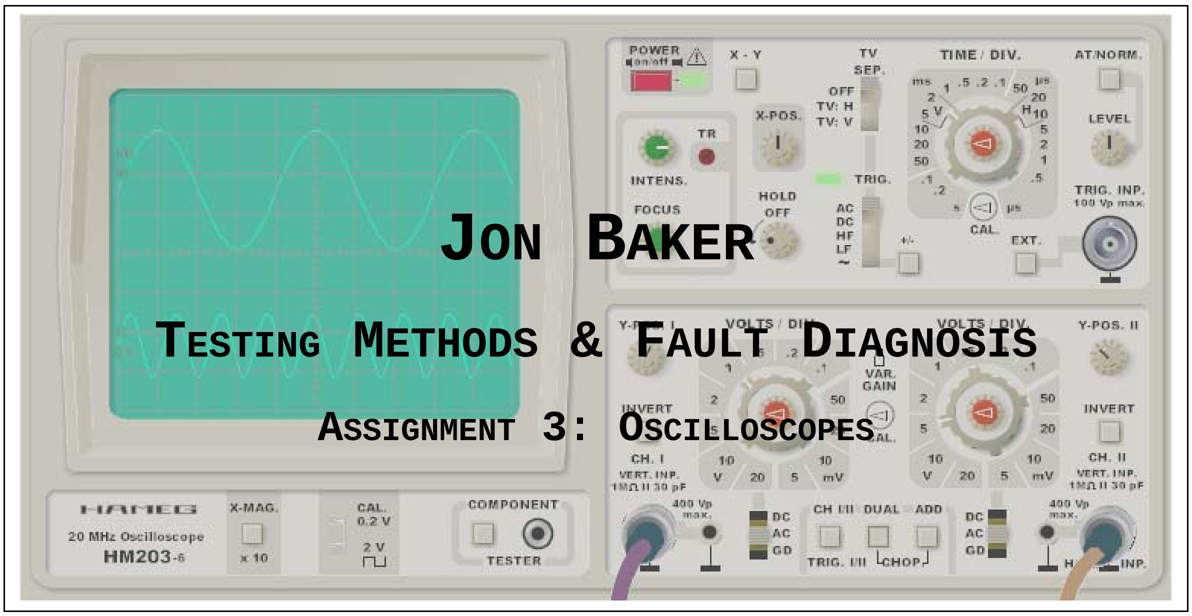

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Testing Methods & Fault Diagnosis

Assignment 3: Oscilloscopes

Introduction

This assignment is an explanation of the basic components and processes to explain the construction, usage, and application of an oscilloscope.

Page 3: **Section A**
With regard to the general purpose industrial oscilloscope (twin trace), draw a block diagram and briefly describe the operation to include:

1. Attenuator and Vertical Input Supply
2. CRT Circuitry and Power Supply
3. Trigger, Timebase and X-Deflexion Circuitry

Page 6: **Section B**
Discuss briefly, the modes of trigger selection and describe typical examples where each mode may be employed.

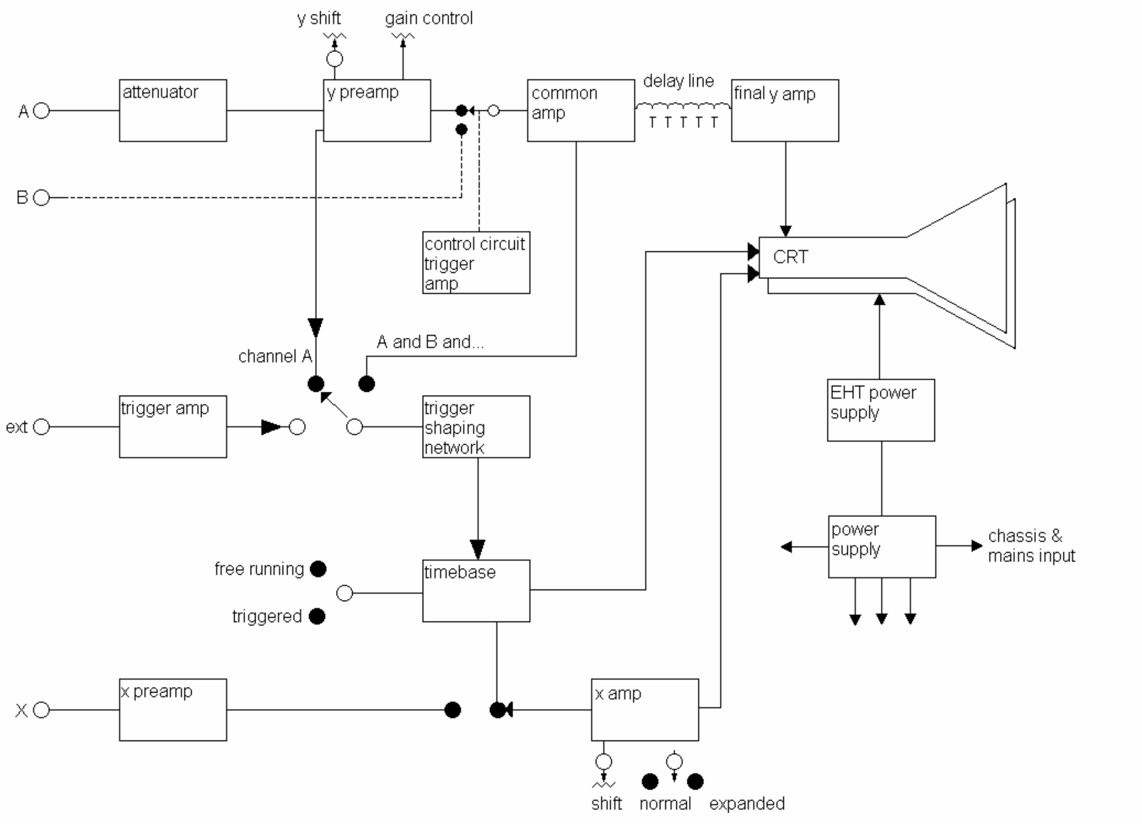
Page 8: **Section C**
Explain briefly the fundamental properties and reasons for using the oscilloscope probe.

Page 10: **Section D**
Outline the requirements typically required for calibration procedures.

Page 11: **Section E**
Indicate the main constructional differences of the Digital Storage Oscilloscope compared with the real time analogue ‘scope. Indicate an application in which the DSO would prove to be of advantage.

Section A

Below is a block diagram of a typical twin trace oscilloscope:



Starting from the channel inputs and working towards the CRT I will now explain several of the blocks.

Channel A Input
As you can see the attenuator and vertical input amplifier (y preamp) are directly connected respectfully after the input to channel A.

Since amplifiers only have a certain range over which they are amplifying equally, the bandwidth of the oscilloscope input, there is an input attenuator preceding this amplifier. The attenuator brings down the input signal to the same level as it would be on the oscilloscopes most sensitive range, as this is what the fixed gain of the oscilloscope is set to.

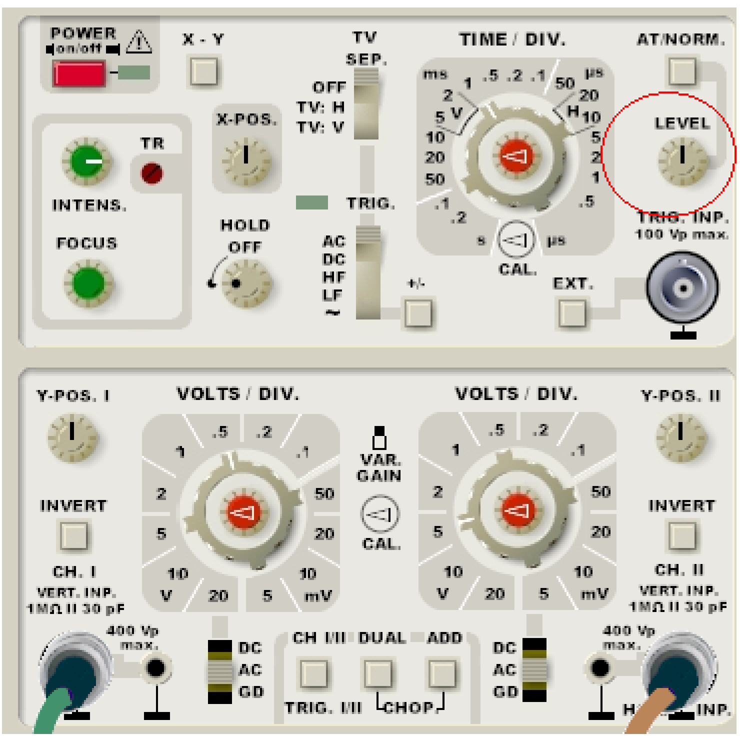
This is then sent to the common amplifier which has a range set to amplify equally over the inputs.

The A and B inputs are switched alternately to the common amplifier. After this amplifier is a length of delay cable before going to a final Y amplifier and into the CRT. The CRT will be dealt with soon.

Triggering and Timebase
Now that we have our two signals going in, our Y axis, the next logical step would be the X axis, in the case of an oscilloscope, time.

The timing of the signal(s) can be taken from one of three sources:
1. An external trigger
2. Channel A
3. The common amplifier (Channels A and B)

You can see this selection on the block diagram. The signals are then fed into the trigger shaping network, this circuitry processes the signal coming in and derives a timing pulse from it, this process can also be altered by the user from the manual level control, as shown below:



Oscilloscope Controls with Level Highlighted

The level control allows the user to alter the voltage level of the waveform that triggers the circuit. This timing is then fed to the timebase which makes the signal relative to the timing set on the TIME/DIV (shown above) thus controlling the 'width' of the onscreen waveform. This is then sent to the CRT.

The external input allows the level control to be read in from an external source if you require a carrying level selection.

CRT and Circuitry

A CRT, Cathode Ray Tube, is both complex and simple, simple in the sense there isn't much in the quite large device, but complex in what little is there is very delicate and complicated equipment. At the back of the CRT is a set of anodes and a cathode. The signal is connected to the cathode, the anodes inside are more complex than a simple connection, it contains focusing and accelerating elements in the form of electrostatic lenses. Since the anode is positive and the electrons are being sent to the cathode they are attracted towards the anode. There are more than one pair of these and there are also acellerating anodes, in fact electrons can be moving at up to $8*10^7$ metres per second! The actual tube is a vacuum through which electrons can flow, and it is covered in a conductive coating to allow the electrons to be controlled in direction. The controls are actually opposingly charged deflection coils (inductors) that are weak enough as to not attract the electrons and hold them, but strong enough to influence their path. It is this outer conductive coating, these coils that we wish to influence. The actual timing to steer the beam from left to right on the screen is the timebase control and is constantly moving (we'll forget the speed for the moment). However, at the moment we have just a flat line, until we connect the channel to the input, it is this information altering the Y deflection coils the shows us the waveform. At the front of the screen is a phosphor covered surface, this is what you actually see, it glows showing a picture. That is all there is really to the tube, the cathode, anodes, vacuum tube, deflection coils and phosphor surface.

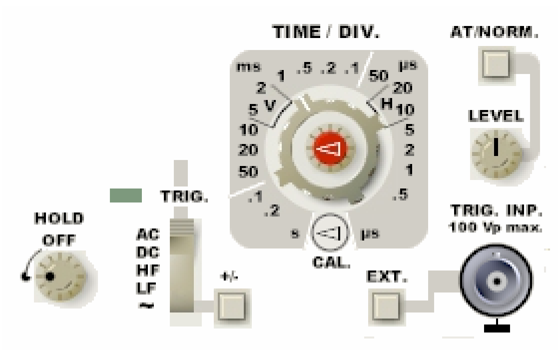
There we have it, everything from the input signal and timing, through to the output at the phosphor surface.

Power Supply

The input power supply for an oscilloscope is usually a mains input but you can get portable battery powered 'scopes. Either way the circuitry inside will require +5V in places for some ICs, various other supplies and then the EHT for the CRT. EHT (*Extra High Tension*) is a stage before the CRT which takes the standard power supply and using a series of transformers takes this up to +5kV for a monochrome display and up to around +15kV for a colour display.

Section B

Triggering circuitry in an oscilloscope ensures that the trace shown always starts at the same point on the waveform. Triggering is used on repeating waveforms to steady the picture among other things. On non-repeating waveforms, such as faulty circuits, microphone outputs etc the picture may not be steady or flicker free on the screen, so as can be derived, only some oscilloscopes are designed for non-repeating waveforms to be handled well.



Triggering Controls

Here you can see the triggering controls. The **AT/NORM.** control is used to selection between automatic triggering (AT) and normal manual triggering selection (NORM). On manual the level control can be used to control at what voltage level the circuit should trigger on.

The Hold Off control is simply a delay that determines the time between the end of one sweep and the beginning of the next.

The external triggering input allows you to use an external signal level as a trigger.

One option not on the above control panel is the option to use channel 1 or channel 2 inputs as triggers.

The other trigger control selects between AC/DC/HF/LF and mains. The "Trig." switch is used to configure the trigger coupling.

In position "AC" (alternating current coupling) the trigger signal is RC-coupled. Its direct current component is filtered. This means that signals, which have a frequency lower than the lowest frequency the oscilloscope allows, cannot be triggered. In this simulation however there is no low frequency limit. In position "DC" (direct current coupling) all signal components starting at 0 Hz influence triggering.

In position ""HF" (for "high frequency"), low frequent signal components are filtered, in position "LF" (for "low frequency") high frequent signal components are filtered. These positions are used to filter noise. Noise amplitudes can trigger unwanted sweeps.

In position "~" the signal is triggered by the power supply frequency 50Hz.

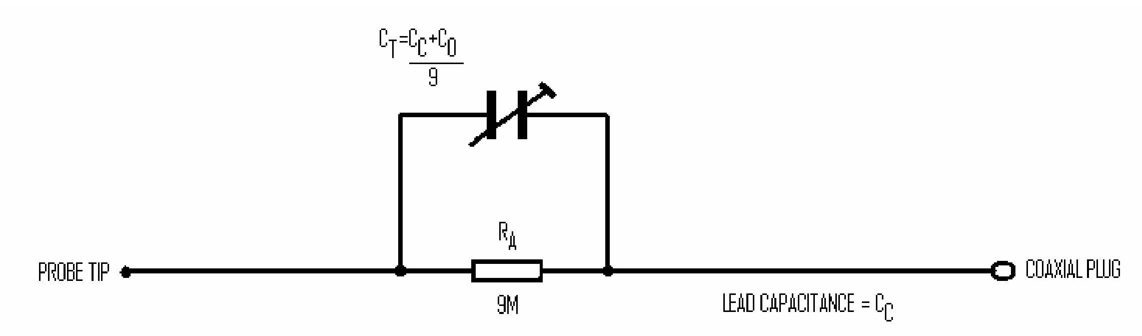
Finally the +/- control allows you to chose between triggering on ascending signals of descending signals.

Section C

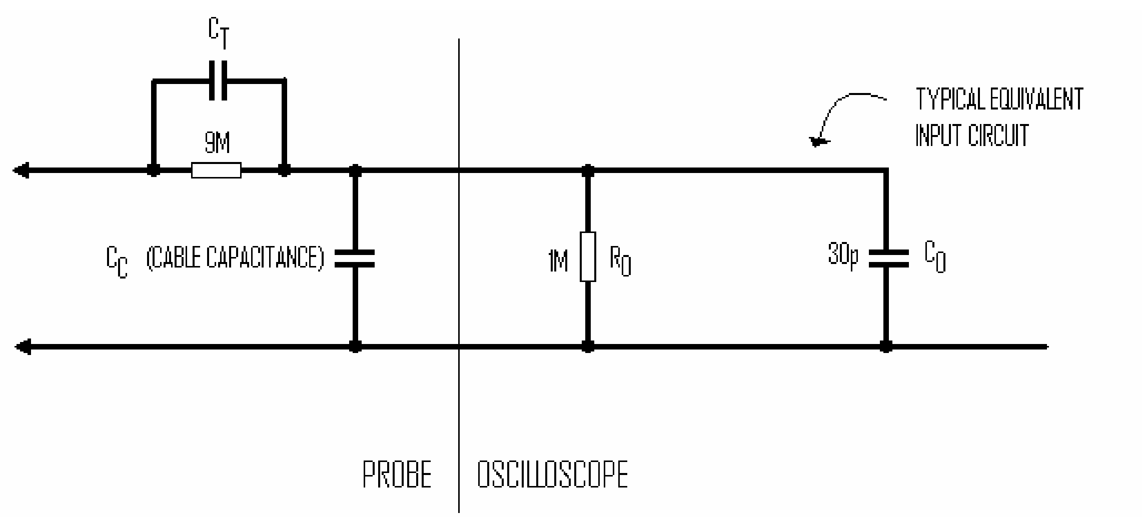
Oscilloscope connection is not as simple as a piece of wire between the channel input and the test point in question on your circuit. A standard 'scope input channel is regarded as having a 1MΩ input and an input capacitance in the range of 15-40pF depending upon model. If you try and use any normal cable you could experience either increased capacitance on the line, interference and/or hum from trying to read a small signal.

These problems can be overcome by using a probe.

Usually one metre of screened cable is sued to avoid hum on high impedance circuits. Even this can increase the overall capacitance to 100pF so a 10:1 passive divider probe can be used to reduce this effect to around 10pF.



(a) A Passive Divider Probe



(b) Equivalent Circuit

It is worth noting that a passive divider probe has to be calibrated too along with ‘scope to maximise its efficiency. Also probes can have settings on them, such as 10 and 1 where the 1 setting short circuits the resistor and capacitor in the above circuit (a) allowing a straight 1:1 ratio.

The only problem with even a very well configured passive divider probe is that it reduces the sensitivity of an oscilloscope by up to a factor of 10.

The answer is an active probe. These utilise a unity gain buffer actually in the probe head, this can give a 1:1 probe reading whilst still keeping a low capacitance.

So, probes come in all manor of designs allowing for better voltage readings when compared to a piece of wire instead.

One final thing to note about probes is it is possible to use a *current probe*. This probe usually has a slotted head with the slot being closed by a sliding member, after slipping in the wire carrying the current to be measured. Because of this the circuit does not need to be broken to thread the wire through the probe. Current probes work with oscilloscopes since they produce a voltage waveform output in sympathy to the current being measured, thus the voltage waveform on the CRT is actually the measured circuit current.

Section D

The calibration procedure generally involves:

CRT Tests
- Check intensity
- Check focus

Vertical Amplifier Tests
- Invert Button Check
- Symmetry Check on Amplifier

Calibration of the Vertical Amplifier
- Checked via the calibration signals on the front panel

Transmission Performance of the Vertical Amplifier
- Checked by the rise time of a square wave signal at varying frequencies

Operating Modes
- Make sure Dual channel works
- Y Position changes
- Check chop mode

Triggering Checks
- Check all trigger modes work

TV Checks
- Check TV modes work with TV signal

Timebase
- Check each timebase option in turn with a different frequency signal with a known number of divisions to expect on screen
- Check trace length is just over width of screen
- Check Hold off knob

Component Tester
- After starting the tester the line should appear immediately
- Line is correct length at 8div
- Connected to ground horizontal line 6div appears

Trace Alignment
- The trace alignment control should allow for a variance of 5 degrees or more of the on screen grounded signal line.

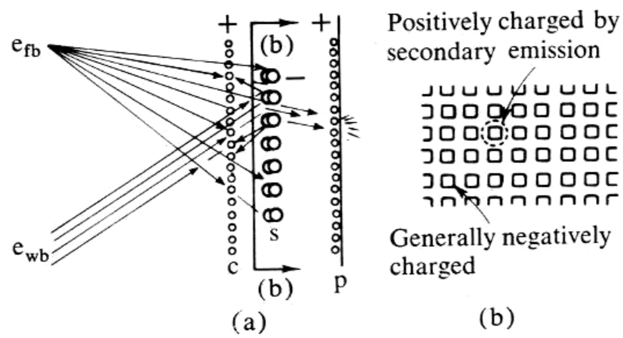
These are the basic tests for oscilloscope calibration.

Section E

The basic constructional difference from a real-time ‘scope to a DSO is the usage of digital converters and memory instead of the conventional analogue circuitry.

One way in which a storage oscilloscope can be designed is by using several electron guns in the CRT. These extra guns can repeat a pattern, a waveform, using only a low energy electron gun with sufficient energy to maintain the pattern without exciting it enough to initiate it.

This process is best shown in the diagram and explanation below:



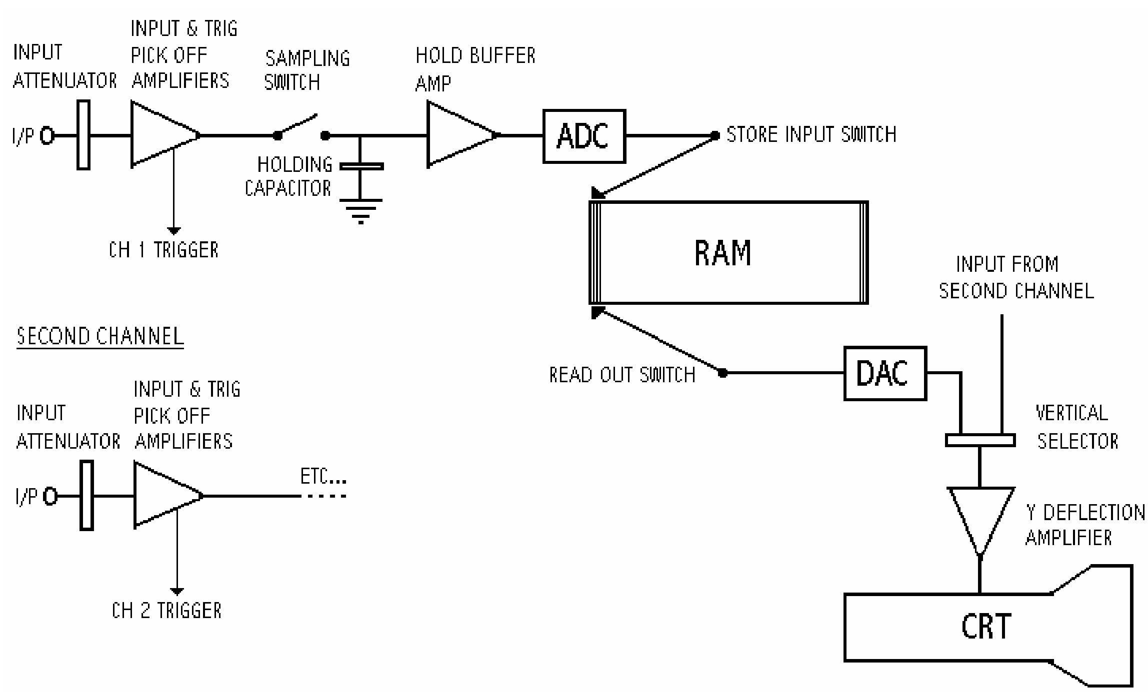
e_{wb} = high-energy writing beam
e_{fb} = low-energy flood beam
c = collector mesh for secondaries
s = storage mesh, insulator deposited on permeable mesh
p = phosphor screen

Fig. 26. Conventional storage structure. (*a*) As the writing beam e_{wb} strikes the (slightly) negatively charged insulating storage target deposited on the target screen S, secondary electrons are emitted, creating a region which is slightly positive, relative to the potential of the flood beam e_{fb}, permitting the electrons to pass through the “hole” created, in the storage screen and, being accelerated by the highly positive charge on the viewing screen p, duplicates visually the pattern written on the storage screen by the writing beam. The secondaries are collected by the collector c, as are the flood electrons which are repelled by the charge on the unwritten portion of the storage screen, which normally is slightly negative to the potential of the flood beam. (*b*) The appearance of the surface of the storage surface, normally an insulator with a high secondary-emission ratio, deposited on a metallic permeable mesh.

This is how storage oscilloscopes worked pre-DSO. Storage oscilloscopes now are digital and instead of extra guns and insulated phosphor screen layers we use RAM, and digital and analogue converters.

A digital storage oscilloscope uses RAM (*Random Access Memory*) instead of writing the information to an insulating screen layer. The signal is digitised through a sample and hold circuit, a buffer, and then finally an ADC (*Analogue to Digital Converter*). This process finishes with the signal being stored in the systems RAM. The data can be stored in the RAM and kept there just as in a computer. This signal data can be recalled from RAM and output to the units CRT using a DAC (*Digital to Analogue Converter*). Unlike a real-time 'scope that is control circuitry a DSO can be controlled via a micro processor though some older units will be control circuitry. Please note that the CRT itself is the exact same component and it is only the method in which the signals to be displayed on the CRT are dealt with that changes here.

The diagram below shows the concept I have briefly explained.



How Can A DSO Be Useful?

The prime example of when a DSO would prove to be more valuable than a real time 'scope is if you have a signal that proves to be hard to trigger in such a way that it can be held on the screen.

With a DSO you could literally freeze the display and hold it as necessary, store it, remove it from the screen, and call it back at another time.

This is the sort of problem a DSO can solve.