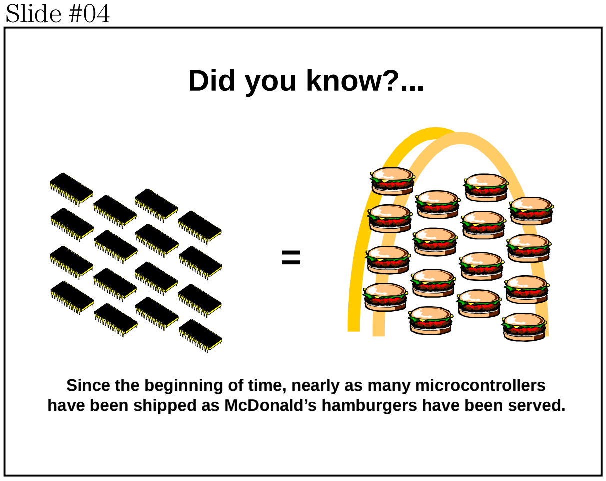
Welcome to Hewlett-Packard's workshop on "Debugging Microcontroller-Based Designs". We would like to share with you our latest innovations in helping you with the design, test, and debug of your 8- and 16-bit microcontroller-based designs. You are also encouraged to ask questions and share your insights with us. This workshop has been structured with a focus on letting you use the HP LogicDart and HP54645D mixed signal oscilloscope to quickly solve some common measurement problems associated with 8- and 16-bit microcontroller-based designs.

We will begin by sharing with you some insights Hewlett-Packard has discovered about an "explosion" in design and product technology based on microcontrollers. HP has done extensive market research in this field to better understand the measurement needs of designers of 8- and 16-bit microcontroller-based products. We will share with you our understanding of your unique measurement needs, as well as HP's unique solutions. But the focus of today's workshop will be to allow you to make real hands-on measurements on microcontroller-based designs. We will keep the lecturing to a minimum so that you can gain practical measurement experience today.

Slide #03



Slide #04

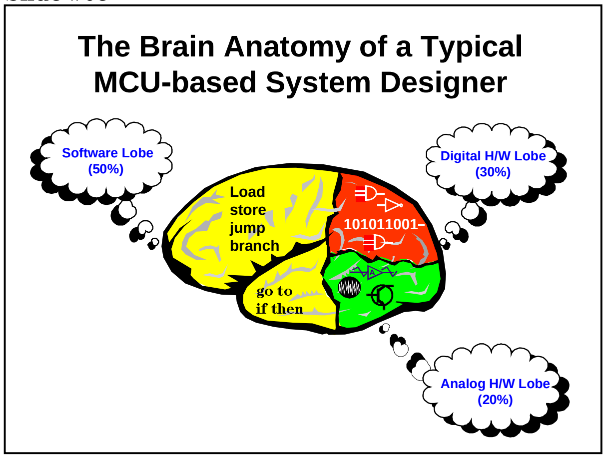


Microcontroller Explosion

How many of you are currently working on designs which include a microcontroller? If you're like most system designers, your design probably includes some type of microcontroller as its heart of control. Microcontroller shipments are growing at such a rate that even in their relatively short existence they've almost surpassed the total number of McDonald's hamburgers ever sold. That's a lot of burgers flipping off the grill - and that's a lot of microcontroller-based products shipping out of various plants around the world! In fact, did you know that the average person comes in contact with more microcontrollers than people on a daily basis. This explosion in the use of microcontrollers is led by the 8-bit version. These devices are used in almost every conceivable application from consumer products to automobiles to numerous industrial applications. And competitive forces are driving this trend to even broader usage.

The explosion in the use of microcontrollers has caught HP's attention. Obviously, we would like to capture a piece of this explosion by providing better test solutions for designers of 8- and 16-bit microcontroller-based designs. So we talked to thousands of designers like yourselves to better understand your unique designs, your work environment, and your particular measurement needs. And this is what we discovered ...

Slide #05



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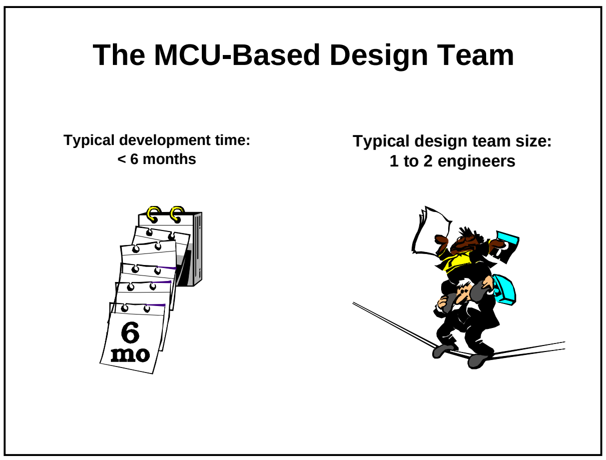
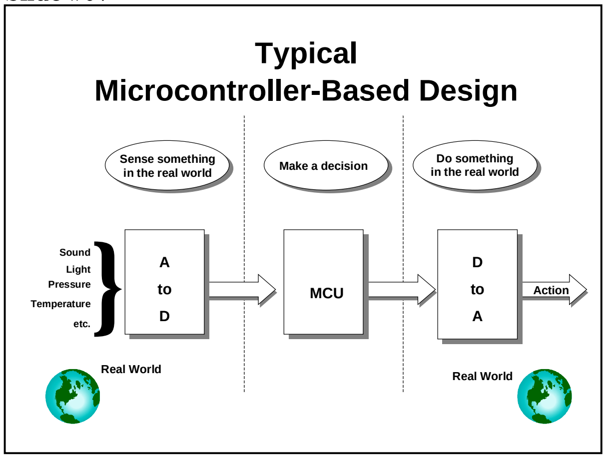


"I Am" the Design Team

If you're like most designers of 8- and 16-bit microcontroller-based products, your brain has just three lobes. Approximately half of your brain is consumed with software matter. In other words, you spend approximately half of your design and debug time focused on software issues. The other two lobes of your brain deal with hardware issues; both analog and digital. And of course your brain never has to deal with personal issues, such as family or hobbies, because you are always under a time crunch to get your design finished, and with very little help from others. The typical time-to-market for an 8-bit microcontroller-based design is less than 6 months. And the typical design team consist of just one or two designers. Often, YOU are the design team. You do it all: analog hardware development, digital hardware development, software development, maybe even marketing!

Slide #07



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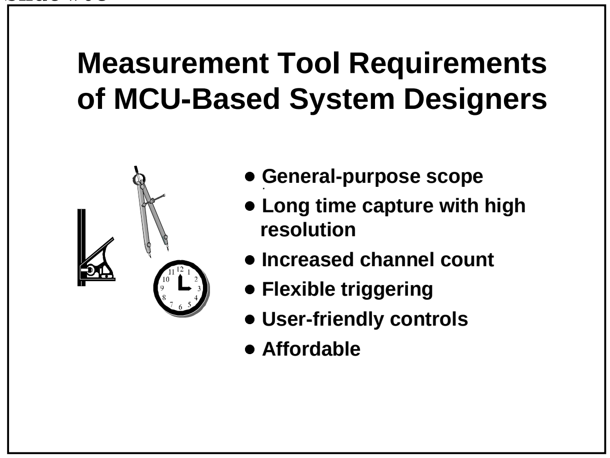


Typical Microcontroller-Based Design

To better understand your measurement needs, we needed to better understand your particular designs. We discovered that most 8- and 16-bit microcontroller-based designs consist of three major hardware blocks. Typically, MCU-based designs sense some type of real-world analog phenomena with sensors or transducers, convert to digital for processing or decision making by the microcontroller, and then convert back to analog for the purpose of taking some type of real-world analog action. The type of real-world analog phenomena we are talking about are actions such as: sound, movement, temperature, pressure, etc. All of these phenomena generate relatively low frequency analog signals. However, the MCU block may be clocking at several megahertz. This often creates a measurement problem for you. If you want to cross-coorelate the higher speed digital control signals with the lower speed analog action signals, how do you capture and view both at the same time? So we kept investigating and asking additional questions about your measurement needs, and this is what you told us . . .

Measurement Tool Requirements

First of all, you told us that you need a good general-purpose scope for most of your daily measurement needs. In fact, you told us that you prefer using a 2-channel analog scope because of its ease-of-use, display confidence, and lower cost.

Next, you informed us that in order to simultaneously capture and compare those relatively slow analog signals with the much faster digital control signals, you need "long time capture capability with high resolution". Hewlett-Packard interprets this to mean that you need an instrument with a relatively high sample rate and deep acquisition memory.

You also told us that even though you rely on the 2-channel scope, when it comes to testing microcontroller-based designs, the 2-channel scope was running out of steam in terms of number of channels and triggering capability. So we asked "why not just use a logic analyzer?" Your response to this question was: "No thanks!" Today's logic analyzers are too difficult to use and cost too much. A logic analyzer is typically "over-kill" in terms of the measurement power needed to troubleshoot a typical 8-bit microcontroller-based design.

Lastly, you told us that not only did you want all this measurement power, but that it had to be easy to use and not cost very much. Regardless of the potential measurement power that an instrument may possess, if a piece of test gear is found to be hard-to-use, then it just won't get used. And unfortunately for Hewlett-Packard, your budgets are very tight.

So you've given us quite a challenge. But we believe that we are up for it. So here is what we've come up with to meet the measurement demands of 8- and 16-bit microcontroller-based designers . . .

Slide #09

HP's Response to the Needs of the MCU-Based System Designer

The HP 54645D Mixed Signal Oscilloscope

- 2 Channels at 100 MHz
- 200 MSa/s sample rate
- 16 Logic timing channels --- seamlessly integrated
- Sophisticated triggering
- MegaZoom technology
  - Deep memory (1 Meg)
  - Responsive display and controls
  - Pan and zoom
- 5 ns peak detect
- Affordable

HP 54645D Mixed Signal Oscilloscope

HP's solution? We invented the world's first mixed signal oscilloscope. . . the HP 54645D. This product has won numerous product innovation awards and features:

- Sufficient bandwidth for most 8-bit and many 16-bit microcontroller designs
- 16 channels of logic timing analysis
- Sophisticated triggering that you can actually use
- Deep memory that's usable because of HP's exclusive MegaZoom technology

HP's mixed signal oscilloscope, or MSO, combines all of the benefits of a traditional scope, with some of the benefits of a logic analyzer. But remember, it's a scope first. It looks, feels, and runs very much like your familiar analog scope. And yes, we remembered about your tight budgets as well.

Slide #10

The Hewlett-Packard LogicDart

A handheld advanced logic probe for quick & easy turn-on and debug.

Logic Activity Indicator (LED/Beeper)

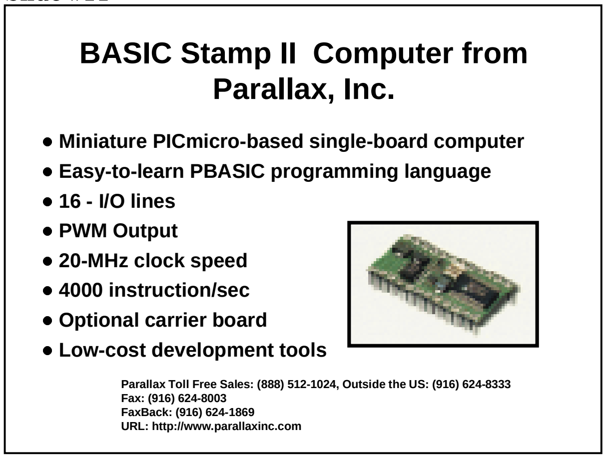
- Measures volts & frequency
- Resistance, Continuity & Diode tester
- 3 Channels of logic timing analysis
- Autoscale
- Flexible triggering
- Delta time cursor measurements
- New fine pitch probing system

The HP LogicDart

Hewlett-Packard's latest innovative product for the microcontroller-based system designer is the HP LogicDart. This new product is the world's most advanced logic probe. Like a conventional logic probe, this handheld instrument indicates logic signal activity with blinking LED's. But this instrument can also do a whole lot more to help you more quickly debug your designs. For instance, with the HP LogicDart, you can quickly verify your system's DC power supplies, you can measure the frequency of your system's clock, and you can even "see" up to three logic timing waveforms on the instrument's LCD display. In addition, this instrument can make some basic resistance, continuity, and diode measurements.

So let's begin using these powerful MCU-based design debug instruments in our hands-on labs!

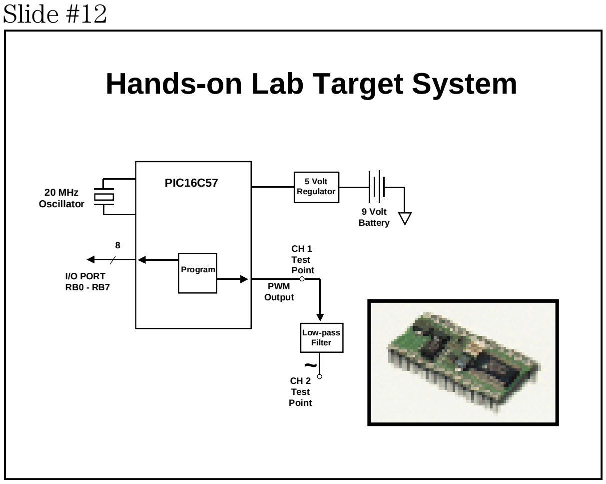
Slide #11



BASIC Stamp II Computer from Parallax, Inc.

For our four hands-on labs today, we are using the Parallax Basic Stamp II Computer as the device under test (D.U.T.). The BASIC Stamp II is a miniature microcontroller-based single board computer. If you are interested in possibly using this integrated control device in your future designs, you can contact Parallax yourself using the information that we have provided in your handout.

Slide #12

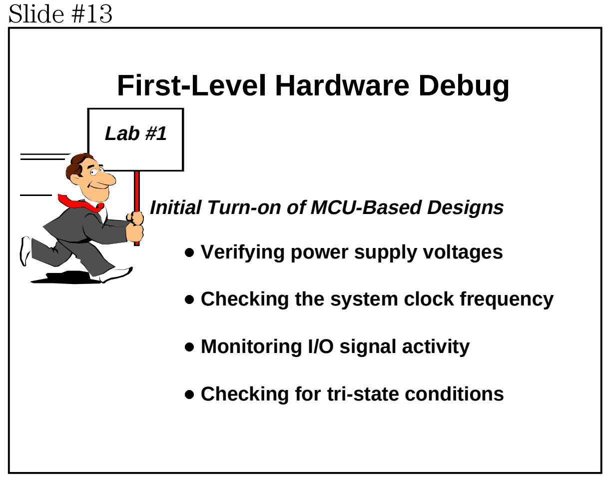


Hands-0n Lab Target System

We will initially use the HP LogicDart to verify proper operation of the power supplies, system clock, and check for logic signal activity at various nodes. We will then use the MSO to analyze the signal in more detail.

The scope's channel 1 input will monitor a complex burst signal generated by the MCU's PWM output. This signal is then run through a low-pass filter and will be probed at this point by the scope's channel 2 input. And finally, we will monitor the output of the MCU's I/O port using 8 logic channels of the MSO.

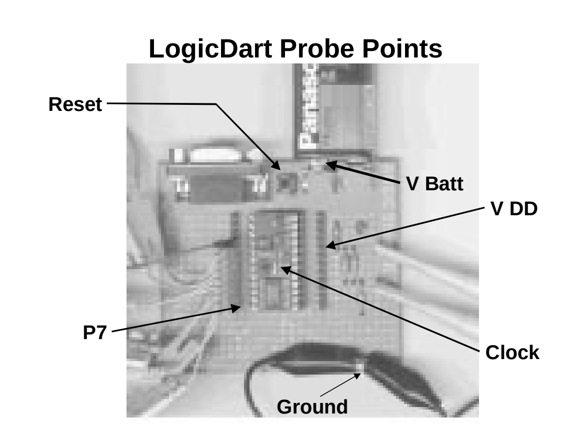
Slide #13



The main purpose of this lab is for you to become familiar with how to use the HP LogicDart to quickly perform first-level hardware debug. You will check power supply voltages, measure the system clock frequency, and then monitor various I/O signals for logic and tri-state activity.

Lab #1
First-Level Hardware Debug

Figure #01



Lab #1

1. Install a 9V battery in the BASIC Stamp II microcontroller board.

2. Press the **RESET** button on the microcontroller board. *(After 30 minutes, the BASIC Stamp II board will automatically power-down. Press reset again when this happens.)*

3. Connect probe (with browser) to CH1 socket on the LogicDart.

4. Connect the probe ground lead grabber to ground loop (Figure #01) near the bottom of the Stamp II board.

5. Press the LogicDart ON key

6. Press to select "Investigate" mode.

7. Measure the battery DC voltage.
V Batt = _________ .

8. Measure output level of voltage regulator at Vdd pin (figure #01). Vdd = ___________.

9. Measure the system clock frequency.
(Probe on left side of SMT capacitor.)
Clock freq = _____________

10. Does the LogicDart detect clock activity (blinking LED's)? ___________

11. Press Auto to view the system clock waveform.

12. Probe I/O pin P7 (at solder point on hybrid) and then press Auto to view waveform.
P7 freq = _____.

13. Probe the "red" test point and then press Auto. (Notice the tri-state display of this waveform.)

14. Press and to change TIME/DIV scaling of this display.

15. Press to move X marker to second rising edge. Period (X-O) = ________ .

16. While probing the red test point press SHIFT and then select **COMPARE** mode.

17. Select the NEW softkey and then press Auto to store a reference waveform in the compare register.

18. Press Single and note where the two waveforms differ as signified by the vertical bars.

19. Press SHIFT and then CONTINUOUS to view updated waveforms. Note the areas of difference.

20. Press Single to store waveforms on screen for analysis.

21. Press to select the DIODE/CONTINUITY modes.

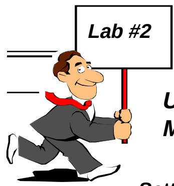
21. If DIODE mode appears on screen, press the CONT softkey.

22. Probe VSS. Is this pin shorted to ground?
______

21. Press System and then use and softkeys to change user preferred options.

Slide #14

Monitoring MCU-Based I/O Signals



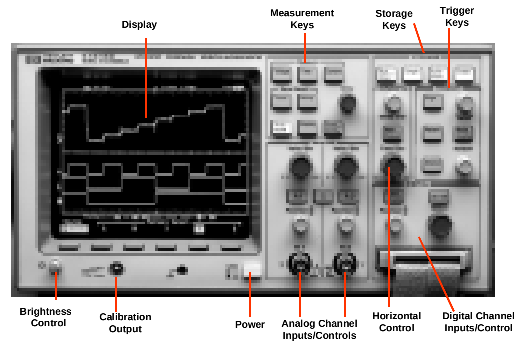
Unleasing the Power of a Mixed Signal Oscilloscope

- **Setting up the MSO to view 10 channels of microcontroller I/O signals**
- **Triggering on an RB port output word**

In this lab, you will begin using some powerful capabilities of HP's mixed signal oscilloscope to help you more efficiently debug your microcontroller-based designs. You will experience how easy it is to set up the scope to view multiple analog and digital I/O signals of an MCU-based design. And then using the scope's pattern trigger, you will synchronize the scope's acquisition and display on a unique output word of the MCU's I/O port.

Slide #15

HP 54645D Mixed Signal Oscilloscope Front Panel



HP 54645D Mixed Signal Oscilloscope Front Panel

Before we jump into the hands-on labs using the MSO, let's quickly review the front panel layout of the HP 54645D mixed signal oscilloscope. HP has done extensive research concerning the importance of front panel controls. Our customers have informed us that they want digital scopes that look and feel more like analog scopes. We believe that we have done a pretty good job with the 54600 series of scopes. As you can see from this front panel layout, there are 3 major blocks of controls which should look very familiar to you. In the "Analog" section, you can control the vertical scaling of your waveforms, just like you would with your analog scope. Each channel has its own independent set of controls. With this scope, we do NOT multiplex the channel 1 and channel 2 controls into a single set of controls, like some other DSO's on the market.

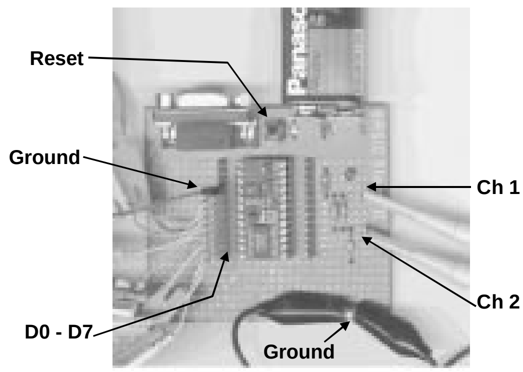
With the "Horizontal" section of controls, you can control the timebase scaling, just like the analog scope. And in the "Trigger" section, you can easily change the trigger level or holdoff, again, just like you would with your analog scope.

The other major blocks of this scope's front panel will allow you to control the digital inputs, as well as take advantage of the digital "power" of this instrument, such as making automatic parametric measurements or permanently storing waveforms and setups. During the next three hands-ons labs, you will get a chance to use some of this digital power. So let's begin our second lab.

Lab #2
Monitoring Microcontroller I/O Signals

Figure #02

MSO Probe Connections



A. Probing the MCU-Based System with the MSO

1. Install a 9V battery in the BASIC Stamp II microcontroller board.

2. Press the RESET button on the microcontroller board.
   (After 30 minutes, the BASIC Stamp II board will automatically power-down. Press reset again when this happens.)

3. Connect channel 1 probe to the "blue" test point (PWM output).

4. Connect channel 2 probe to the "red" test point (RC filtered output).

5. Connect both scope ground clips to the "large" loop test point.

6. Connect logic channels 0 through 7 to the pins label P0 through P7 (RB I/O port) respectively on the microcontroller board as shown in Figure #02.

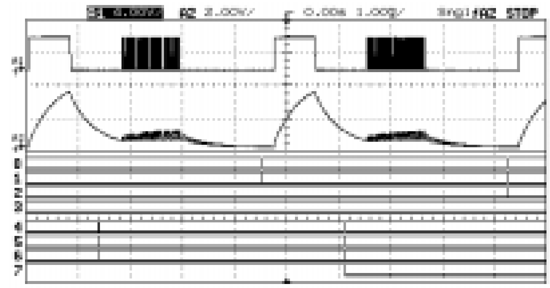
7. Connect the logic probe ground lead (black) to "VSS" on the microcontroller board.

8. Press [Setup] in the Save/Recall section of the oscilloscope front panel.

9. Select *Default Setup* using the menu softkeys under the screen.

Figure #03

Mixed-Signal Display



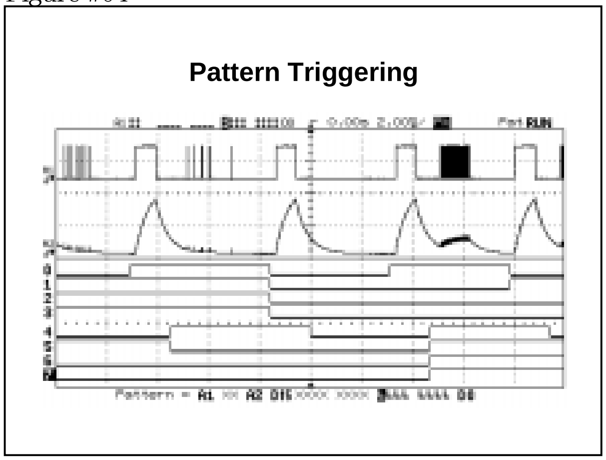
B. Setting Up The MSO For Mixed-Signal Measurements of an MCU-Based System

1. Press [Auto-Scale] to obtain a display similar to Figure #03.

2. Rotate Time/Div and Delay
   (Note the fast display update rate and responsiveness.)

3. Rotate Volts/Div and Position
   (Note how this scope operates similar to an analog scope.)

Figure #04



C. Triggering on a Unique Digital Pattern of the MCU's I/O Port

1. Press [Auto-Scale] again.

2. Change [Time/Div] to 2 ms/div.

3. Press [Mode Coupling] in the Trigger section of the front panel.

4. Select the *Normal* softkey.
   (Note: To trigger on a slow repeating trigger event, the *NORMAL* trigger mode must be selected to prevent auto-triggering.)

5. Press [Pattern] .

6. Rotate [Select] clockwise until the *Source* softkey indicates *D0 bit00*.

7. Press the *L* softkey.

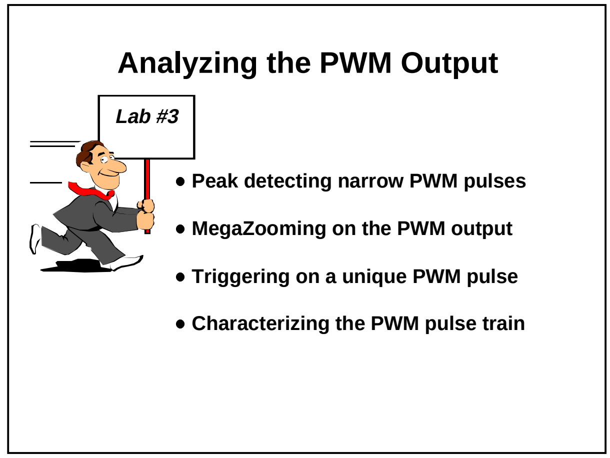
8. Rotate [Select] counter-clockwise until *Source* indicates *D1 bit01*.

9. Press the *L* softkey again.

10. Continue this process of entering all "lows" for bits D0 through D7 (Figure #04) until you have the following digital trigger pattern condition specified and have locked-on to the repeating digital pattern:

Pattern =
A1 XX A2 D15 XXXX XXXX LLLL LLLL D0

Slide #16



PWM outputs are often very complex waveforms. You will use the MSO's Peak Detect mode to more clearly view narrow pulses within the PWM output data stream. And then using HP's exclusive MegaZoom technology, you will experience for yourself how easy it is to "zoom-in" and analyze this complex serial output signal. You will then have an opportunity to use some of the scope's automatic measurements to characterize some of the pulses within the PWM output pulse train.

Lab #3: Analyzing the Microcontroller PWM Output

A. Using Peak Detect To See Narrow Pulses within the PWM Output of the MCU

1. With the MSO triggering on the I/O port as described in lab #2, notice the "apparent" intermittent pulses displayed on channel 1.

2. Press Display

3. Select *Peak Det* using the menu softkeys to more clearly see the narrow pulses and bursts on channel 1.

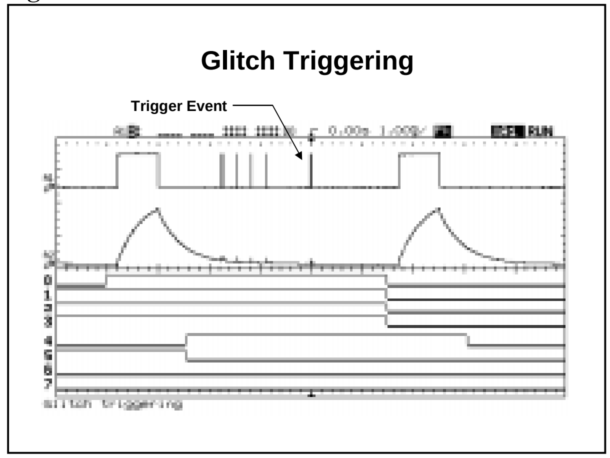
B. Using *MegaZoom* to Analyze Details of the MCU's PWM Serial Pulse Train Output

1. Press Run/Stop to "stop" the scope.

2. Use Delay and Time/Div to "pan" and "zoom-in" on the narrow pulses of the pulse width modulated (PWM) signal of channel 1.

(Hint: First use the Delay knob to position a pulse or burst at center-screen, then "zoom-in" using the Time/Div knob.)

Figure #05



C. Triggering on a Glitch within the PWM Output Signal

1. Press Auto-Scale

3. Press Advance in the Trigger section of the front panel.

4. Select *Glitch* using the menu softkeys.

5. Press the *Source* softkey until it indicates A1 scope1.

6. Press the *Polarity* softkey until it indicates: ⎍

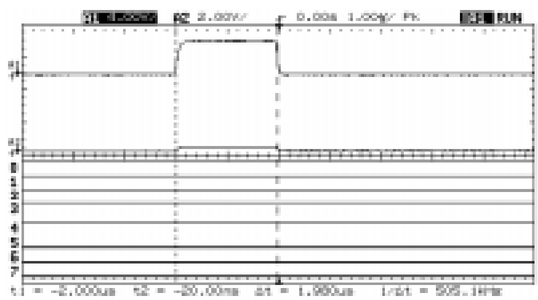
7. Press the *Qualifier* softkey until it indicates: <

8. Rotate Entry until the time qualification indicates: < 2.2 ms and your display looks similar to Figure #05.

9. Change Time/Div to 1.00 ms/div to more clearly observe the narrow pulse trigger event at center-screen.

Figure #06

Time Cursor Measurements



D. Making "Time" Cursor Measurements

1. Press Cursors

   in the "Measure" section of the front panel.

2. Rotate Entry

   to position the t1 cursor on the rising edge of channel 1 as shown in Figure #06.

3. Select *t2* using the menu softkeys.

3. Rotate Entry

   to position the t2 cursor on the falling edge of channel 1.

5. Channel 1 pulse width = __________

Figure #07

Voltage Cursor Measurements

E. Making "Voltage" Cursor Measurements

1. Select *V1* using the menu softkeys.

2. Rotate Entry

   to position the V1 cursor at the bottom of Channel 1 as shown in figure 07.

3. Select *V2* using the menu softkeys.

4. Rotate Entry

   to position the V2 cursor at the top of Channel 1.

5. Channel 1 Vp-p = _________ DV(A1)

(To measure voltages on channel 2, you must first select the Source as A2, then repeat the above procedure.)

F. Making "Digital" Cursor Measurements

1. Change Time/Div to 5.00 ms/div

2. Select *t1* using the menu softkeys.

3. Press the *Readout* menu softkey until it indicates *Binary*.

4. Rotate Entry to measure binary patterns along the digital waveforms.

5. What is the binary pattern at center-screen?

____

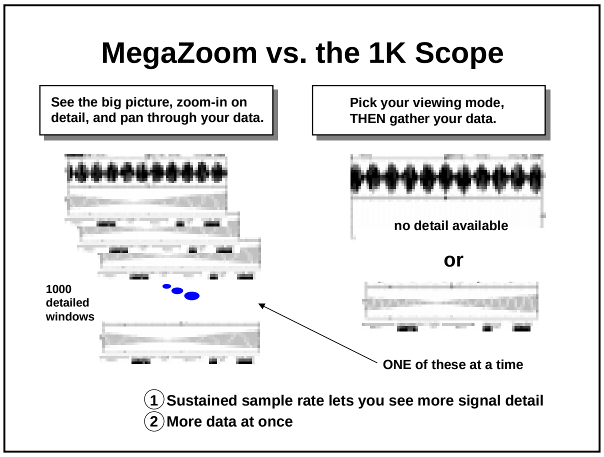
G. Making "Automatic" Parametric Measurements

1. Press Voltage in the "Measure" section of the front panel.

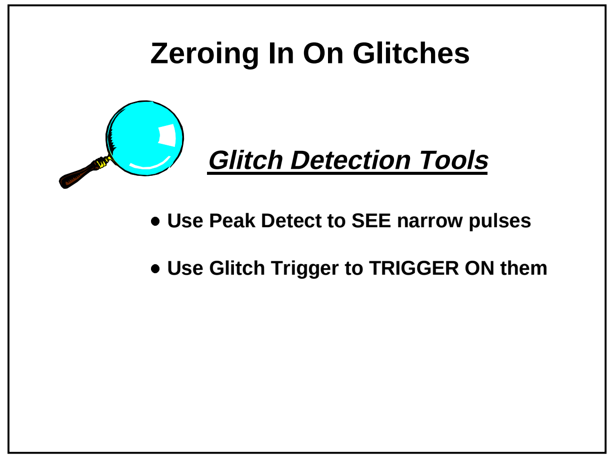
2. Select *Vp-p* using the menu softkeys. Vp-p = _______________.

3. Try a few other automatic parametric measurements.

Slide #17



Slide #18



MegaZoom vs. the 1K Scope

What did you think? Were you expecting that dealing with 1 M of acquisition memory would be difficult and slow? With HP's exclusive MegaZoom technology, we believe that we have made using the deep memory in this scope to be effortless and painless. And being able to capture and view the "big" picture along with the "detailed" picture can often simplify the task of correlating fast digital control signals with the typically much slower analog action signals. In addition, just having the ability to capture a long trace can often help you debug elusive design problems.

If you compare MegaZoom technology to a traditional scope's acquisition, the results have pretty dramatic implications for the amount of time saved trying to analyze a problem. Using a 200 MSa/s maximum sample rate, the digitized points are 5 ns apart. With the HP 54645D mixed signal oscilloscope and its 1 Meg of memory you can display 5 ns times 1,000,000 points or 5 ms of waveform information from a single-shot acquisition.

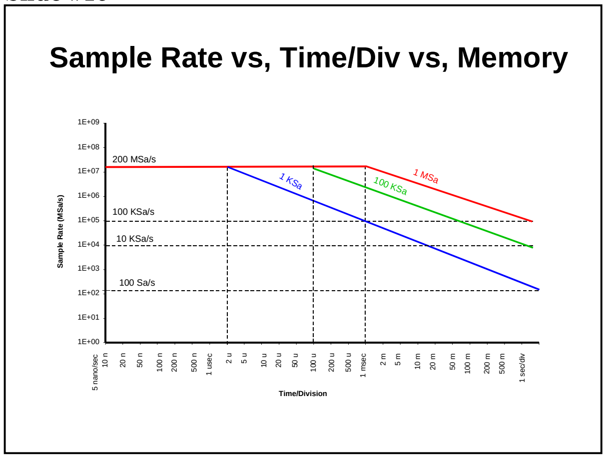
Contrast this with a typical 1K memory scope where you get 5 ns times 1,000 points, or only 5 µs of information at the detailed level. Or you can choose to scale the shallow memory scope to capture and view the "big" picture, but with lost waveform detail because of a reduced sample rate. But you can't get both pictures simultaneously as you can with MegaZoom. With MegaZoom, you can capture 1000 times the waveform information of a 1 k scope.

Zeroing In On Glitches

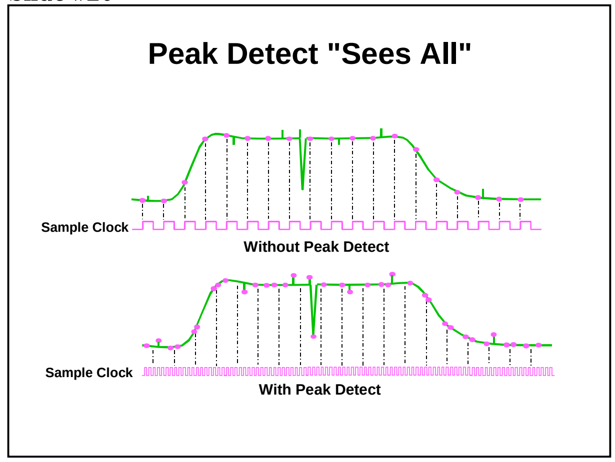
You've come face to face with some of the issues involved in using measurement tools to get a clear picture of what's going on in your design. If we define a glitch as any unwanted narrow pulse that has the ability to cause unwanted operation in the system under test, it can be important to know how to track one down.

Let's take a closer look at the techniques for zeroing-in on narrow pulses: peak detect and glitch trigger. Peak detect lets you SEE the narrow pulse on the display because it uses more information about what occurs between sample clocks to reconstruct the waveform. And glitch triggering allows you to TRIGGER ON an unwanted pulse to determine when it's happening and what might be causing it.

Slide #19



Slide #20



Sample Rate vs., Time/Div vs., Memory

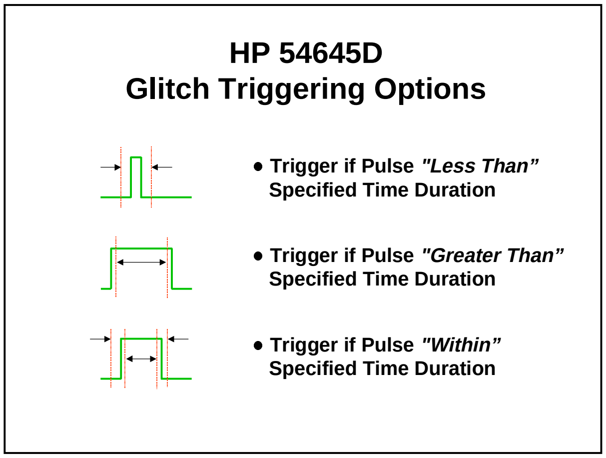
First of all, let's discuss why the Peak Detect mode is necessary in order to view narrow pulses. As this graph shows, there is a direct relationship between a digital scopes sample rate and timebase setting. Because all scope's have a limited amount of memory, they will automatically reduce their sample rate if a long timebase setting is selected by the user. But when the scope's sample rate is reduced, narrow pulses can be missed. One way to solve this problem is to increase the memory depth of the scope. As you can see from the graph, the HP 54645D's 1 MB of memory allows this scope to maintain its maximum sample for much longer than most DSOs. But even this scope must reduce its sample rate when very slow ranges are selected. Another solution to this problem is to use the scope's *Peak Detect* mode.

Peak Detect Display Mode

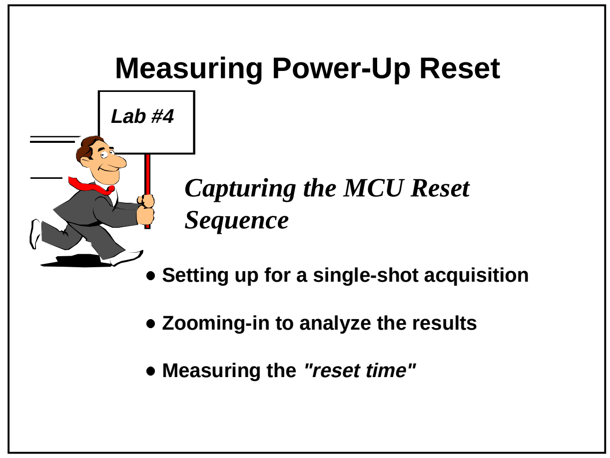
In the *Normal* display mode the HP 54645D mixed signal oscilloscope will display its digitized waveform using only the sampled value at each sample point to form a picture of the signal. All digitizing scopes have memory limitations-i.e. there are only so many time "buckets" to fill with information (yes, limits exist even with 1 M of memory!). As a result, information can be "missed" between samples.

In the Peak Detect display mode, the "missed" information is collected by having the sampler always run at maximum speed (200 MSa/s), but only store the min and max excursion values for each time "bucket." In other words, rather than storing all samples, in the Peak Detect mode the scope selectively stores the most important waveform information. This information is then used in developing a better picture of the waveform. By the way, these narrow pulses are often completely invisible on traditional analog scopes, so this is one advantage of the digitizing technology.

Slide #21



Slide #22



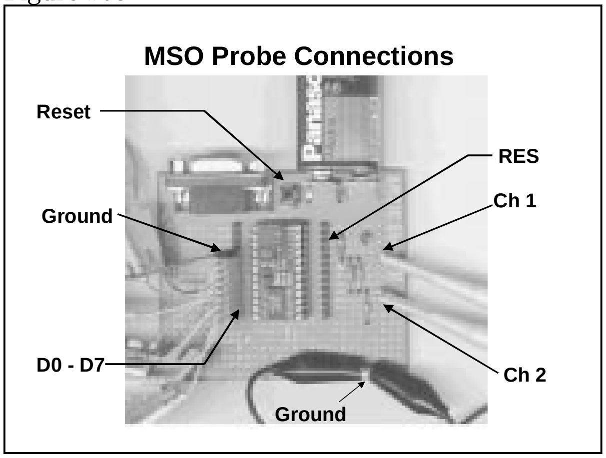
HP 54645D Glitch Triggering Options

Peak Detect is very powerful for viewing glitches and narrow pulses. But what if the glitch is intermittent? Triggering on the narrow pulse may be the right choice. The HP 54645D mixed signal oscilloscope allows you to trigger on pulses which last for "less than" a specified amount of time. Sometimes pulses can be too wide and cause problems. If this is the case, you can specify for the scope to trigger if it detects a "greater than" time violation. You can also specify a time range. This can be very useful if you are attempting to synchronize the scope of a unique pulse.

Now that you are familiar with the basic use of this scope, let's try a very practical hands-on lab. In this lab you will set up the scope to take a single-shot acquisition of the power-up cycle of the target system. You will then use MegaZoom to "zoom-in" and measure the system's reset time.

Lab #4 -
Measuring Power-Up Reset

Figure #08



1. To begin this lab, scope probes must be connected as described at the beginning of lab #2,.
and as shown in figure #08 above

2. Press [Auto-Scale] .

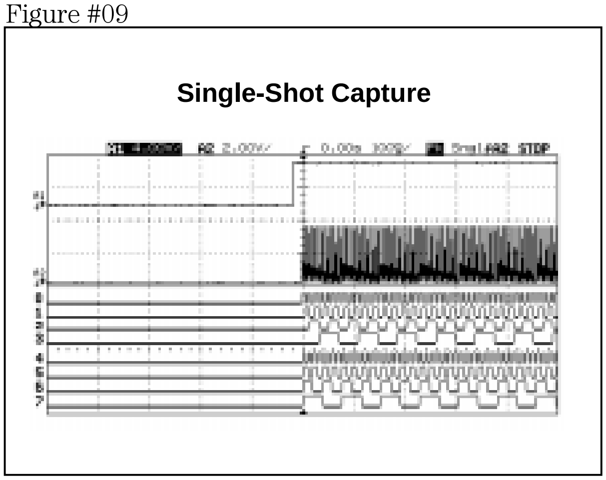
(Note: It is important that you perform this step before moving the channel 1 probe.)

3. Set [Time/Div] at 100 ms/div.

4. Move Channel 1 (A1) probe to the pin labeled RES on the demo board as shown in Figure 8. *(Note: Do NOT press Autoscale again.)*

5. Press [Mode Coupling] in the "Trigger" section of the front panel.

Figure #09



6. Select *Normal* trigger mode using the menu softkeys.

(To capture true single-shot events, you must use the Normal trigger mode.)

7. Press the *Reset* switch on the demo board and hold it down. (LED will extinguish)

8. Press [Single] on the scope while the Reset switch is depressed.

(The scope should now be setup to take a single acquisition on the next trigger event.)

9. Release the *Reset* switch on the training board.

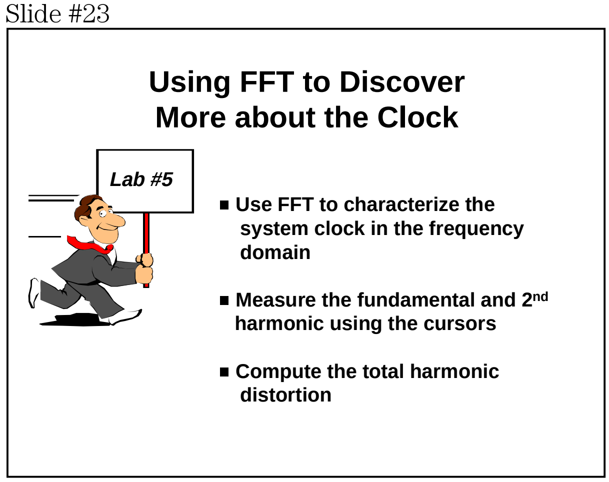
(The LED will light up and the scope will take a single acquisition of the reset sequence of the demo board and your display should look similar to Figure #09.)

10. Rotate [Time/Div] both directions to "zoom-in" and "zoom-out" on the stored waveform.

11. Rotate [Delay] both directions to "pan" left and right through the stored waveform.

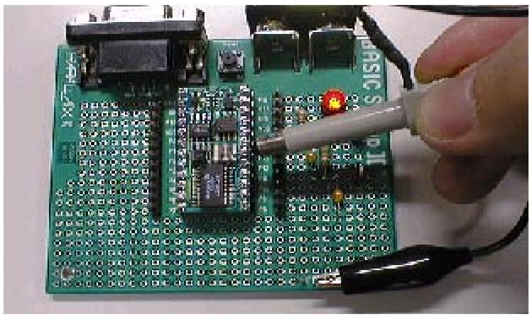
12. Measure the time from when the reset line (channel 1) goes high until the analog signal (channel 2) begins switching on channel 2.
Reset Time = ____________

Slide #23



Lab #5
Using FFT to Discover More about the Clock

Figure #10



This lab requires an optional HP 54659B module. This module has been installed at the back of the MSO.

1. Press [Setup] in the Save/Recall section of the oscilloscope front panel.

2. Select *Default Setup* using the menu softkeys under the screen.

3. Disconnect all the probes and digital channels from the demo board.

4. Connect probe ground lead grabber to the ground loop near the bottom of the demo board.

5. Remove the hook tip from channel A1 probe.

6. Use the probe tip to contact the right side of the white SMT capacitor.

7. Press [Auto-Scale] to observe the signal.

8. Press [Run Stop] to stop the scope.

   Now you can remove the probe tip from the SMT capacitor. Restore the hook tip back to channel A1 probe.

9. Do you think the signal is a pure sine wave?

____

10. Press [Time] in the "Measure" section.

11. Select *Freq* in the softkey menu. What is the frequency of the signal? __________

12. Press [+ -] in the "Analog" section.

13. Select *On* under Function 2.

14. Select *Menu* under Function 2.

15. Press Operation softkey until it shows FFT.

16. Press *FFT Menu* softkey. Press Autoscale FFT softkey.

17. Change [Time/Div] to 200 ns/div .

18. Press [A1] two times, in the "Analog" section to turn off the time domain display.

    Now you are seeing the frequency spectrum of the signal.

19. Press [Cursors] in the "Measure" section of the front panel.

20. Select *Find Peaks* of the softkey menu.

    Record f1(F2) = ________ This is the fundamental frequency of the signal.

    Record f2(F2) = ________ This is the 2nd harmonics of the signal.

    Now it is clear that this signal is not a pure sine wave.

Further interests:

If time is allowed, find out
1) the total harmonic distortion THD of the signal, and
2) the dynamic range of the MSO.

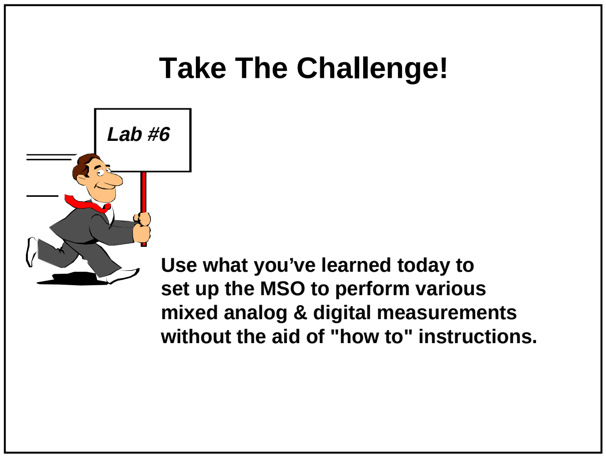
hints: 1) total harmonic distortion

$$THD = \frac{\sqrt{\sum v_i^2}}{v_f} \times 100\%$$

where Vi = rms value of ith harmonic
Vf = rms value of fundamental

2) dynamic range = the difference (in dB) between the largest signal and the noise floor

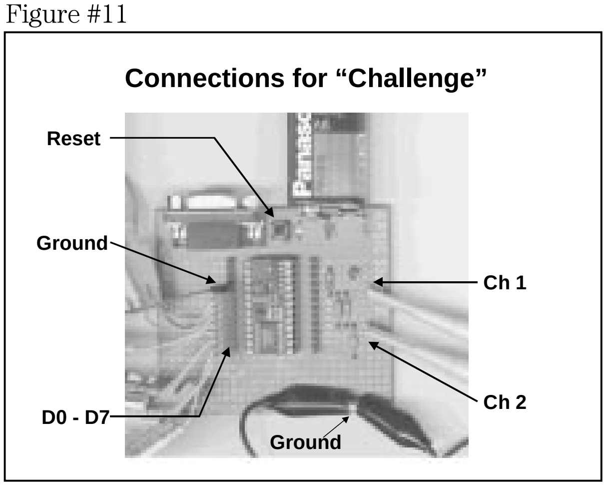
Slide #24



In this lab, we are challenging you to perform various set ups and measurements using the HP 54645D without the aid of detailed "how to" instructions as in the first four labs. Use what you've learned today to make these measurements. Good luck!

Lab #6
Take The Challenge!

Figure #11



Reconnect all probes as outlined in Lab #2 as shown in Figure #11, and then perform the following set ups and mixed-signal measurements using the HP 54645D mixed signal oscilloscope:

1. Set up the scope to trigger on the longest zero time of the MCU's PWM output. (Hint: treat it as a wide negative glitch.)

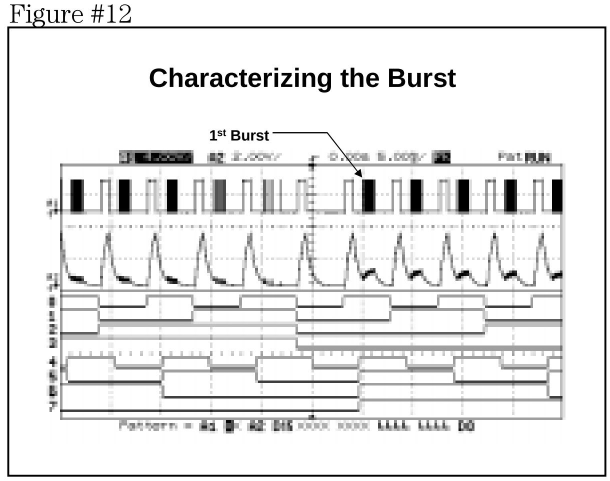
2. What trigger condition did you specify?

____

3. Measure the PWM Cycle Time.
   (Hint: How often does the PWM signal repeat on channel 1? This is also the execution time of the MCU's firmware program.) PWM Cycle Time =

   ____

Figure #12



4. What is the digital binary pattern of digital inputs (D0 - D7) during the 1st burst after the trigger event (fig 11) ?__________

5. Set up the scope to trigger during this PWM burst.

6. What trigger condition did you specify?

____

7. What is the duty cycle of most of the pulses during this burst? (Hint: Zoom-in on the burst)

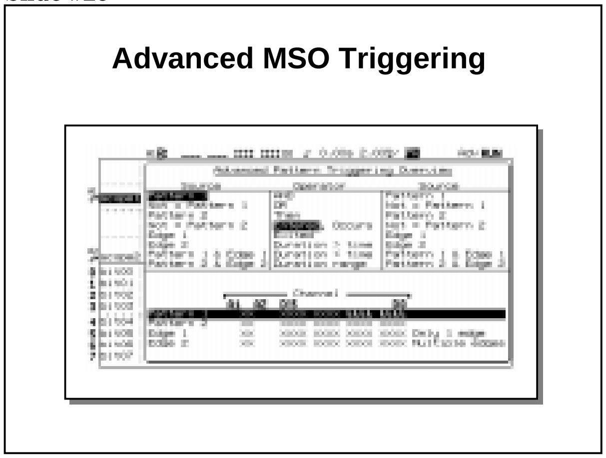
____

8. Fully characterize the last pulse of this burst to determine the following parameters:

   Pulse Width = _______
   Rise Time = _______
   Fall Time = ______
   Vp-p = ________

9. Assign labels to the MSO inputs using the default labels (PWM & RB*) found in the LABELS menu.

Slide #25



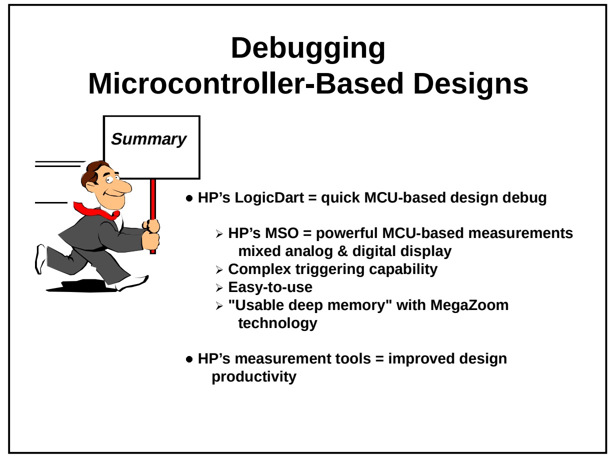
Advanced Pattern Trigger

In today's four MSO hands-on labs, you only touched the surface in terms of using the full power of HP's mixed signal oscilloscope. Besides triggering on patterns and glitches, you can also set up the scope to trigger on a sequence of events, or even a time duration of a pattern.

In additional to more advanced triggering, this scope also has more advanced measurements that you did not exercise today. With the optional Measurement/Storage I/O module, this scope can perform FFT measurements, as well as automatic pass/fail mask testing.

If you are interested in obtaining additional information about this scope, as well as other test & measurement products, talk to a Hewlett-Packard representative.

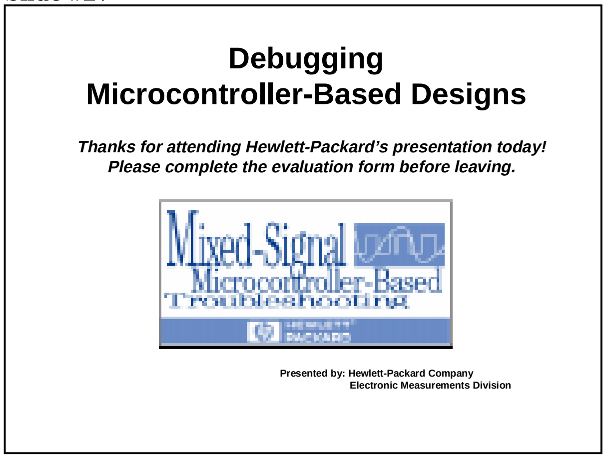
Slide #26



Workshop Summary

In today's hands-on workshop you had the opportunity to use HP's LogicDart to quickly verify functional operation of a microcontroller-based design. You then used HP's mixed signal oscilloscope to view and analyze a complex combination of mixed analog and digital signals using "pattern" and "glitch" triggering, and HP's exclusive MegaZoom technology. We hope that you found that Hewlett-Packard's MSO is not only be a very powerful instrument, but is also a relatively easy and intuitive piece of gear to use. We believe that HP's new line of instrumentation for the microcontroller-based designer will improve your debug productivity and enable you to get your products to market faster.

Slide #27



We hope you've enjoyed your hands-on adventure today with the world's only Mixed Signal Oscilloscope and the world's most advanced handheld logic probe. Thank you for participating and sharing your thoughts with us. We invite you to give us further input by completing the workshop survey. Because Hewlett-Packard is committed to an on-going process of product improvements to better meet your measurement needs, we need and appreciate your honest feedback.