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Current measurement tools and process

My experiences with current measurement goes all the way back to the dark days of off-car ECU testing, initially relying on load simulation with the ATP network 500 terminal. It became painfully obvious that load simulation could not fully, and accurately, test the current path through various components, especially ignition and injector circuits. Recent increases in mechanical devices driven by PWM makes it ever more essential that the relationship between command and response is fully understood.

Let's begin with some absolute basics:

Voltage is electrical pressure, or potential difference. Voltage differential cannot exist without a complete circuit, including a load. The unit of measurement is the volt.

Current is electrical flow, and cannot exist without a energy-consuming load. In a conventional circuit, a change in voltage will result in a change in current. The unit of measurement is ampere.

In a good circuit, virtually all of the load should be taken by the intended consumer. The unit of load is the watt.

It should therefore be possible to predict the response in a circuit by applying Ohm's Law. However, current will be affected by mechanical or hydraulic resistance, this is a very useful tool in assessment of functional performance of actuators and fluid pumps. In complex vehicle control circuits, it's not that straight forward. However, the tools and process do not change.

Vehicle components vary in nature, they do however share one common fact, they apply a resistance in a circuit, and sometimes it's so small or switched so quickly that it cannot be measured accurately, without specific high-performance current clamps.

When a load is applied in a circuit, the voltage will change very quickly. This depends how the load is switched, the current change is much slower in response. This phenomenon depends on the available pressure, flow rate and load.

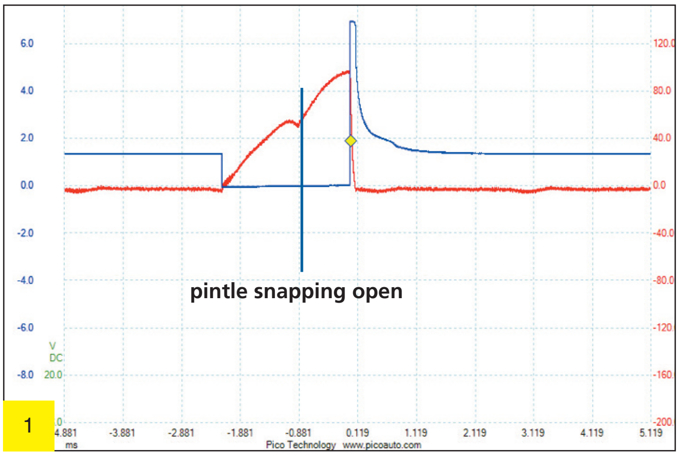
Most vehicle components fall into the category of inductors or actuators. Essentially, they are coils, the nature of which carry considerable load when introduced into a circuit.

They can be either power or ground switched, conventionally or by discharging a capacitor. The onset of complex control motors in vehicle systems demands a more responsive means of switching whilst, reducing where possible the current through the PCM. This method is referred to as pulse width modulation (PWM). By pulsing a circuit, the duty cycle controls the current ramping. It also provides accurate response and feedback.

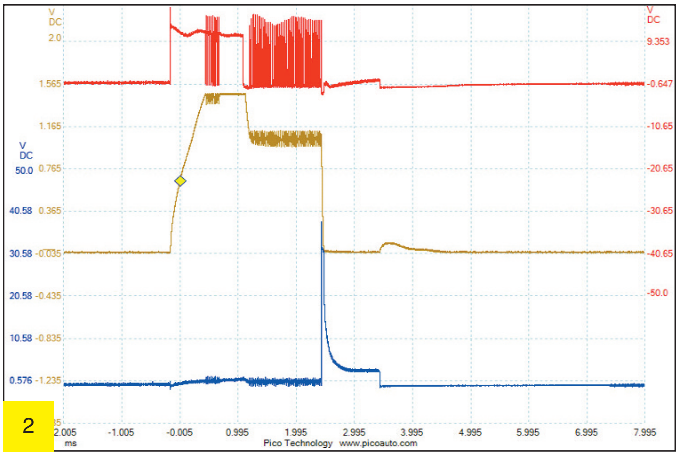
Examples that require ultra-rapid response are, CR injectors employing capacitors to multiply the voltage from a nominal 15V to 80-120V. This has the added effect of increasing the rise time of current flow, and mechanical response. Poor old Ohm's law looks a little vague.

So what is the critical criteria when evaluating actuators and what tools actually work, and where can I get them?

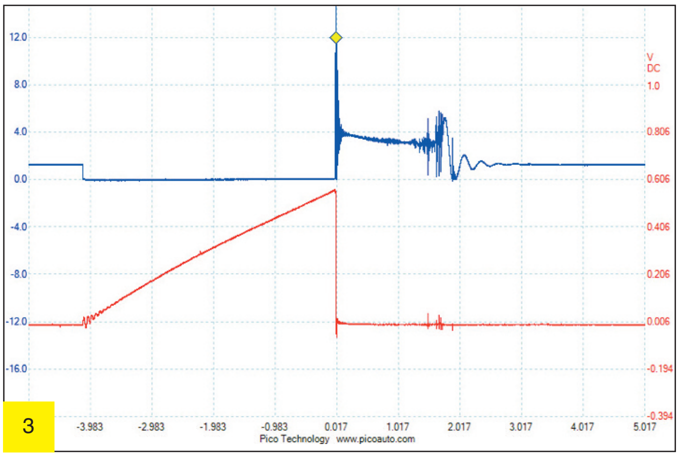
The Correct Current profile is critical, but its only part of the total circuit criteria. The other components are:



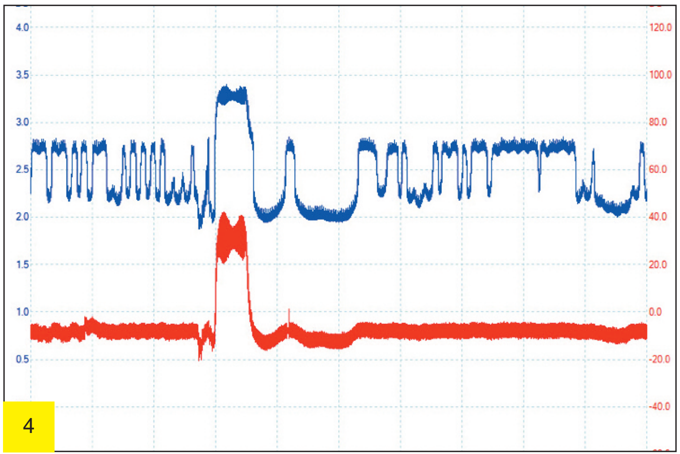
Simple Ground-On Injector
Note the voltage drop and somewhat slower current ramp, the kink represents the pintle snapping open, effecting the inductance in the injector winding.



A Power-On Injector
Note a much more rapid increase in current path, this is due to the discharge of a capacitor. To protect the component from damage current control is introduced via the PCM, rapid switching of the voltage limits the current flow during the extended open period.



Ignition Current Profile
Note how rapidly the current is interrupted, this provides excellent induction and good high tension energy, measured in joules.



Wide Band Sensor
Current range is volts, divide by 10 = milli amps. This takes a special current clamp, the K2 (0 – 500ma)., that is not available from automotive sources.

1 - current peak value (amps)
2 - rise time (m/s)
3 - induction (milli/henry)
4 - mechanical, hydraulic load

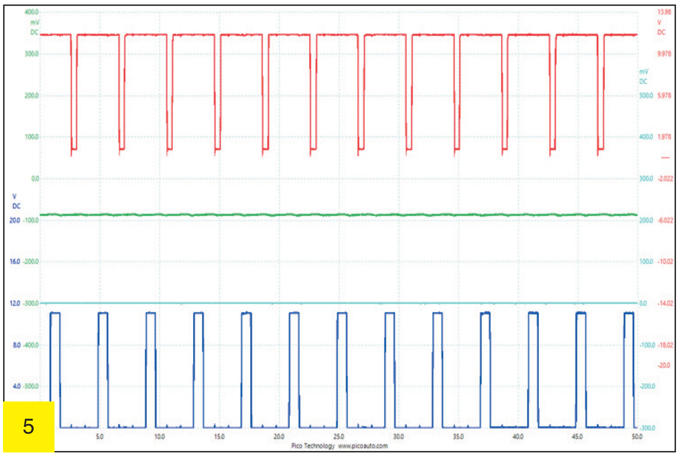
Rise time relates to the resistive value and the available pressure. Ever try to get a golf ball down a drinking straw! The unit of induction is the Henry. This applies especially when testing the rate of response within an injector, against the control on signal. It takes into account voltage, current flow, current rise time, speed of current interruption, and the electromagnetic field effect. Movement within the magnetic field and temperature also effects rise time.

Theoretically, voltage and current should respond simultaneously. You will, however, experience offset in high frequency response. Current flow is equal throughout the entire circuit, so the opportunity of measurement is quite flexible, through the control fuse or power relay for example.

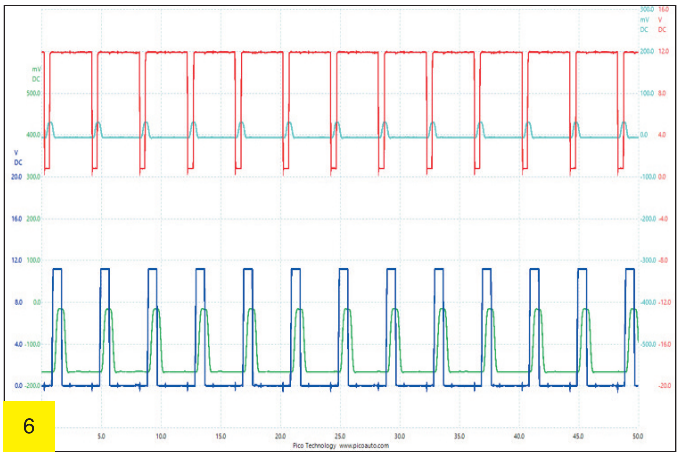
The use of an inductive current clamp (it's actually a hall device) ensures a non-intrusive means of measurement. Sensitivity rise time and frequency response of the clamp is vital. A current clamp not only provides accurate measurement of peak flow, but the effectiveness of the current interruption, this of course is imperative for good induction. This is the responsibility of the power transistor within the PCM, or ignition coil as with the latest direct ignition systems.

My tool of choice is a PicoScope, with a range of current clamps. The critical observation will be the profile or shape. You won't find this data in any books it's taken me over 30 years to find the experience, confidence and knowledge in current testing.

I hope this helps and clarifies the inaccuracies I earlier referred to, current is a wonderful tool, its quick, non-intrusive, and confirms the total circuit condition.



A6 Runner Flap Control
The control is a moderatley high frequency duty contolled motor. The PicoScope clamp can't measure current quickly enough and the aqua and green traces are not showing the true condition



A6 Runner Flap Control
The current is now in complete sync with the control signal via the PCM, even at this frequency, and with the correct amplitude.