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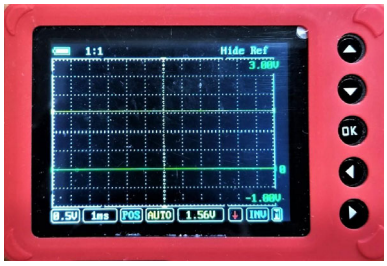
A ConsuLab Presentation

TEACHING DSO'S TO MY STUDENTS



Class Instructor Handout

VERSION 2021

CONSULAB
"TEACHING DSO'S TO MY STUDENTS"
CLASS HANDOUT

Having your students exposed to the DSO (digital storage oscilloscope) has become a necessity in today's educational environment. The oscilloscope is now recognized by many as an essential diagnostic tool used for the proper diagnosis of many of today's newer vehicle technologies. The speed of signals on these vehicles often exceeds a digital multimeters ability to accurately measure them. Many OEM's have now included scopes as required tools in the service bay and technicians are expected to be able to use them. The aftermarket repair industry is being divided into those shops that embrace new system technologies and can use the new diagnostic tools and those that are limiting what vehicles they can repair.

Schools and instructors need to accommodate this need by introducing the oscilloscope to their students and then, conduct training assignments and activities for them to gain diagnostic abilities using this equipment. Even the HD vehicle and Agricultural industries now have extensive vehicle systems that in some cases outpace the OEM car technologies. Oscilloscopes are an integral part of their diagnostic strategies.

WHY SHOULD I TEACH MY STUDENTS HOW TO USE AN OSCILLOSCOPE??

- Scopes allow students to "see" what is going on in a circuit which provides better circuit understanding
- Scopes provide an easier method of teaching circuit understanding and comprehension
- Scopes are now an essential tool for today's technician at all levels

ADVANTAGES OF USING THE OSCILLOSCOPE:

- DSO's allows signals to be seen in great "detail" and more than a scan tool or digital meter would allow
- They measure signals much, much faster than scan tools or digital meters. (nothing is faster or more accurate)
- Only tool that can "catch" and identify causes of intermittent circuit "glitches"
- Enhances student engagement with "hands-on" activities
- Students learn more effectively by "seeing" the circuit in operation
- Transducers can be used to measure pressures, vacuum, temperature, and noise/vibration
- The scope is the best diagnostic tool for fast and accurate testing of CAN Bus systems
- DSO's can provide quick and accurate diagnostic information using RELATIVE COMPRESSION and IN CYLINDER pressure testing including:
    1- Much faster than doing a mechanical compression test
    2- Can determine exact cause of compression loss
    3- Can determine cam/crank timing relationships
    4- Can determine correct valve train operation or malfunctions
    5- Detailed analysis of the operation of valves, springs, pushrods, cam lobes, etc. can be evaluated with scopes
- Using amp clamps, "current ramping" of motors, injectors, coils, and other components provides very accurate information in the diagnosis of performance, cause and effect of damaged or defective components
- Current waveforms provide extensive details of how the circuit is operating and clearly identifies defective components, voltage drops and mechanical failures
- Multiple signal inputs can be viewed at the same time to see changes in volts, amps, resistance, pressures, etc.
- Scopes can record and play back information after a road test for more accurate diagnosis.

TEACHING DSO'S TO MY STUDENTS

WHY DOES CONSULAB PRESENT A CLASS ON TEACHING DSO'S TO STUDENTS?

ConsuLab

WE BELIEVE THE DSO IS NOW AN ESSENTIAL DIAGNOSTIC TOOL NEEDED TO BE TAUGHT

WE ARE PASSIONATE ABOUT HELPING INSTRUCTORS IN THEIR DAILY JOB DUTIES

WE KNOW THERE ARE MANY SCHOOL PROGRAMS NOT "UP TO SPEED" ON DSO'S

WE ARE VITALLY INTERESTED IN THE SUCCESS OF STUDENTS WITH THEIR CAREERS

WE FEEL WE CAN HELP INSTRUCTORS WITH THIS SUBJECT MATTER

WE HAVE AFFORDABLE PRODUCTS TO ASSIST WITH THIS TOPIC

CONSULAB MAKES AWESOME VEHICLE SIGNAL "GENERATORS" THAT HAVE THE ADVANTAGE OF USING "REAL-LIFE" SIGNALS THAT ARE IDENTICAL TO WHAT WOULD BE SEEN ON A VEHICLE.

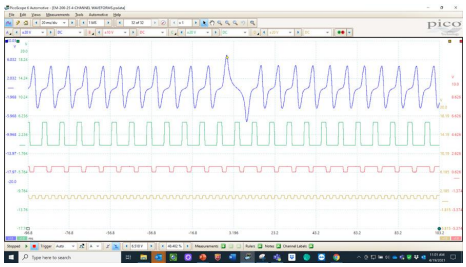
THE BELOW TRAINERS ARE A FEW SAMPLES OF OUR PRODUCTS THAT WILL PROVIDE VARIOUS SCOPE SIGNALS

CL-1919-05 OHM'S LAW & DC CIRCUITS TRAINER

Straight DC voltages from 1.00V to 14.80V±
Pulse Width Modulated signal (0-100% duty cycle)
Relay coil voltage inductive kick (resistor suppressed)
Voltage drops through various resistances

EM-200-25 SPEED & POSITION SENSORS TRAINER

Variable Reluctance Inductive sensor (AC sine wave) amplitude and frequency adjustable. (also, adjustable air gap for creating abnormal conditions)
Hall Effect sensor (DC digital) with varying frequency
Magneto-Resistive Radial sensor (low resolution) DC digital square wave with varying frequency (and adjustable air gap)
Magneto-Resistive Axial sensor (high resolution) DC digital square wave with varying frequency



SAMPLE SCOPE WAVEFORMS OBTAINED FROM THIS TRAINER

MD-4000 MODULAR ELECTRICITY/ELECTRONICS & ENGINE PERFORMANCE

This trainer is available in three different configurations covering basic electricity, electronics, and engine performance systems. An unlimited amount of component and circuit signals can be created for scope display and learning.

EM-200-14 COP (COIL ON PLUG) IGNITION SYSTEM TRAINER
All RPM, current ramp and voltage signals used with COP ignition systems are available.

EM-200-24 WASTE SPARK IGNITION TRAINER
All RPM, current ramp and voltage signals used with waste spark ignition systems are available.

EM-200-12 DISTRIBUTOR IGNITION SYSTEM TRAINER
All RPM, current ramp and voltage signals used with a distributor type ignition system are available.

EM-200-19 CUTAWAY FUNCTIONAL STARTER TRAINER
All voltage, voltage drop and current ramping signals found in a typical starter system are available.

EM-330-1 FUEL INJECTION & ENGINE PERFORMANCE TRAINER
This trainer provides all the signals available on a real vehicle. All sensors, actuators, relays, fuses/circuit breakers, fuel pump, fuel injectors, ignition coils, CAN Bus, signals, and more are available. This trainer also has the ability to adjust the MAP, MAF, ECT and IAT sensors to demonstrate abnormal conditions and all of systems react accordingly to the changes. The trainer contains an ECM breakout box matching OEM configuration providing easy signal access receptacles without having to back probe connectors. This trainer is an extremely valuable product allowing students to see changes in scope waveforms with the adjustments creating abnormal conditions.

EM-140 SERIES OF OPERATING ENGINE BENCHES
The ConsuLab engine bench trainers provide all the signals available on a real vehicle. The engine starts, runs, and can have faults inserted. All sensors, actuators, relays, fuses/circuit breakers, fuel pump, fuel injectors, ignition coils, CAN Bus, signals, and more are available. The trainer contains an ECM breakout box matching OEM configuration providing easy signal access receptacles without having to back probe connectors. There are many OEM models to choose from.

OTHER SOURCES FOR SCOPE SIGNALS

- Actual vehicles (access & viewing limitations)
- Available signal generators from SnapOn, (EESX306SP & EESX306A) ATS (Etrainer JR – ETR-3000), and other firms
- DC batteries
- Basically, any electrical signal can be seen with an oscilloscope

SCOPES – BRANDS – TYPES & ACCESSORIES

There are several different brands of oscilloscopes. Some are dedicated for automotive use and some are not. The ones that are automotive dedicated usually have built-in software to accommodate capture and waveform features based on common automotive components and test procedures. Non-automotive scopes can certainly be used on vehicles but can be somewhat cumbersome to use. A scope is a scope, and it is the internal software that makes it easier to use for vehicles.

SCOPE TYPES

There are many different types of scopes available. The following is a list of the most common types of scopes found in the transportation industry.

- Self-contained (hand-held) (uScope, Fluke 97 & 98, Interro, etc)
- Bench top unit (quite rare in vehicle repair due to its limitations of power, etc)
- Integrated within scan tool (Snapon, Autel, and many others)
- PC based requiring a computer (Pico, ATS, OTC Tech-Scope, etc)


SELF CONTAINED – "BENCH TYPE" UNIT


PORTABLE – "HAND-HELD"


PC or TABLET BASED


INTEGRATED WITH SCAN TOOL

SCOPE CHANNELS

An oscilloscope has at least one "channel". Each channel is a circuit built into the scope for measuring a voltage connected to the scope. A one channel scope can measure just one circuit at a time. A two-channel scope can measure two different signals at the same time. Two or more channel scopes have distinct advantages in that different signals can be displayed at the same time for comparison purposes. Multiple channels add cost to the scope. Most scopes with more than one channel will allow different voltage scales to be selected but will use the same time base for all channels. Recently, there are some available exceptions to this rule, but are very expensive. Currently, automotive scopes are available with 1, 2, 4 or 8 channels. A one-channel scope can be used to teach all scope basics needed for a full range of skills and knowledges.

SCOPE ACCESSORIES

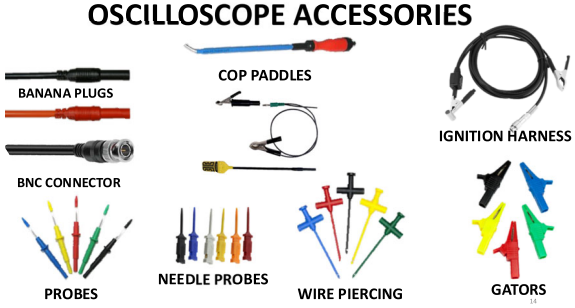
DSO's can be equipped with almost an unlimited number of accessories, attachments, and additional components. Often users "over-purchase" more of them that they may initially need. Among the most common accessories are:

- Scope lead extensions
- Adapters (BNC – Banana)
- Attenuators
- AC/DC filters

* Alligator Clips (large and small)
* Amp Clamps (all ranges)
* Ignition Probes/Adapters
* Wire piercing probes

* Temperature probes
* COP (Coil On Plug adapters)
* Pressure/Vacuum transducers
* NVH transducers

OSCILLOSCOPE ACCESSORIES



IMMERSION, CONTACT AND CLAMP-TYPE TEMPERATURE PROBES

ATTENUATORS

VOLTMETER RANGE "EXTENDER" TO ALLOW READING OF HIGHER VOLTAGES

Attenuators allow the scope to measure voltages higher than its rated voltage range. Think of an attenuator as a "voltage range" extender. Common attenuators are available in X10 and X20 ranges and can prevent damage to scopes that can occur from measuring voltages higher than the scopes designed limits. Attenuators are commonly used when measuring ignition and fuel injection signals that can have higher voltages. When using attenuators, be sure that the attenuator matches the brand of scope you are using.

AMP CLAMPS

The **AMP CLAMP** allows the scope to accurately measure current. Remember that any scope can only measure voltage, therefore if any signal other than voltage is to be measured, whatever it is must be converted to a voltage that the scope can recognize. The amp clamps used by scopes are the same as those used with digital multi-meters and therefore any amp clamps you currently have should work with any scope. When attaching an amp clamp to a scope, you must make the necessary adjustments to the scope for that amp clamp. If your scope does not have amp clamp adjustments, then just like with a digital meter, you will have to convert the displayed milli-volts into current readings. Example: 1mv = 1 amp or 100mv = 10A. Amp clamps are available based on the maximum current they can measure.

Low range amp clamps are used for measurements of milli-amps, parasitic draw and voltage drop testing, etc. Mid-range amp clamps are used for measuring current in fuel injector, ignition, pumps, and motors. High range amp clamps are used for starter and alternator current, including **RELATIVE COMPRESSION** testing and circuits drawing higher current ranges. It will be necessary to have both a low and a high amp clamp for general testing.

AMP CLAMPS

YOURS WILL WORK WITH ALL SCOPES

PICO 30A PDI 60A PDI 400A PDI 600A

AFFORDABILITY OF SCOPES FOR SCHOOLS

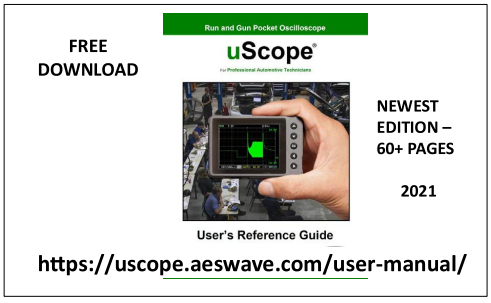
With the often-limited budget concerns schools often face, it can be difficult to purchase the necessary number of scopes so that more than one or two students can access them in a classroom situation. The accepted top-of-the-line scope brands are Pico and ATS (Automotive Testing Solutions). Both companies provide high quality products filled with valuable features and performance specifications. The only disadvantage of purchasing those products is that they are often very expensive with prices ranging from $2,000-$3,000 and higher depending on how the unit is packaged with accessories. There are less expensive scope options, but one should be concerned to purchase units that have good reputations, have usable features for specific needs, contain the features you need and yet are within your budget constraints.

The uScope is a single channel digital storage oscilloscope that often represents an affordable option for teaching DSO's to a group of students. While the unit cost of a uScope is very affordable, it is still a feature packed diagnostic tool and in many ways matches the very high end and expensive scopes. Its only disadvantage is the single channel limitations. However, when used to present students with the operation of, use of and application of a typical digital storage oscilloscope to students, the uScope and an accompanying signal distribution harness provides an awesome educational package that puts scopes into student's hands while allowing the generation of signals from the instructor to be seen by everyone at the same time. Schools often have a small quantity (or just one) of a very high-end scope or scan tool/scope but having 15-30 students work with those units at the same time is often troublesome and very inefficient.

Another very distinct advantage that the uScope has is that all software updates are offered free of charge. This is a huge factor when dealing with school budgets and limitations. Information is available from ConsuLab on how to check your software version and update the latest.

FREE DOWNLOAD FOR THE USCOPE USER MANUAL

A 60+ page uScope user manual is available for a free download (PDF) by following the below download instructions. It is periodically updated with new information so be aware of the latest version number.



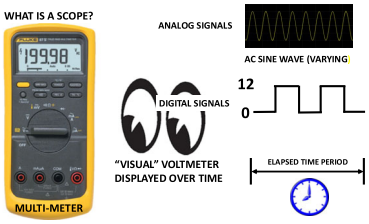
When you click on the above link, you will get this message. Click on **DOWNLOAD**.

Upon clicking the **DOWNLOAD** button, this dialog box will appear. Fill in the information and hit **SEND LINK** You will get an email with a download link attached. Download and save the PDF to your file folder.

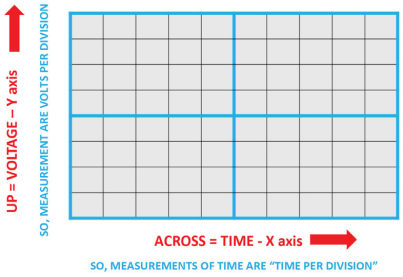
SUGGESTED EVOLUTION ON HOW TO TEACH SCOPES TO YOUR STUDENTS

SCOPE BASICS (USE THE K.I.S.S. METHOD)

Explain that a scope is a "visual voltmeter displaying voltage in a given period of time" (see below)



Continue to discuss that a scope is nothing more than a voltmeter that displays voltage (**UP**) within a given amount of time (**ACROSS**) on the scope screen. Therefore, any signal going up is **voltage** and going across is **time**. How much voltage and time is displayed is adjustable with scope controls. Think of the volts adjustment as the "volts range switch" and think of the time adjustment as how much time is displayed from left to right on the scope screen. (see below)



DISCUSS THE SCOPE SCREEN

Each component that is tested with a scope will have the desired voltage, time, and trigger settings adjusted on the scope for that specific component or circuit. There is a list of common parts with associated scope settings in the additional handout recommended in this document. Be sure to obtain one or use some of the learning resources listed later in this document to learn what the common adjustment levels are.

There are three basic concepts one must fully understand to learn how to use a scope. They are:

- Anything going up on the screen is **VOLTAGE** and is measured and expressed as "volts per division".
- Anything going across on the screen is **TIME** and is measured and expressed as "time per division". Time can be measured in **uS** (micro-seconds), **mS** (milli-seconds) or **seconds** per division.
- Trigger is the set point at which the signal crosses and begins to display on the screen

There are basically three levels of a learning curve to master using an oscilloscope. They are:

1- **OBTAIN A PATTERN**: Hook up the correct scope leads to the correct circuit access points and make the necessary scope adjustments to obtain a pattern which is commonly called a **waveform.** This will be the "easiest" step to master.

2- **DETERMINE IF THE PATTERN IS NORMAL OR NOT:** This skill is more difficult than the first as it requires knowledge of what a "known good" pattern should look like. One of the best methods of learning scopes is to hook up the scope to vehicles that have nothing wrong with them. This will build a library of known good patterns. "Known good" patterns are also available in books on oscilloscopes, many professional websites and Facebook forums dedicated to using oscilloscopes. (see list at the end of this document) Once a known good pattern is learned, then each portion of the pattern is carefully observed (often using scope controls to zoom in) to see more details. This skill is ONLY successfully mastered with time committed to practice obtaining patterns from "non-defective" vehicle circuits and components.

3- **IDENTIFY WHICH COMPONENT CAN CAUSE AN ABNORMAL PATTERN:** This is understandably the more difficult of the three levels to master. Using the many available learning resources and networking with other instructors and technicians is a great way of building your knowledge base. Scopes can provide astonishing detail and give a much more accurate and time-saving diagnosis of circuits than can be accomplished with digital meters or scan tools. The best method of mastering this step is to continually practice, develop a waveform library of past jobs and network with others to gain from their experiences and knowledge.

SCOPE TRIGGERS & TRIGGER ADJUSTMENTS

A trigger is an adjustable level of voltage on the scope screen that "tells" the scope when to start to display the waveform pattern. The trigger level is an adjustment made on the scope screen and varies based on what component is being tested. There are different types of triggers that initially may sound confusing, but after a bit of scope use, they will be more easily understood. The below information defines the trigger types:

At this point, begin to cover scope triggers: How to adjust, set trigger level and purpose of triggers. Specific names for the different types of triggers may vary by scope brands, but follow a common theme. Cover each of the following:

- **TRIGGER LEVEL** (an adjusted voltage point at which the signal must cross before "triggering")
- **TRIGGER SLOPE** (either an upwards or downwards direction that the signal must cross before "triggering")
- **AUTO TRIGGER** (a waveform will be displayed on the screen regardless of trigger level settings. The pattern may be synced or unsynced depending on the trigger voltage level)
- **NORM TRIGGER** (a waveform will only be display IF the signal crosses the adjusted trigger level point)
- **SINGULAR** TRIGGER (a snapshot of the waveform will be captured and held once the signal crosses the adjusted trigger points)
- **SCAN TRIGGER** (on very slow time/div settings, a SCAN trigger will begin displaying a waveform without having to wait for the entire adjusted time span to be displayed on the screen)
- **HOLD TRIGGER** (pushing the HOLD button will freeze the pattern at the point the HOLD button was pushed)
- **TRIGGER WINDOW** (A trigger window is a range of trigger level voltages [high & low] that the signal must be within before the waveform is displayed.)

AUTO/SCAN

"STACKS" SIGNALS ON EACH OTHER
WILL DISPLAY A PATTERN NO MATTER WHAT

NORM

SCOPE MUST SEE A SET A VOLTAGE POINT SIGNAL TO DISPLAY

SINGLE

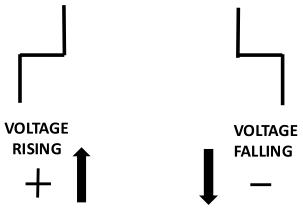
DISPLAYS A SINGLE SIGNAL & HOLDS IT

HOLD

CAPTURES CURRENT PATTERN ON SCREEN & HOLDS IT ("A" BUTTON)

TYPES OF TRIGGERS

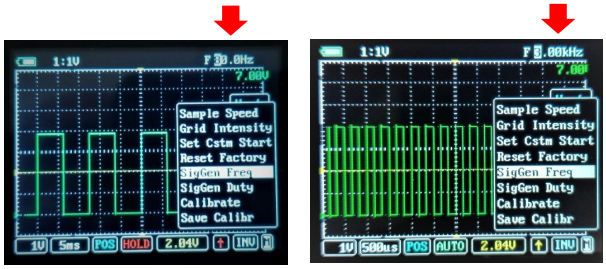
TRIGGER SLOPE



FREQUENCY

Explain that a signals frequency is how many times the signal repeats in each period of time. Frequencies are normally defined in Hertz or CPS (cycles per second). Use drawings, sketches or captured waveforms showing various frequencies for better understanding. Frequency measurement is a very common diagnostic test with some components like speed sensors, some MAP and MAF sensors, rotation detection sensors and motors.

EXPLAIN & DEMO SIGNAL FREQUENCY AND HOW TO CALCULATE IT OR USE SCOPE'S MEASURING OPTIONS

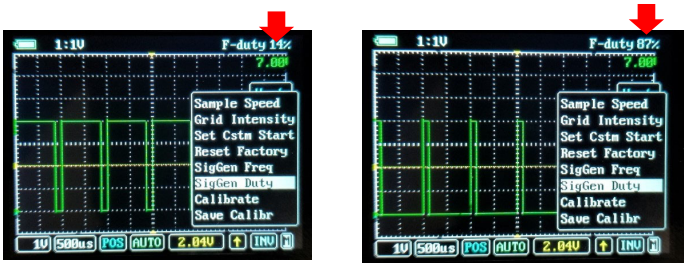


DEMO FREQUENCY CHANGES WITH SPEED

DUTY CYCLE

Duty cycle is a period during a range of a signal during which the circuit changes from on to off or off to on. Duty cycle can be measured in percentage or pulse width (milli-seconds). Use drawings, sketches or captured waveforms showing various duty cycles for better understanding. Duty cycle measurements are very common on all pulse width modulated controlled components such as solenoids, motors, relays, injectors, switches and more. Be sure to explain how duty cycle is used in both positive switched and ground switched circuits. (they will appear to be opposite). "Is it on more than off or off more than on?" is a good discussion question for students.

EXPLAIN & DEMO SIGNAL DUTY CYCLE AND HOW TO CALCULATE IT OR USE SCOPE'S MEASURING OPTIONS



EXPLAIN GROUND SWITCHED and POWER SWITCHED CIRCUITS

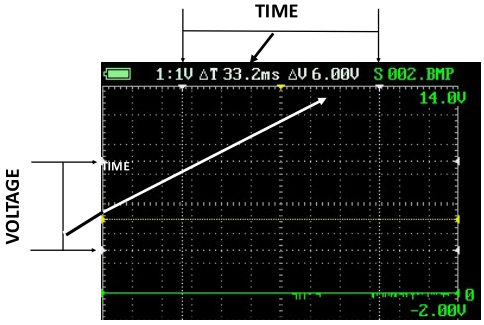
SCOPE CURSORS (USE & ADJUSTMENT)

Scope cursors provide very accurate means of measuring voltage and time on the scope screen. Not all scopes are equipped with cursors but better quality scopes have both voltage and time cursors. Cursors are commonly used for measuring items like pulse width, duty cycle, spark plug burn time, ignition coil oscillations, frequencies, and many others.

VOLTAGE CURSORS are two adjustable horizontal lines on the screen and the scope will display a "**DELTA Δ**" voltage on the screen indicating the voltage measured between the two horizontal lines.

TIME CURSORS are two adjustable vertical lines on the scope screen and the scope will display a "**DELTA Δ**" time on the screen indicating the amount of measured time between the two vertical lines.

EXPLAIN & DEMO USING CURSORS FOR ACCURATE MEASUREMENT OF VOLTAGE AND TIME



EXTREMELY IMPORTANT CONCEPT FOR STUDENTS TO MASTER

AFTER SCOPE BASICS HAVE BEEN COVERED

GENERATION OF SIGNALS FOR BEGINNING SCOPE INSTRUCTION

- Suggest staying away from component specific signals at first. Measure straight line DC voltages in the beginning.
- Strongly suggest that you stay away from "**case studies**" and examples good and bad component patterns until students master the simple functions of measuring voltage, time and make trigger adjustments.
- Keep it simple! **UP** and **ACROSS**!!

A scope is nothing more than a voltmeter that displays the measured voltage over a given period of time. Therefore, any available voltage can be used as a signal input to the scope. As stated in the presentation, for simplicity, it is suggested to start your students off measuring straight-line DC voltage. Doing this allows the understanding of the voltage measurement features of a scope without adding the display time (time/div) which can confuse students. When measuring different DC voltages (using batteries or an adjustable power supply (**CL-1919-05**) for example) it is suggested that students make different voltage/division settings to get used to the voltage scales of the scope. Using different voltage DC batteries can be a great source of voltage signals. No trigger or time/div adjustments are needed to read just voltages.

Then as proficiency increases, add time/division into the learning by measuring analog AC signals like those generated from a simple variable reluctance wheel speed, distributor pickup coil, crankshaft, camshaft, or some wheel speed sensors. The **ConsuLab EM-200-25 Speed & Position Sensors** trainer can be used for these signals. Changes in frequency and signal amplitude can be easily demonstrated. Then, make various time/div adjustments to show how the displayed pattern can be manipulated until the desired setting for best waveform viewing can be obtained.

WHERE DO I GET SIGNALS??

START SIMPLE ---------- VOLTAGE (SCALES)

1.5 V **9.0 V** **12.6 V**

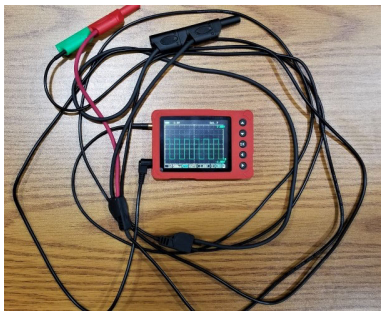
PROVES TO STUDENTS THAT A SCOPE IS A VOLTMETER – ALLOWS USING DIFFERENT V/DIV SCALES WITH NO TIME/DIV CONFUSION

USE ANY OTHER TYPE OF BATTERY (WATCH-DEVICES, ETC) – WARNING!!! DO NOT CONNECT TO 120V WALL RECEPTACLE!!!

Use voltage cursor practice to accurately measure the displayed voltages. NOTE- With straight line DC voltages, you can also use the trigger level voltage adjustment as a method of measuring the voltage level. This is true ONLY for straight line DC voltages without any amplitude changes.

USING A "LIVE" VARYING SIGNAL

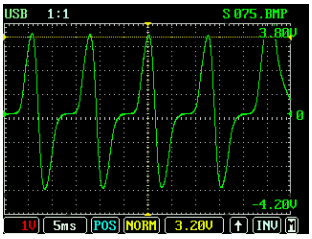
SUGGEST USING A SIGNAL GENERATOR or TRAINER

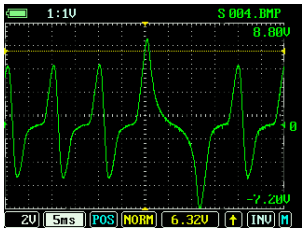


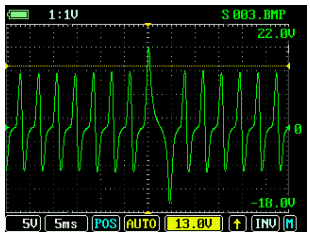
INTRODUCE FREQUENCY & DUTY CYCLE WITH AN ADJUSTABLE SIGNAL SOURCE (i.e. uScope generator or ConsuLab trainers)

At this point, introducing a "live" and varying signal is the next step in learning the scope. A varying AC sine wave can be used to introduce time/div practice and changing frequencies. Any device you have that generates this signal will work. Examples are: ConsuLab trainers, remote signal generators or, if you have an old distributor lying around that has a pickup coil, simply drive the distributor with a drill motor to generate the AC sine wave that will vary in frequency and amplitude with speed changes. (Examples below are taken from the **EM-200-25** or a distributor would give similar signals without the "wide notch". Have students adjust voltage and time settings to see effect on the waveform.

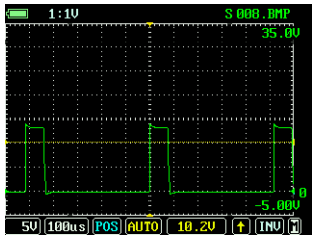
FREQUENCY DEMONSTRATION



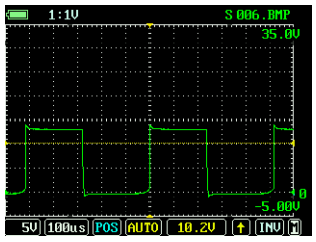




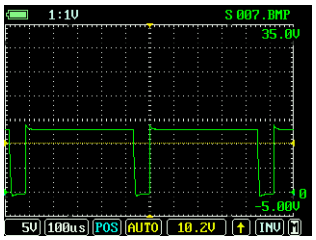
DUTY CYCLE DEMONSTRATION



15% DUTY CYCLE

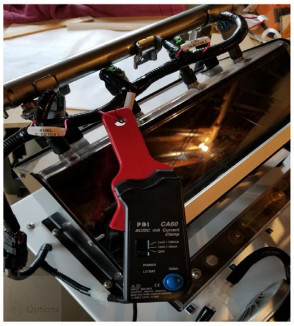


50% DUTY CYCLE



85% DUTY CYCLE

USING SCOPES TO MEASURE CURRENT USING AMP CLAMPS



CURRENT MEASUREMENT
&
CURRENT RAMPING

The scope is now going to measure current by using an AMP CLAMP

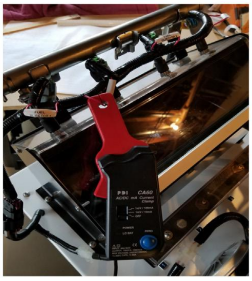
The same amp clamp used on DMM's can be used with a scope

It is important that students understand that for a scope to measure anything other than voltage, an "adapter" must be installed that changes whatever is being measured to a voltage. An amp clamp is attached around a wire which measures the strength of the magnetic field around the wire when current is passing through it. The amp clamp can convert that reading into a milli-volt signal which is sent to the scope with a signal harness and the scope displays the resulting milli-volt reading on the screen. Some scopes have settings to change the voltage reading on the screen to a current reading, while others require that you use the amp clamps conversion table. A typical example would be 1mV = 1amp, or 100mV = 10A, etc. It should be noted that the same amp clamp that is used with digital multimeters can be used on any scope as long as you know what the millivolt to amp conversions are.

Current measurement is a very common diagnostic procedure performed on vehicles. It provides very accurate information for the testing of fuel pumps, motors, ignition coils, solenoids, relay, starters, alternators, and many other components. The amp clamp is also used when conducting a **RELATIVE COMPRESSION** test. This method of testing the mechanical condition of the engine is MUCH faster and often more accurate than using a mechanical compression gauge.

A few things that students should remember when using the amp clamp is that some have internal batteries that MUST be fully charged for proper operation. There is a "zero" calibration procedure for the clamp before using that ensures accuracy. Be sure to check with each amp clamps operating instructions. When installing the amp clamp around a wire, the observed waveform may appear "upside down" on the scope screen. If this happens, you may either reverse the amp clamp around the wire or using the pattern invert button on the scope to turn the waveform "upside down". Current should "go up" on the screen as current increases.

CURRENT RAMPING FUEL PUMPS



CURRENT MEASUREMENT
&
CURRENT RAMPING

The scope is now going to measure current by using an AMP CLAMP

The same amp clamp used on DMM's can be used with a scope

The term "**CURRENT RAMPING**" is used when observing the increase of current when testing a component. Careful observation of the shape of the current slope as current increases upon initial "turn on" can reveal important diagnostic information. Often, the number of oscillations as well as the peak inrush current is also measured and observed.

FUEL PUMP CURRENT WAVEFORM

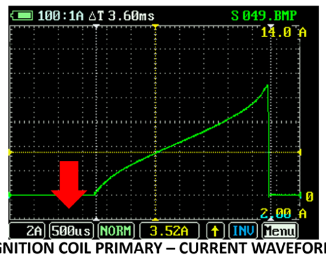
9.12ms FOR 1 REV.

1 / .00912 = 109.649 (109 RPMS IN 1 SEC)

109.649 X 60 =6,578.94 (PUMP IS RUNNING @ 6,579 RPM'S)

THERE ARE EIGHT (8) SEGMENTS ON THE PUMP COMMUNTATOR

PUMP PATTERN IS A BIT "SHAKY"



IGNITION COIL PRIMARY – CURRENT WAVEFORM

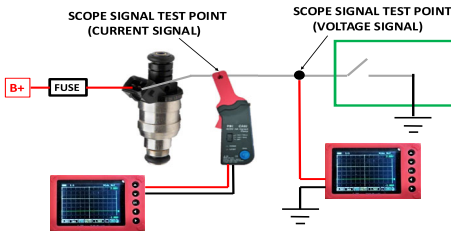
ADJUST T/DIV FOR MORE DETAIL VIEWING

DETERMINE STUDENT COMPENTENCE AND MASTERY AT THIS POINT

If your have demonstrated a basic understanding of scope setup and operation at this point, I would move on to a typical fuel injector pattern. If they have not had full understanding, it is important that you go back and remediate any topic they do not fully understand. This knowledge is **CRUCIAL** for knowing how to effectively use a scope for any test.

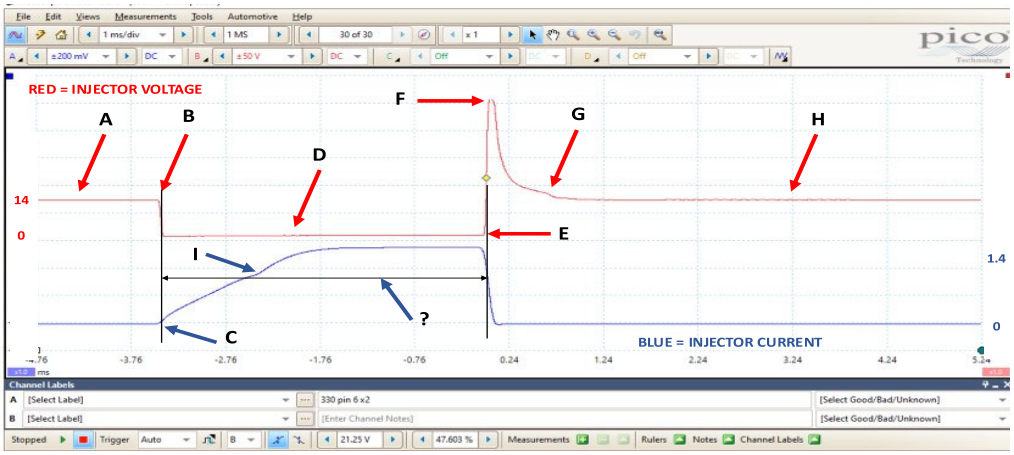
TEACHING HOW A CIRCUIT WORKS USING A FUEL INJECTOR PATTERN EXAMPLE

The intent of this section is to show instructors how to teach circuit operation using scope waveforms. In this case a typical non-GDI magnetic coil type port fuel injector is used. The pattern showing two traces below was taken with a two-channel scope with the blue trace being the voltage and the red trace being the current. A one channel scope could easily be used for this exercise. Just measure voltage and current separately.



Connect a scope to the ground side of a fuel injector to obtain the voltage signal. If desired, connect an amp clamp anywhere in either the B+ side or ground side of that injector circuit to obtain the current signal.

TYPICAL NON-GDI FUEL INECTOR PATTERN



Use the above waveform to explain to your students what is happening at each of the identified points.

A- B+ voltage is available to the injector, but because it has not turned on yet, it is equal to system operating voltage.

B- At this exact point, the computer turns "on" the injector by providing a ground path. This causes the voltage to immediately drop to zero. Current is now flowing in the injector circuit, but the injector is still not spraying fuel at this exact point.

C- When the injector is turned on, the current which was a zero, now begins to "ramp up" until its maximum potential is reached based on the resistance of the coil inside the injector. In this case, the maximum current shown is about 1.4amps.

D- This period is the time the injector is commanded to be ON by the computer. This is called "pulse width" and is measured in milli-seconds. The voltage potential is at ground while the injector is on. This answers what the blue question mark is asking for. This is the PCM's command of turning on and keeping on the fuel injector for one injection event.

E- At this point, the PCM turns OFF the injector circuit and thus, the voltage starts to go back up. How clean or abrupt the signal goes up is an indicator of the "health" of the connections and the injector.

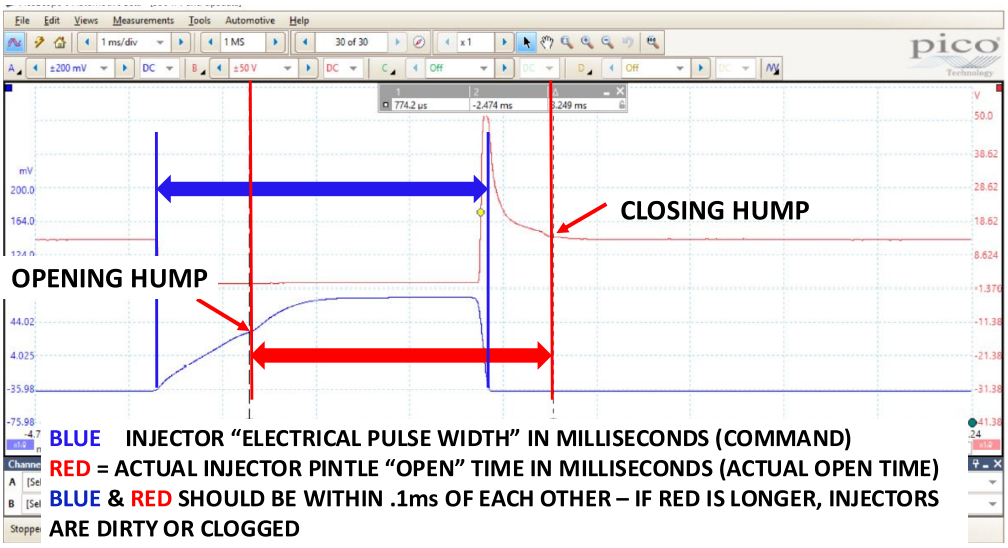
F- As we know, anytime current is flowing in a coil of wire and is turned off, an "inductive kick" is generated and that is what is being seen at this point. Depending on the specific type of injector, this induced voltage can be 40+ volts or much more. This part of the circuit will also be affected by shorted injectors or high resistance injector circuits.

G- One needs to notice a little "hump" in the voltage line as the voltage begins to dissipate after the inductive kick. This hump is created when the injector pintle which is a metal rod moves by closing and this creates a mini-inductive kick which can be seen. Therefore, even though the PCM turned off the injector, it DID NOT fully close until at the point that the voltage hump was generated. If the injector were "stuck open" there would be no hump visible at this point.

H- This represents the voltage returning to B+ operating voltage until the next time the computer turns on the injector.

I- At point I, the current starts to ramp up in the injector coil. However, it is not strong enough to start opening the injector pintle until it reaches point I. Here you see a little current hump which is caused by the injector pintle starting to move in opening. Therefore, even though the computer commanded the injector to open at point B, the pintle did not start to open until at point I. This proves that the pulse width of the injector seen on a scan tool or measured on a scope DOES NOT indicator how long the injector is open. If the injector is stuck closed, stuck open or the tip is dirty or partially restricted, the oxygen sensor will recognize either a lean or rich condition and try to make adjustments by telling the computer to change injector pulse width either richening up or leaning out the injector flow. The only method of measuring the actual open time of an injector is by measuring the time between the current opening hump and the voltage closing hump. Therefore, a two-channel scope is required to perform this test.

ARE MY INJECTOR DIRTY OR RESTRICTED??



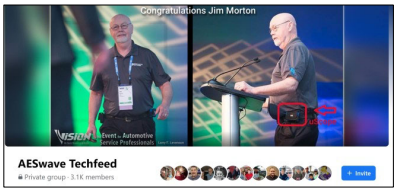
The above capture shows how to measure the actual injector opening time and compare it to the PCM commanded pulse width. This test is the only valid test to determine if the injectors are dirty or partially restricted. Both the pulse width command and the pintle opening times must be within .1mS of each other for normal operation. Greater than .1mS indicates the injectors or restricted, dirty, or electrically abnormal. The proper use of time cursors (vertical) is required to make the measurement of the actual opening of the injector (pintle humps). The injector pulse width can be indicated by using the measurement function that many scopes have or if necessary, you can also measure with cursors. The waveform must be "captured" and not "live" to properly perform this test.

THE ADVANTAGES OF USING SCOPES

Just as the procedure for determining proper fuel injector operation was discussed above, there are similar tests and observations for all the electrical components in vehicles. Accurate testing "under load" of ignition coils especially (COP coils), spark plug wires, spark plugs, starters, alternators, solenoids, relays, motors, ground circuits and much more is possible using similar procedures that were explained regarding the fuel injector. Obtaining the knowledges and test procedures for these tests requires a serious time commitment for learning as well as access to known good and known bad waveforms. There are several learning resources available to those wanting to learn the proper use of scopes. The following information lists just some of the numerous resources available.

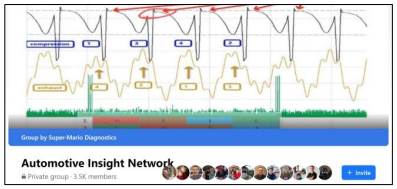
AVAILABLE LEARNING RESOURCES

FACEBOOK PROFESSIONAL FORUMS

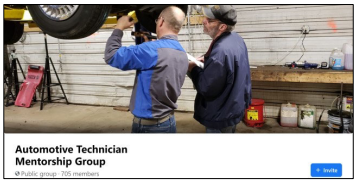


AESwave Techfeed

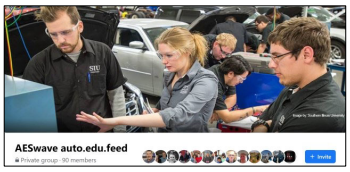
AutoMD (Diagnostics & Repair for Professional Technicians)



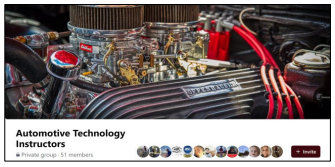
Auto Insight Network



Automotive Technician Mentorship Group

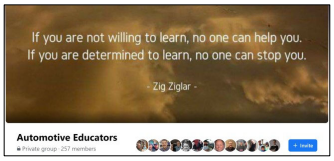


AESwave auto.edu.feed

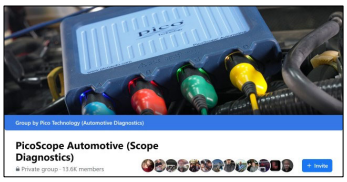


Automotive Technology Instructors

Commitment to Training

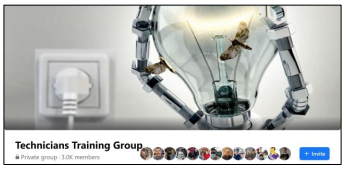


Automotive Educators

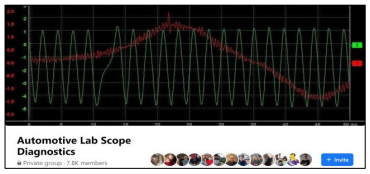


PicoScope Automotive (Scope Diagnostics

Pico Automotive Users



Technicians Training Group



Automotive Lab Scope Diagnostics

DIAGNOSTIC NETWORK

DISCUSSION FORUMS ON MANY TOPICS

STORED WAVEFORM LIBRARY

FREE TO INSTRUCTORS – BUT REQUIRES SUBSCRIPTION TO HAVE ACCESS TO LIBRARIES

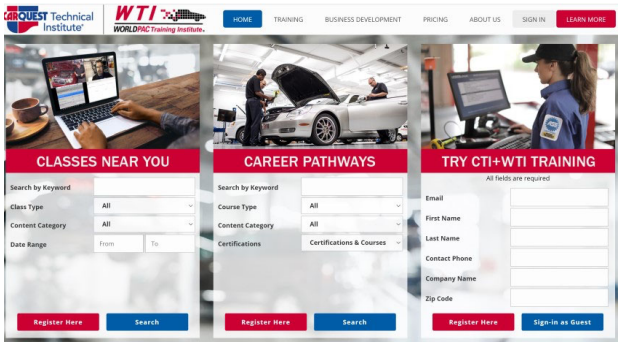
INTERNATIONAL AUTO TECHNICIANS NETWORK

DISCUSSION FORUMS ON MANY TOPICS

STORED WAVEFORM LIBRARY

FREE TO INSTRUCTORS – BUT REQUIRES SUBSCRIPTION TO HAVE ACCESS TO LIBRARIES

OTHER LEARNING RESOURCES



www.ctionline.com FREE TO INSTRUCTORS – TONS OF CLASSES & MORE

The Carquest/World Pac learning website is an awesome source for training classes on many topics held year-round. Membership is required but is offered without charge to instructors. Go to the website and fill out the membership information to be given credentials. The classes are first rate given by great instructors like Brandon Steckler, Brin Kline, Rich Falco, Jr, and many others. Take advantage of this great learning resource.

YouTube VIDEO RESOURCES

YouTube is a collection of both very good and some very questionable videos on a variety of topics. There are too many possible resources to list them completely, but I have validated the below results when entering this information in YouTube **SEARCH** box. The listed results are great sources of training on oscilloscopes, use, setup and specific testing of components and systems.

PICOSCOPE TRAINING - PICO SETUP - PICOSCOPE BASICS - PICOSCOPE CAN BUS

PICOSCOPE COMPRESSION TEST - PICOSCOPE RELATIVE COMPRESSION TEST - AUTOMOTIVE OSCILLOSCOPE

AUTOMOTIVE OSCILLOSCOPE TRAINING - AUTOMOTIVE OSCILLOSCOPE BASICS - AUTOMOTIVE PICO SCOPE

AUTO SCOPE WAVEFORMS - AUTO SCOPE WAVEFORM ANALYSIS - OSCILLOSCOPE AUTOMOTIVE DIAGNOSTICS

AUTOMOTIVE LABSCOPE - AUTEL OSCILLOSCOPE TRAINING - AUTOMOTIVE OSCILLOSCOPE TUTORIAL

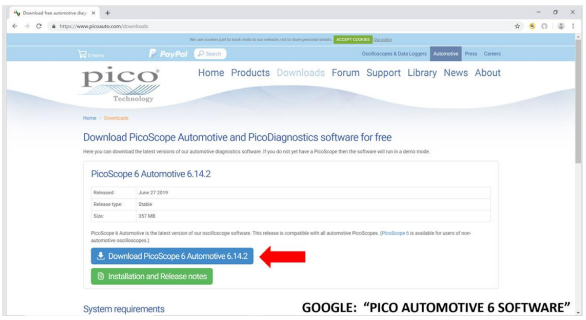
MOTORAGE TRAINING VIDEOS - CARQUEST OSCILLOSCOPE BASICS: ⟶ https://youtu.be/9Gs1rnaKO7c

AUTOMOTIVE OSCILLOSCOPE SNAP ON - SNAP ON OSCILLOSCOPE TRAINING - DELPHI YOUTUBE CHANNEL

PICO AUTOMOTIVE 6 SOFTWARE

Pico has an awesome operation software designed for Pico scope owners to operate their scopes. In addition and unknown to many, this same software can be used without owning or having a Pico scope in their possession. It is a awesome learning tool for students and technicians for those wishing to become familiar with component testing and understanding waveforms.

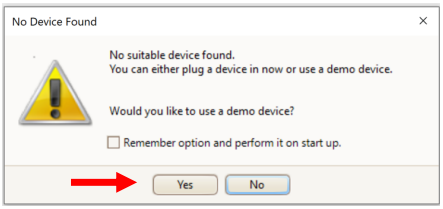
I strongly suggest that anyone interested in learning oscilloscopes download this software and learn how to use it to their advantage. To repeat, it is NOT necessary to own a Pico scope to use this software. See below information for obtaining and using the software. NOTE: It is NOT necessary to be connected to the internet to use this software once the first download has been completed..

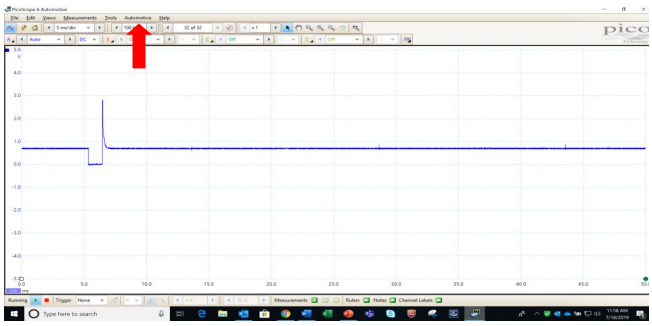


GOOGLE: "PICO AUTOMOTIVE 6 SOFTWARE"

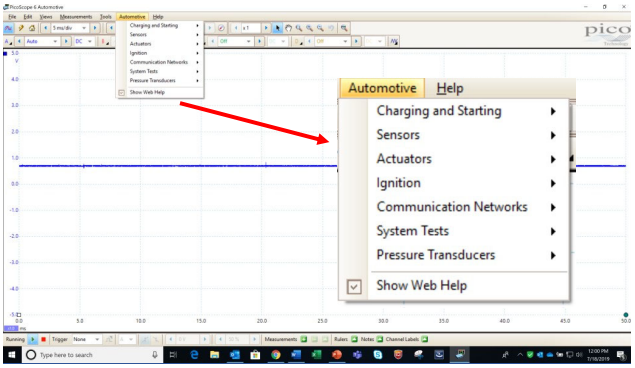
From your browser, search: "**PICO AUTOMOTIVE 6 SOFTWARE**" You will get the above page. Click on the indicated tab. After the download, you will have this icon on your desktop. Choose to put it on your bottom tool bar (as shown) for convienence.

Click on the Pico Automotive 6 icon. If you have a Pico scope connected to your computer, the "live" screen of the Pico will be displayed. However, for student learning activities, I suggest not having a Pico scope connected. Without a Pico scope connected, you will get the below message. Always click the **Yes** box when a scope is not connected.

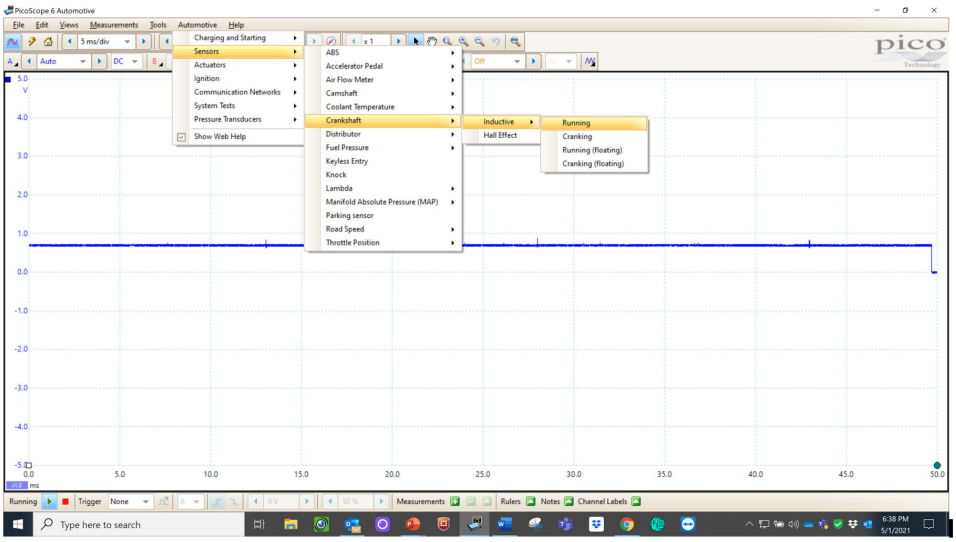




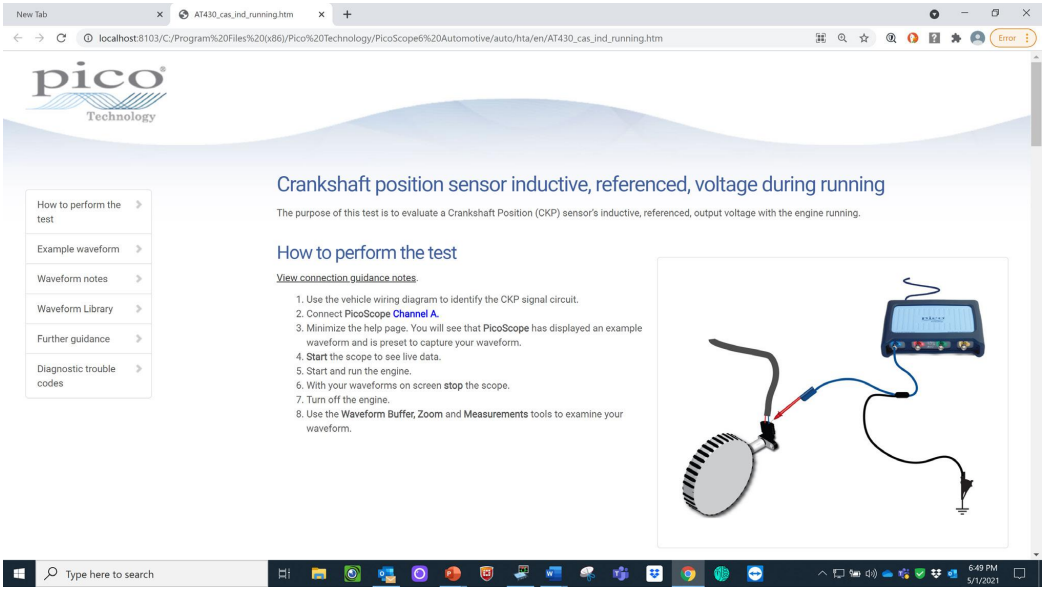
When the screen shown appears, the fuel injector waveform will appear to be "live". **NOTE: You can adjust voltage, time and trigger with this "created" injector waveform for student practice and learning. (As though the pattern was "live") Then,.....** Click on "**Automotive**" on the top tool bar as shown.



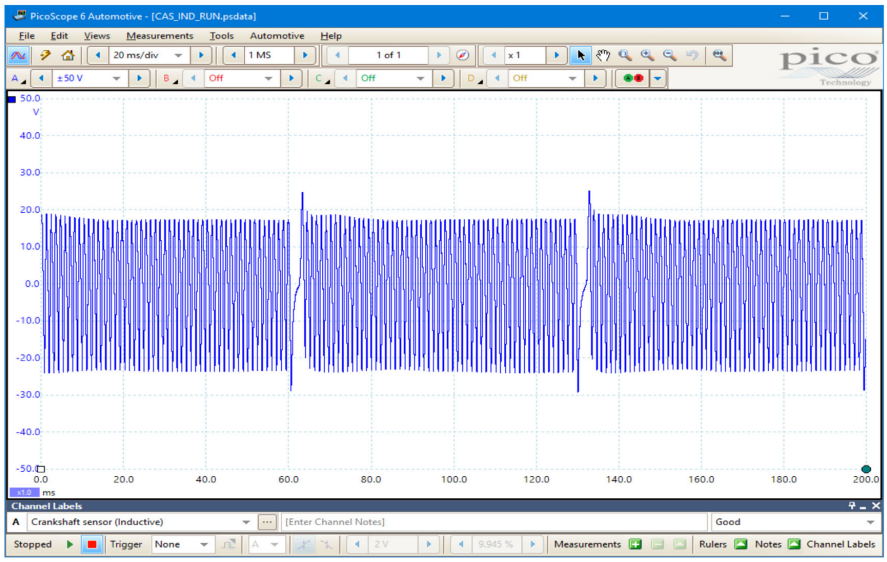
A menu appears giving you choices on which test or which component you would like to test or learn about. Each menu item has a sub-menu behind it. In this case, we are going to choose **Sensors.**



As can be seen, there are lots of choices of sensors available for learning. Here the choice path was: **Sensors, Crankshaft, Inductive** and **Running**. At this point, a captured waveform of the sensor you selected will appear as well as an instructional tutorial giving information on how to test the sensor, where to connect scope leads, suggested scope settings and much information about testing this component.



A tutorial on how to hook up the scope, suggested settings and more information is provided for this sensor.



Also, a sample waveform is provided for the senor being tested.
Additional information is also provided often listing related DTC's set by a defective component or circuit within your choice of device.

Further guidance

An inductive Crankshaft Position (CKP) sensor provides an Engine Control Module (ECM) with its primary engine timing reference signal. The ECM uses the signal to calculate the engine speed and position for accurate injection and ignition control. The signal is also used to detect engine speed anomalies from misfires etc.

An inductive CKP sensor consists of a circuit with a wire coiled around a magnet. The sensor is accompanied by a pulse wheel, typically arranged about the flywheel circumference. The pulse wheel passes through and disturbs the sensor magnetic field inducing a circuit voltage. The induced voltage depends on engine speed: the faster the pulse wheel rotates, the greater the magnetic field disturbance.

When either the tooth or gap centres align with the sensor, there is an equal and opposite magnetic field disturbance and no voltage is induced. Conversely, as either a tooth leading or trailing edge aligns with the sensor, the magnetic field disturbance and induced voltage are greatest.

Positive voltage is produced when a tooth leading edge is closer than its trailing edge, and a negative voltage is produced in the opposite case.

The missing tooth on the pulse wheel provides the main timing reference mark. As the gap passes through the magnetic field, there is a period of reduced disturbance and voltage. Furthermore, the trailing and leading edge of the teeth that immediately precede and follow the gap are further apart, thus they produce a larger net magnetic field disturbance and induced voltage.

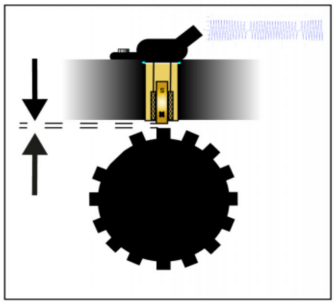
The CKP sensor signal is critical to ECM operation and it will not start or run an engine if the signal is missing or faulty. Therefore, the sensor can cause engine cranking but not starting or engine cutting out symptoms.

Possible faults are:

- Short or open circuits and high resistance in the sensor coil or circuit.
- Reduced sensor output due to excessive dirt and detritus on the sensor housing or pulse wheel.
- Incorrect fitment or operation of the sensor or crankshaft components, causing:
  - excessive gaps between the sensor and pulse wheel
  - damage to the sensor housing or pulse wheel
  - excessive crank or flywheel movement or vibration

A two pin CKP sensor and ECM circuit can be arranged in two ways, with either:

- a constant reference, non-floating, voltage to one side of the sensor and the sensor output signal on the other; or
- a floating voltage, with mirrored output signals on each side of the sensor.



Diagnostic trouble codes

Selection of component related Diagnostic Trouble Codes (DTCs):

P0016 Crankshaft Position - Camshaft Position Correlation Bank 1 Sensor A

P0017 Crankshaft Position - Camshaft Position Correlation Bank 1 Sensor B

P0018 Crankshaft Position - Camshaft Position Correlation Bank 2 Sensor A

View more

TEACHING DSO'S TO MY STUDENTS

Pico 6 Automotive software provides a wealth of information to scope users of all proficiencies. It is a GREAT learning tool that is often not used by users, or many do not know that it exists.

PICO 6 AUTOMOTIVE SOFTWARE (FREE DOWNLOAD)

INFORMATION ON THE FOLLOWING TOPICS:

- CHARGING & STARTING SYSTEM TESTS
- SENSORS
- ACTUATORS
- IGNITION
- COMMUNICATION NETWORKS
- SYSTEM TESTS
- PRESSURE TRANSDUCERS

TUTORIALS ON:

1. HOW TO PERFORM THE TEST WITH A SCOPE
2. SUGGESTED SCOPE SETTINGS YOU SHOULD USE
3. WHERE TO HOOK UP THE SCOPE LEADS
4. SAMPLES OF GOOD AND BAD PATTERNS
5. COMMON DTC'S ASSOCIATED WITH THE COMPONENT BEING TESTED

ADDITIONAL PICO LEARNING SUPPORT

Go to: **picoauto.com/library/training** Tons of valuable training materials including videos, PDF's, classes, etc.

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ADDITIONAL LEARNING ARTICLES AND RESOURCES

https://www.automotivetestsolutions.com/escope-training

Articles:

- Automotive Electronics 101
- Automotive Oscilloscopes
- Common questions asked about scope speed
- A Shift in Strategy
- Oscilloscope comparison chart
- Diagnosing a no-start issue on a Chrysler Town and Country
- Diagnostic Trouble Code (DTC) by the WIRE
- Direct Injection BMW Low Power
- Getting Synced
- Cascade Diagnostic
- Air Strike
- Making the Shift
- Understanding Magneto Resistance Element
- Understanding Fuel Injector Waveforms Tutorial
- 2004 Motor Magazine Top 20 Tool Award Write-Up
- Dealing with customer concerns related to electronic throttle bodies
- Timing is everything with internal combustion engines
- Diagnosing Transmission Control
- Digital Storage Oscilloscopes
- Displacement on Demand (DOD)
- The Fourth State
- Understanding Electric Motors
- Understanding Voltage Drops

USEFUL HARDWARE FOR TEACHING SCOPES

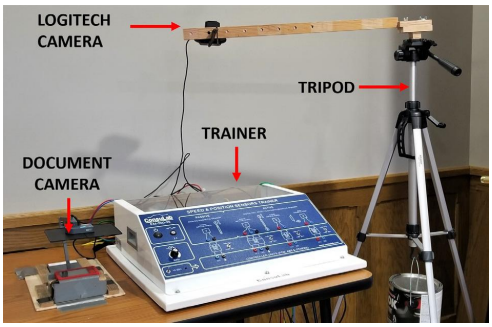
There are many useful items that can be used to assist you in presenting scopes to your students and enhance the quality of the presentation and hands-on activities. Many instructors already have some type of document camera at their instructors desk like an Elmo. Most of these units can be used to focus in on the scope you are using for your presentation. Other scopes (like Pico, Autel and some Snap-on) can be connected to a video display or monitor. Some instructors have an adapter to use their cell phone connected to a video monitor or computer. There are several methods of displaying just one scope at the instructors desk.

Below are some video display options. Elmo's can be expensive, but the IVEPO Ziggy camera is very affordable and does a great job using your laptop or desktop.

IVEPO Ziggy HD-Plus 8.0 megapixel (USB)
"home-made" base and positioning guides

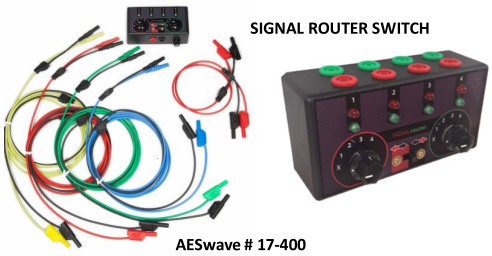
IVEPO VZ-R Dual Mode 8.0 megapixle (HDMI/USB)

This is one typical example of a setup for showing signals obtained from a trainer (trainer operation and adjustments can be displayed), then having the signals sent to a uScope which can be seen "live" by students using the document camera. This setup is not expensive and uses a standard Logitech "Go-Pro like" camera on a homemade extension boom mounted to a camera tripod weighted with a paint can. The uScope is displayed using the Ziggy document camera and instructor switches between cameras to explain what is being done. The signal can also be sent out on the distribution harness to students' scopes which in turn have to be adjusted by them to view the pattern just as though they had their scope connected "live". It can be an awesome teaching tool.



SIGNAL ROUTER SWITCH

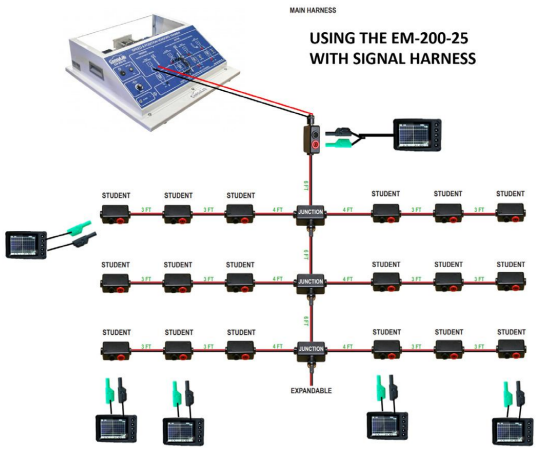
This device can be used to input multiple signals into a scope (and/or harness) controlled by the instructor. It can be used with a one-channel scope to view up to four different signals without having to make any wiring changes. It can also be used to insert faults with high or open resistance in either the positive signal circuit or the ground circuit because each wire is independently switched using a rotary dial. Although not a necessity, it provides easy access to multiple signals without difficulty.



AESwave # 17-400

SIGNAL DISTRIBUTION TO MULTIPLE STATIONS

It is a great advantage to be able to send out a single signal to multiple locations where each student (or groups of students) have a scope that is able to see the signal being distributed. The **SIGNAL DISTRIBUTION HARNESS** (available from ConsuLab) does just that. It is configured to be able to accommodate multiple types of layout or classroom designs. The harness contains different elements that are interconnected using standard BNC connectors. There are multiple signal access points where students connect their scopes to the harness. This harness has proven successful in distributing the majority of available signals to 30 uScopes without significant signal degradation. Signal sources can be obtained from ConsuLab trainers, signal generators or vehicles. Both voltage and current signals can be clearly observed.



ConsuLab offers extensive training on the uScope including:

uScope BUTTONOLOGY (HOW TO USE ALL THE MENU FEATURES)

HOW TO ACCESS & USE THE uScope STORED WAVEFORM LIBRARY

HOW TO USE FULL FUNCTION OF THE VERTICAL MENU FEATURES

HOW TO USE CURSORS, TRIGGERS, METERS AND SCREEN SETTINGS

HOW TO SAVE & STORE WAVEFORMS, THEN INSERT INTO ASSIGNMENTS

HOW TO OBTAIN WAVEFORMS FROM CONSULAB TRAINERS

DESIGNED TO BE A "HANDS-ON" CLASS WITH YOU HAVING A uScope

Contact your ConsuLab representative for more information

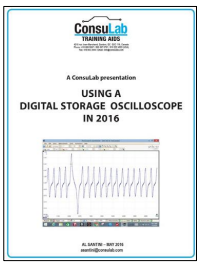
TEACHING DSO'S TO MY STUDENTS

REQUEST A COPY OF THIS CLASS HANDOUT AND USE THE CONTENT TO ASSIST YOU IN TEACHING YOUR STUDENTS

THIS DOCUMENT DISCUSSES WHAT A SCOPE IS AND HOW TO READ IT

REQUEST A COPY OF THIS CLASS HANDOUT AND USE THE CONTENT TO ASSIST YOU IN TEACHING YOUR STUDENTS

THIS DOCUMENT DISCUSSES HOW TO USE A DSO WITH YOUR STUDENTS



Be sure to ask for copies of the above class handouts in addition to this one to assist you teaching scopes to your students. We hope you have found this class and handout helpful to you and your students.

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TRAINING AIDS

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