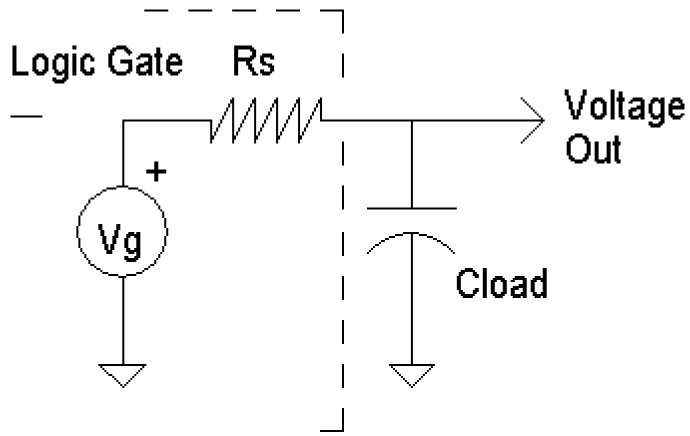
Using the 7200A/7242Bs to measure digital logic

Most books will use 0.35 / fBW = Trise for the conversion from the 3dB bandwidth to rise time. � Where does this conversion come from?�

Let's start by looking at a digital circuit. A digital device's maximum frequency is dictated by its rise and fall times. The rise time is the time it takes to transition from a stable low logic level to a stable high level. The fall time is the time it takes to transition from a stable high logic level to a stable low level. For CMOS type logic, the rise time is roughly equal to the driver output resistance times the output load capacitance. For ECL type logic, the rise time is determined by the equivalent emitter series resistance and the capacitive load. For the fall time it is the pull down resistor and the load capacitance. As a general rule we can model the logic device's output as a voltage source with an internal resistance which is connected to an equivalent load capacitance, which is shown in the following circuit.




The remainder of my report is based on the general idea that the rise and fall times will follow an exponential curve for all digital devices. As we increase load capacitance, the rise times increase. So, my idea on this is only for a given family of logic, when connected to an input of the same logic family.

Logic input thresholds are the voltage at which a logic device detects as a low or high logic level. Using the threshold limits represent the voltage as a "1" or "0" over a guaranteed operating range of a logic device. An approximation of the rise and fall times depicts them as linear ramps that change at a constant rate from one digital level to the next. The most common limits to use are two symmetrical intermediate points on the ramp like 10% - 90%, that will always fall within the guaranteed voltage ranges for high or low when connected to an input of the same logic family.

The voltage across the capacitor at any instant of time is described by the following equation:

VC(T) = E(1 - e^(-T/RC))

Tau (*t*) is used to define one time constant where

*t* = RC

�

VC(T) = E(1 - e^(-T/*t*))

| Time Constant | 1-e^-x |
|---|---|
| 0 | 0 |
| 1 | 0.6321 |
| 2 | 0.8647 |
| 3 | 0.9502 |
| 4 | 0.9817 |
| 5 | 0.9933 |
| 6 | 0.9975 |

TABLE 1

Next let's look at how a typical oscilloscope is specified. The Decibel, or dB, is a relative power unit. When the impedance for both points is the same, the following formula may be used for voltage ratios:

dB = 20 log (V2/V1)

Oscilloscope's are commonly rated by their -3dB analog bandwidth. This is defined as the frequency of a sinusoidal voltage that will display with its magnitude decreased by 1?2. Because the digital rise time is modeled as a simple RC filter, under sinusoidal excitation, the RC circuit has a -3dB corner low-pass frequency FC and a magnitude response given by:

$F_C = 1/(2\pi RC)$

$t = RC$

$t = 1/(2\pi\ F_{C)} = 0.15916 / F_C$

The question now is how do we find the transition time when all we know is the low-pass corner frequency? From table 1 it appears that we may use an approximation between t0 and t3. Using the time it takes for the logic gate to transition from 10% to 90%, we get time constant values of 0.10535 and 2.3025. So:

�$\Delta t(10\% - 90\%) = 2.3025t - 0.10535t = 2.197t$

Substituting

$t = 0.15916 / F_C$

$0.34966 / F_C$

Example:

The LeCroy 7242 has a fBW of 500MHz. The error caused by the oscilloscope alone would be 0.35/500MHz or 700pS. If we know this, and we know the error caused by the probe, we can calculate the actual rise time as follows:

TriseTOTAL = �(TriseSCOPE2 + TrisePROBE2 + TriseDIGITAL2)

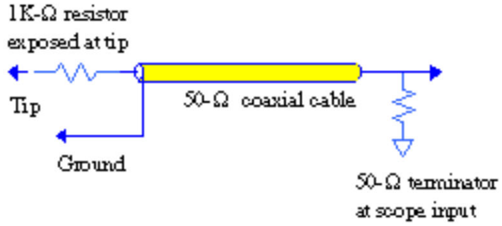
When selecting the 10Meg inputs of the 7242B, the bandwidth is limited to about 250MHz.� For digital circuits, it is better to just use a length of RG174/U with a series resistor.� The following picture shows two of my home made 20x probes using a 950Ω carbon resistor in the tip.� Normally I would solder these to the pins I am trying to look at.� If you build your own, keep in mind that you want to keep the total tip length as short as possible.

A great book to read is HIGH-SPEED DIGITAL DESIGN A Handbook of Black Magic.�

See *High-Speed Digital Design*, *H.W. Johnson and M. Graham, Prentice-Hall, 1993.*

The following was a cut and paste from http://www.signalintegrity.com website:

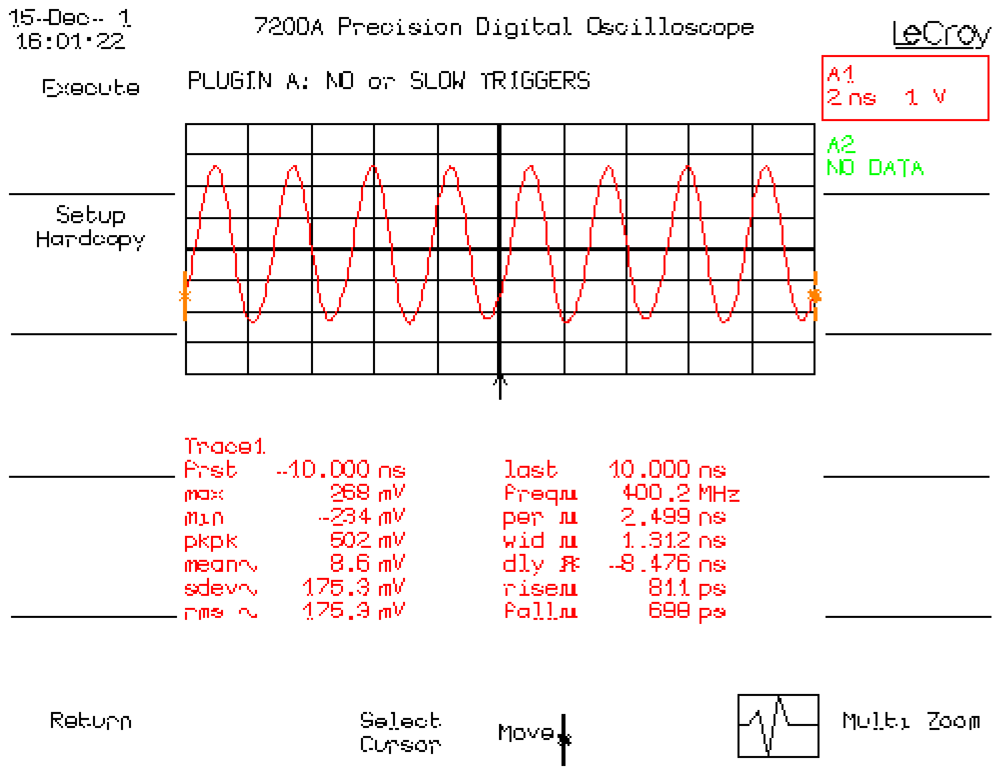
The resistive-input probe is an entirely passive device. That means that it will work with practically any scope. Like the FET-input probe, the resistive-input probe makes optimal use of its 50-ohm connecting cable. Once the input signal is coupled into the cable, it flows in a linear, time-invariant, almost lossless, and practically distortionless fashion all the way to the scope input termination, where reflections are damped. The scope must be set for a 50-ohm termination.



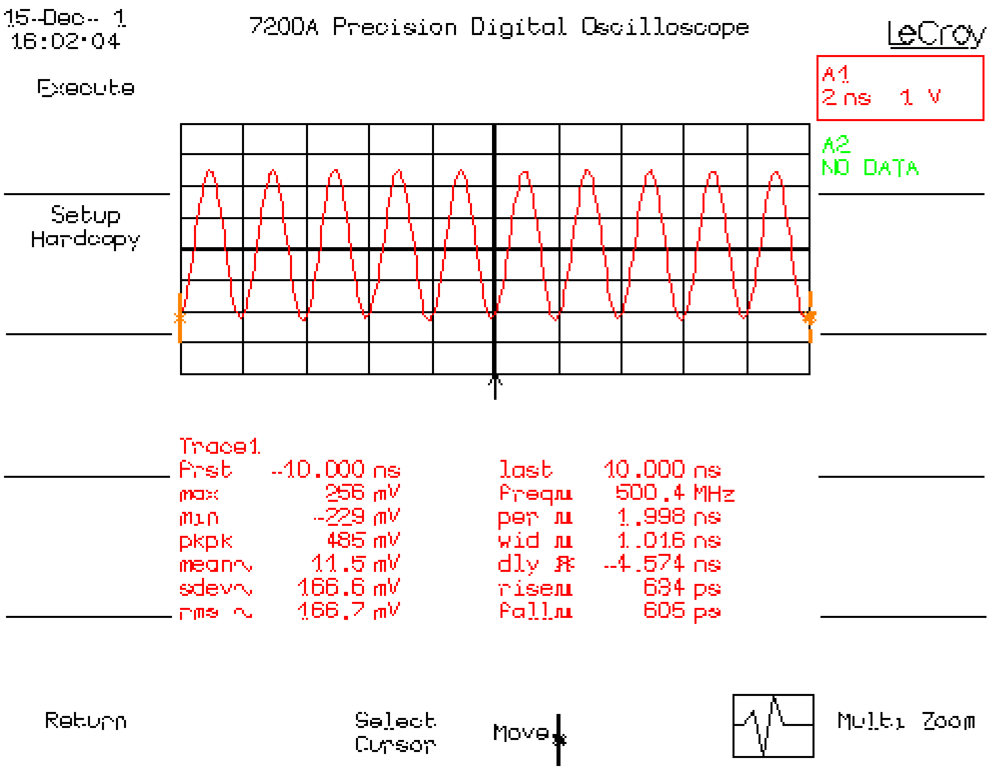

The resistive-input probe is cheap, it has a terrific bandwidth, and it is more tolerant of long ground wires than the other probes. These advantages come at the cost of higher $I_{OH}$ required in your digital circuits in order to drive the 1K resistor. In modern high-speed systems, the extra drive current is almost always readily available.

So, the question is how fast is the 7242 anyway?� Do you think it's 500MHz like the manufacturer rates it for?� To determine the -3dB point we need to sweep the input of the oscilloscope.� Part of the problem is that the coax and generator will cause an error in the measurement.� During the tests, I used a calibrated HP8640B signal generator.� This is a remarkable unit for it's age.� It will hold +/-0.5dB over the entire operating range!� I used a calibrated length of coax for the tests using an HP watt meter to manually plot the response.�

I found both of my 7242B-L1-F2s to be very flat up to about 400MHz.� In the following we can see the 400MHz 0.5V p-p signal being measured. The -3dB point is the frequency at which the input reads 1/SQRT(2)* 0.5 or 0.707 * 0.5 or 0.3535 Volts.��



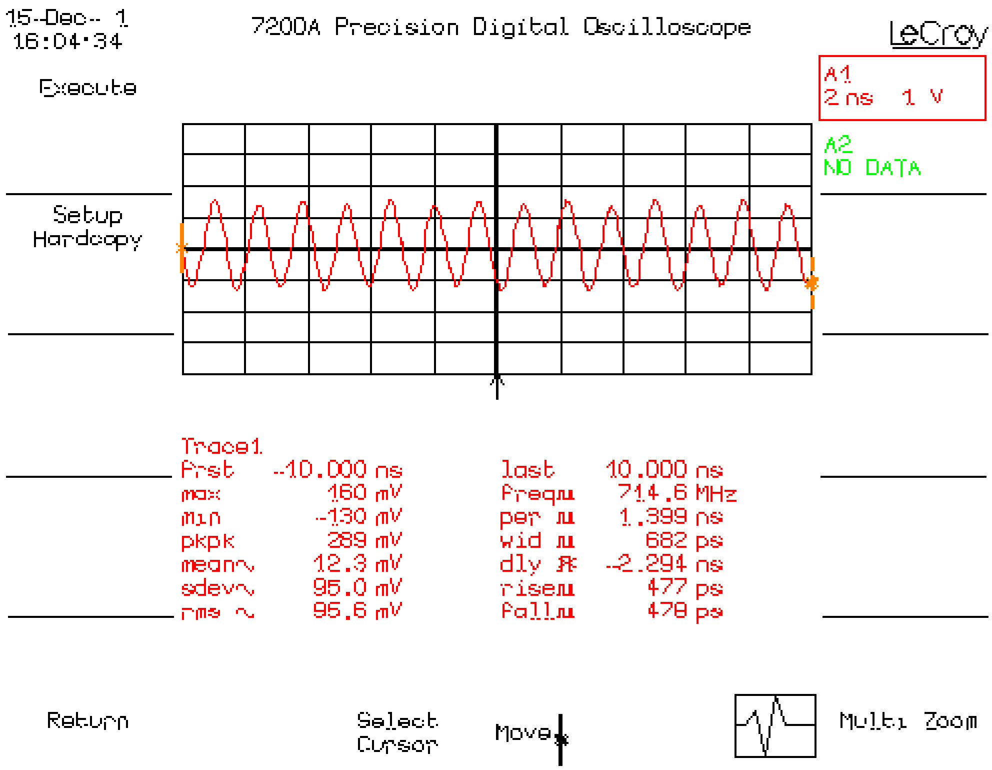

The following plots the 500MHz signal.� Now down about 20mV from the base.�




I did a few sweeps on all four channels and found the inputs good to a bit over 520MHz.

How fast of a wave can the 7242B display?� In the next plot I have injected a 715MHz signal.���

Of course the signal has diminished quite a bit now, but it's interesting that we can see the waveform at all.� This appears to be the limit of my plug-ins.� Any higher frequency and the oscilloscope no longer appears to be able to trigger and we get random noise displayed.�

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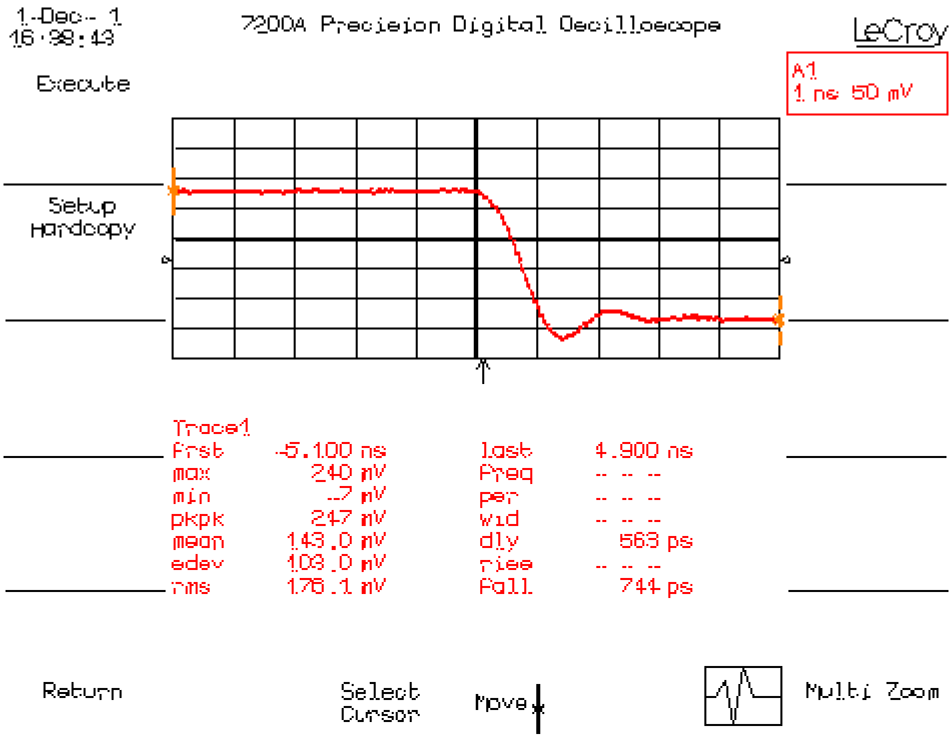
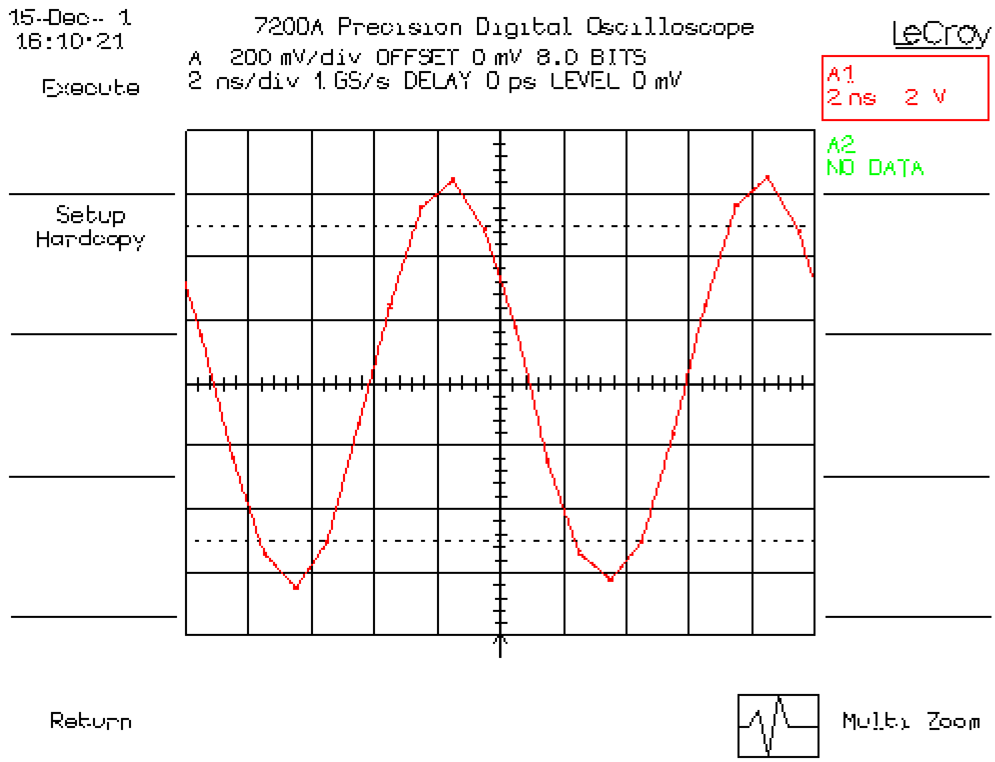
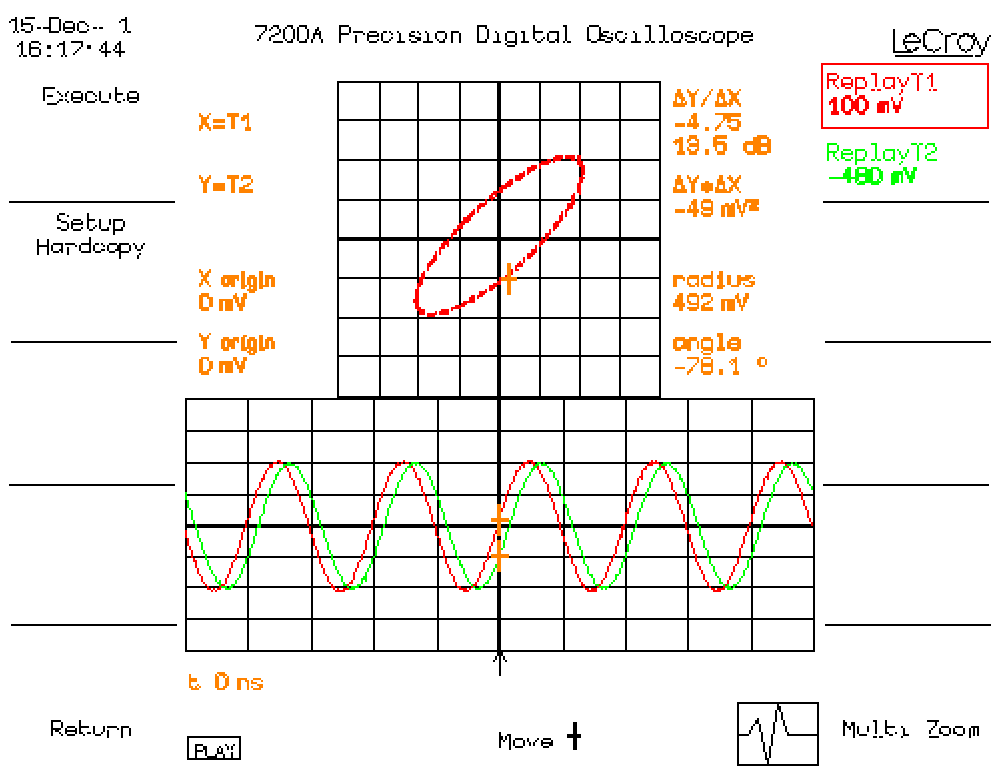
Let's look at the output of a Low Voltage Differential Signaling (LVDS) receiver.� We will use a Pericom PI90LV018A for this test.� These are 3.3Volt logic.� The rise and fall times for these parts is about 0.35nS, to 1.2nS maximum.�



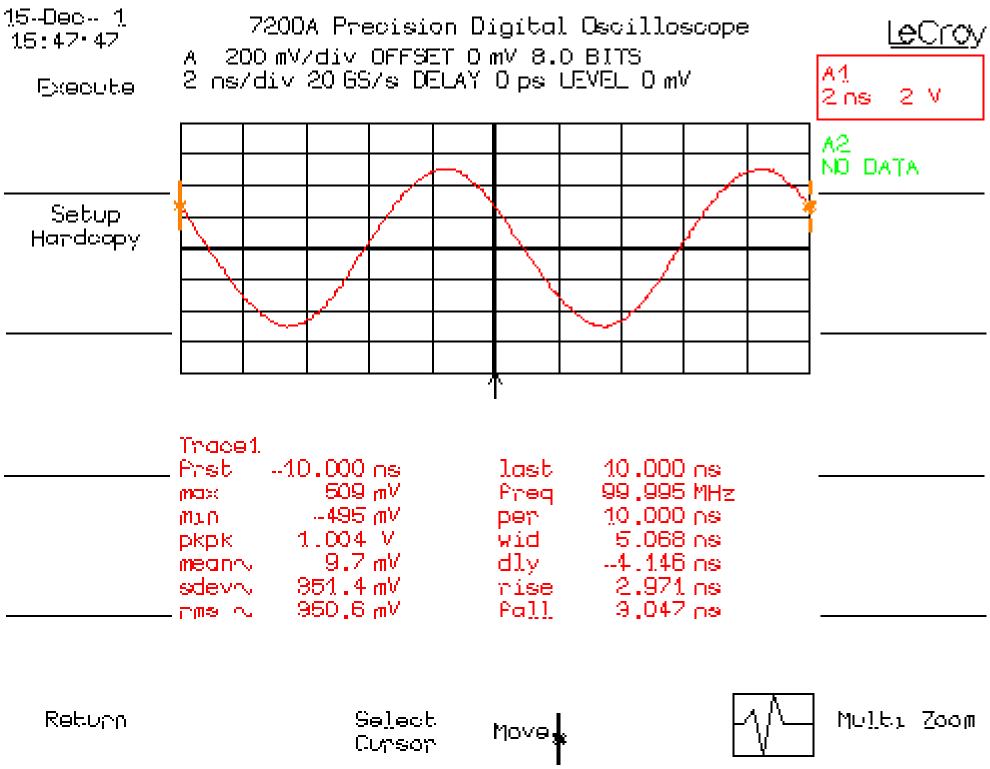

Why do my waveforms look so clean?� You thought the 7242Bs could only sample at 1Gs/Sec?� We are running in interleaved sample mode.� In the following picture I have turned off the interleaved mode and we can see the limit of this scope when used in single shot mode.

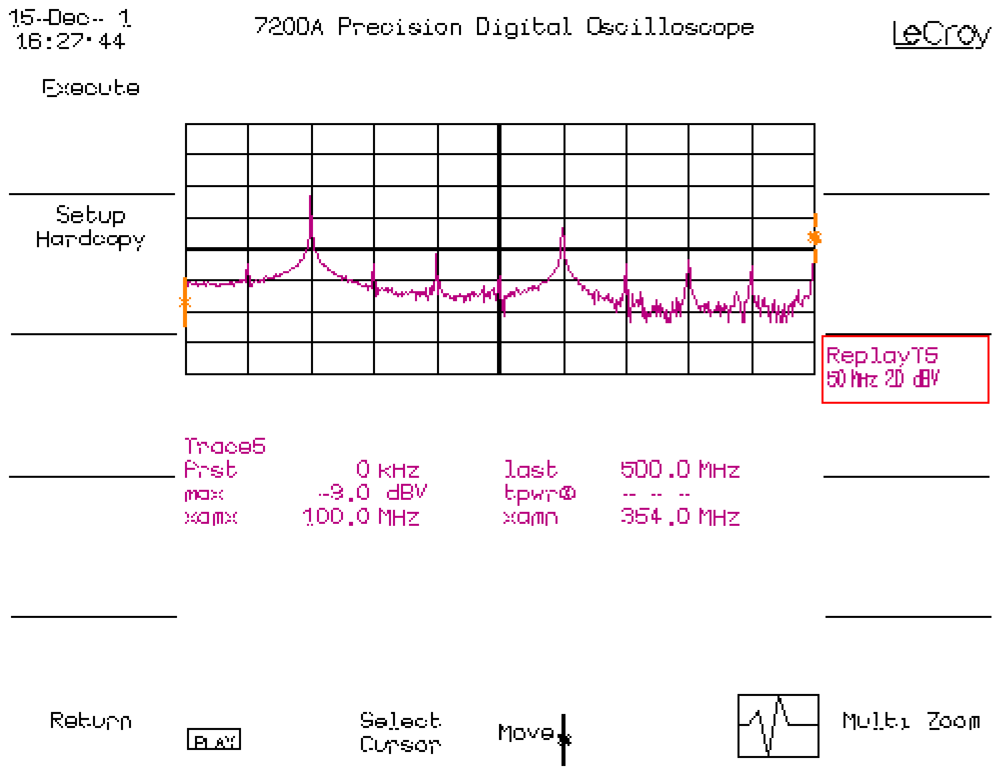

15-Dec- 1
16:10:21
7200A Precision Digital Oscilloscope
LeCroy
A 200 mV/div OFFSET 0 mV 8.0 BITS
2 ns/div 1 GS/s DELAY 0 ps LEVEL 0 mV
Execute
A1
2 ns 2 V
A2
NO DATA
Setup
Hardcopy
Return
Multi Zoom

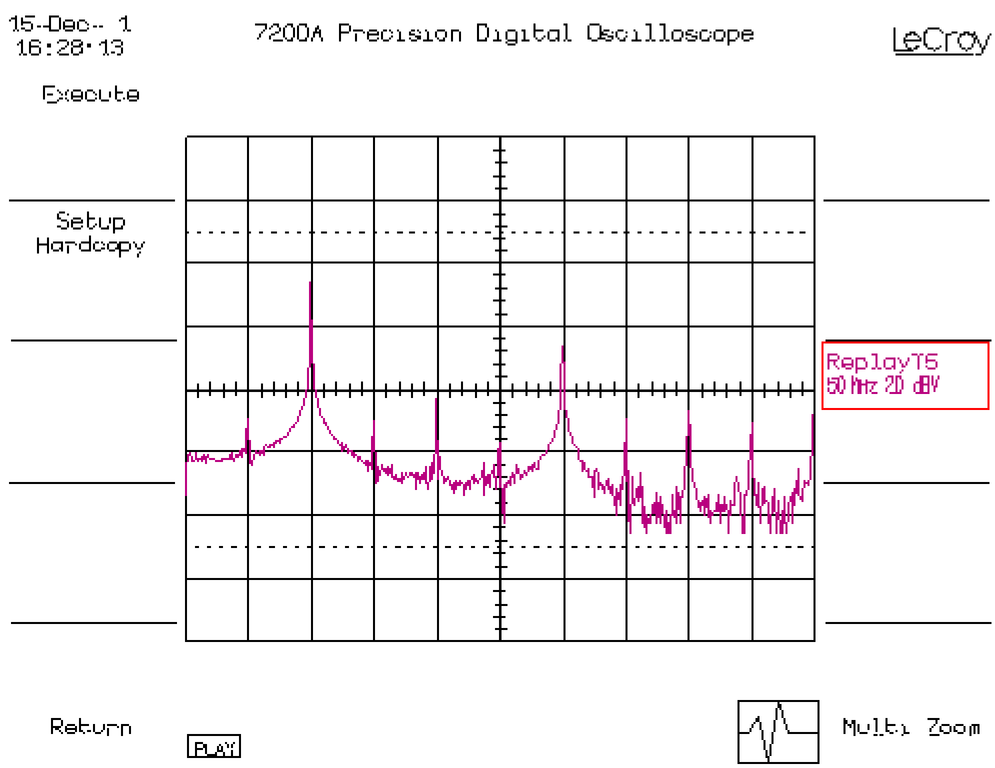
Nice XY plot:


15-Dec- 1
16:17:44
7200A Precision Digital Oscilloscope
LeCroy
Execute
X=T1
Y=T2
ΔY/ΔX
-4.75
13.5 dB
ΔY*ΔX
-49 mV²
ReplayT1
100 mV
ReplayT2
-480 mV
Setup
Hardcopy
X origin
0 mV
Y origin
0 mV
radius
492 mV
angle
-78.1 °
t 0 ns
Return
PLAY
Move
Multi Zoom

Here is a 100MHz wave with the power spectrum shown as the second wave. I have the basic parameters running and the scope it showing the peak at 100MHz.

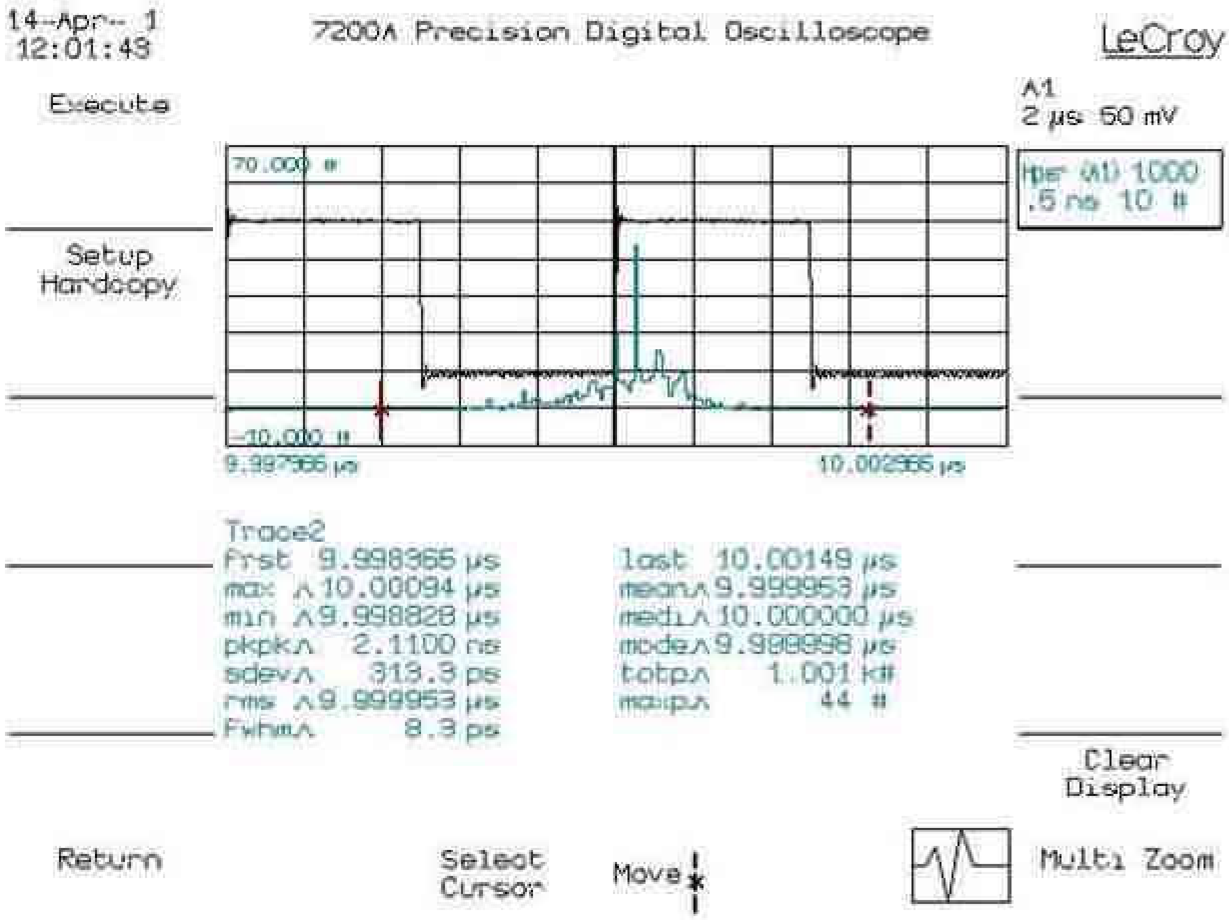





Imagine that. This scope has enough math it's hard to image needing to do more. But if you need a custom function, you can always write one.

A friend of mine was asking about clock jitter so I set the scope up to do a jitter calculation on my HP33120A. Here I have a 100KHz square wave being sampled about 1000 times. The histogram represents the period of the waveform. Notice we are reading about 2.11nS of jitter.

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