Automotive Electronic Functional Test Using Agilent System Components

Application Note

There are many types of electronic modules in automobiles today and new ones are springing up rapidly. In many cases, low frequency modules (i.e., ones without RF capabilities) can all be tested using a single system component architecture. This application note describes how best to use Agilent System Components to create a re-usable system tuned for low frequency automotive electronic functional test.

Of the many electronic modules found in cars, here are a few of the most common:

- Powertrain – engine control, transmission control
- Body – lights, chimes, door locks, windows, windshield wipers
- Anti-lock Brakes (ABS)
- Airbag

Table 1 lists some of the most important characteristics of these modules. Note that the number of pins that must be exercised during test is relatively small compared to data acquisition applications—fewer than 300. Power requirements are similar too. For ABS, Variable Reluctance Sensors or other isolated AC voltages must be generated. These signals are low frequency, just like the Cam/Crank/TDC/Knock signals required by engine/powertrain control modules. Body and ABS modules can require the driving of some high current loads, while Engine Control Modules need to handle high flyback voltages. Still, there are few if any RF signals needed, so there is no need for expensive RF test instruments.

Module	Number of pins	AC stimulus	DC stimulus	Voltages	Currents
Powertrain	100-300	4-8 waves	8-32 dacs	12-48 V	1-8 A
Body	50-150	2-4 waves	4-8 dacs	12-48 V	1-30 A
Airbag	5-80	0	2-4 dacs	12-48 V	2-8 A
ABS	25-50	4 waves	0-2 dacs	12-48 V	10-30 A

Table 1.
Comparison of characteristics of various automotive electronic modules

These modules all have some similar characteristics that allow them to be tested using a single test system if it is architected properly. The subsystems that are required are:

1. Computing and I/O (LAN/USB/GPIB)

2. Serial Communication (e.g., CAN, LIN, ISO9141)

3. Low frequency Stimulus Instrumentation (D/A, Arbitrary Waveform)

4. Low frequency Measurement Instrumentation (DMM, Digitizer)

5. Load and Stimulus/Measurement switching

6. Device Under Test (DUT) DC Power

7. Mass Interconnect

Let's look at each of these in turn.

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Computing

Generally speaking, functional test systems require computers as the central controller. The most common choice today is the venerable PC running a Microsoft® O/S such as Windows® 2000 or XP, although it is certainly possible to use other types, including real-time controllers or Linux. The choice is a natural one because of the huge worldwide investment in the PC/Windows platform, which provides excellent price/performance. In some cases, when it is undesirable to have a PC on a production line for security reasons, equipment can be controlled by Programmable Logic Controllers (PLCs), which use ladder logic to achieve control, but this can be difficult to do since test instruments normally need to have ASCII commands sent to them over a bus such as LAN, USB or GPIB. An alternative to a PLC is an instrument that actually has a computer built-in, such as an Agilent Infiniium oscilloscope. Such an instrument can be used as the system controller. However, most test racks use either a standalone rack-mounted PC or an embedded PC in a cardcage such as VXI or PXI. Standalone PCs generally cost much less than the equivalent embedded PC and also have plenty of room for peripherals inside, so they are the more common choice. Agilent does not offer PC's, either embedded or standalone, but uses Advantech Industrial PCs (**www.advantech.com**) in many of its platform and custom test systems. Industrial PCs offer configuration stability (a given configuration stays constant longer than a commercial version) and a large number of I/O slots for expansion capability. They are also rack-mountable, in contrast to a desktop PC which is usually a challenge to mount in a rack.
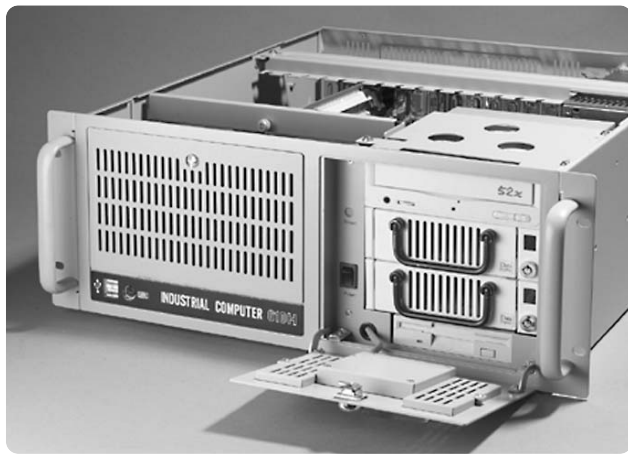

Figure 1.
Industrial Rack-Mountable PC

As for I/O, all new instruments from Agilent are being released with LAN and USB interfaces. LAN provides an effective and inexpensive way to transfer data among the instruments. Agilent I/O libraries provide an easy and industry standard way to connect instruments to the PC through a hub, switch or router. Figure 2 (below) shows how LAN can be the backbone of your system, providing connectivity to virtually any instrument.
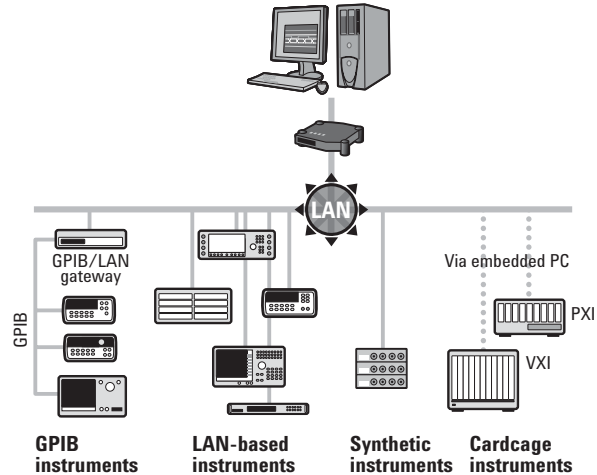

Figure 2.
LAN as the backbone of a test system

Serial communications

Modern electronic modules have serial busses interconnecting them. The protocols in common use are CAN, LIN, ISO9141 and J1850, but there are many more. These serial interfaces are used for several purposes:

1. In operation in the vehicle, they inform a central controller that they are alive and functioning, and can provide run time transfer of sensor information (wheel speed, temperature, etc.) to a host controller. Serial protocols are also used for field diagnostics such as service bay "on board diagnostics" (OBDII).

2. During manufacturing test, they can be used to activate built-in self-test (often called BIST or DUT-Assisted Test) routines that isolate one section of the module at a time so that the entire module does not have to be running in its operational mode in order to perform tests. This is a real time saver. Companies that do not provide BIST routines typically have test times that can take several minutes, compared to about 10-20 seconds for modules having BIST.

3. At final test, operational code can be downloaded into the modules.

Although Agilent does not currently offer serial communications products, many small companies do offer good solutions. One such company is Engenius, of Livonia, Michigan. The Engenius Multicomm III/s has been used in the Agilent TS-5400 Series II automotive functional test system for many years. There are also PCI plug-in cards and other standalone boxes available. For additional information see **www.EnGenius.com.**
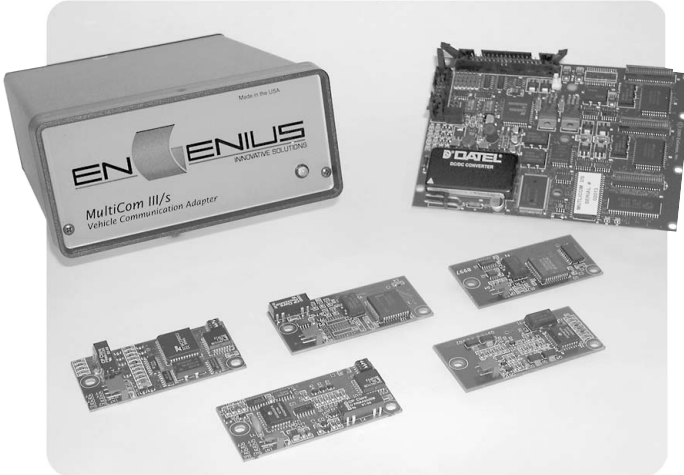

Figure 3.
Engenius Multicomm III/s (with box enclosure removed) with personality modules to handle various serial protocols

Low frequency stimulus instrumentation

In automotive electronics, it is often necessary to create many dynamic (AC) waveforms and many static (DC) voltages at the same time, even when using BIST routines. For example, in a powertrain electronic module, it is necessary to generate Cam, Crank and Top-Dead-Center signals which are phase locked, and a knock signal. Oxygen sensors, throttle position sensors and other sensors are often simulated with programmable DC voltages. Thus, several arbitrary waveform (Arb) channels and several D/A converter (DAC) channels are required. The 34980A can be used for these applications, thanks to its 34951A 4-channel isolated DAC card with downloadable sequence memory, allowing it to be used as both DACs and Arbs.

An Agilent tutorial series on the web shows how to download Cam/Crank/TDC waveforms to the 34951A 4-channel DAC card. See **www.agilent.com/find/waveforms.**

Low frequency measurement instrumentation

A 6.5-digit digital multimeter (DMM) is the most obvious measurement instrument needed by a test system. Not only is it good for taking fast DC and AC voltage, current and resistance measurements for testing the DUT, it also serves as a diagnostic tool to verify switch paths within the system. In most cases, a relatively inexpensive DMM such as the 34401A or the one that is built into the 34980A is sufficient. However, it is wise to not rule out the more expensive 8.5 digit 3458A if a digitizer is also needed. The 3458A can be used as a digitizer for measurements up to about 100K Sa/s. As a dual-purpose instrument (voltmeter and digitizer), it can save rack space and cost over the use of standalone digitizers or oscilloscopes.

Testing of engine control modules typically requires the measurement of inductive flyback from ignition coils (~450 volts) and fuel injectors (~80 volts). These are low energy voltage spikes, but the high voltages require some special care. Since 34980A relays can handle 300V with no problem, the 80 volt spikes from the fuel injectors are easily measured. However, ignition coil flybacks require attenuation before they can be measured. One good way to do this is to add an attenuator to a system using the 34980A breadboard card. A simple resistive divider can be used, or a more exotic solution can be obtained by putting a dual-range attenuator on the card that attenuates voltages above say, 14V, and leaves them alone under 14V. In this way, you can get full accuracy on saturation voltages while still being able to measure the high voltage flyback at somewhat reduced accuracy.
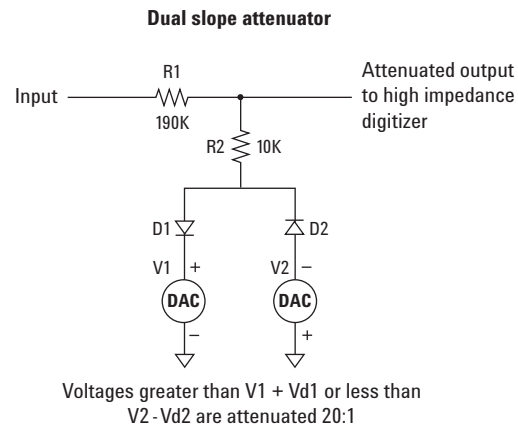

Voltages greater than V1 + Vd1 or less than
V2 - Vd2 are attenuated 20:1

Figure 4.
Typical circuit for breadboard card to allow measurement of high voltage flyback pulses from fuel injectors and ignition coils. The DACs can be on-board voltage sources, or the 34951A card DACs can be routed to the Breadboard card.

Load and measurement switching

Another facet of automotive electronic functional test is the requirement to attach loads to the outputs in order to simulate the loads found in a real automobile. These can be light bulbs, solenoids, resistors, motors and even other electronic modules. This means that a physical space needs to be created in the test system for mounting of such loads. This can be done in a number of ways. Card cages that are large enough to hold relays and loads can be devised, as is done in the Agilent TS-5400 Series II test system's "switch/load unit" (SLU). The SLU is a VME enclosure with a special backplane, and interfaced to the PC via a parallel port. Special relay cards capable of handling the high load currents (2-30 Amps) were developed. In many cases, the required loads could be placed directly on these load cards. This box also served as a place for instrument switching. Alternatively, loads can be mounted on a slide-out load tray, with cables run to the switching system.

Today, with the Agilent 34980A switch/measure unit, much of the functionality previously done in the TS-5400's SLU can now be moved into a standard product. The 34980A can handle load currents up to 5A. Higher currents drawn by motors and light bulbs must still be handled externally, however the 34980A offers the capability of driving such external relays via the breadboard card. A number of latching and non-latching armature relay cards are available for the 34980A to handle load channels.
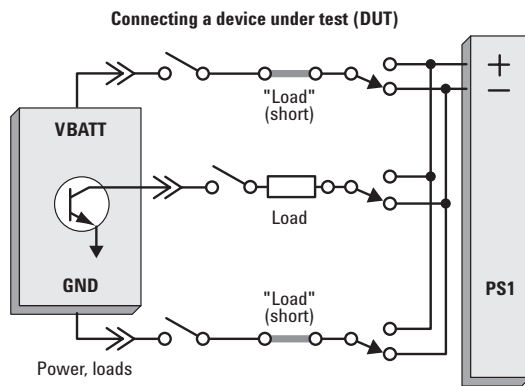
It is necessary in any test system to apply static and dynamic voltages and currents to various pins on the device under test (DUT) and then measure the response on other pins, usually with a DMM and an oscilloscope or digitizer. In order to maximize the re-use potential of such instruments while keeping test system costs as low as possible, a matrix switching architecture is often used. A full m x n matrix that would allow any point on the DUT to be connected to any system resource would be very large and expensive. However, if BIST routines can be used to select only certain sections of the module, an "m" x 8 x "n" matrix can be used, allowing 8 single-ended or 4 differential measurements to be made at once.

Measurement and stimulus relays usually do not need to be high current, and can thus be implemented with reed relays or FETs, providing high speed switching which helps to improve throughput, an important consideration in high volume manufacturing test. Load relays typically require armature relays, which are by nature slow (on the order of 10-20 ms to close and again to open). The 34980A provides all three types of relays in various configurations (general purpose, mux and matrix), providing maximum flexibility.

Figure 6.
"m" instruments x 4 2-wire busses x "n" DUT pins

Figure 5.
Typical load switching in an automotive electronic test system. Loads can be physical parts such as light bulbs, resistors or motors as indicated by the box in the center, or they can be simple wires ("shorts") as shown at the top and bottom, which is a handy and consistent way to connect power supplies to the DUT. The SPDT relays on the right can be omitted if reverse polarity is not needed.
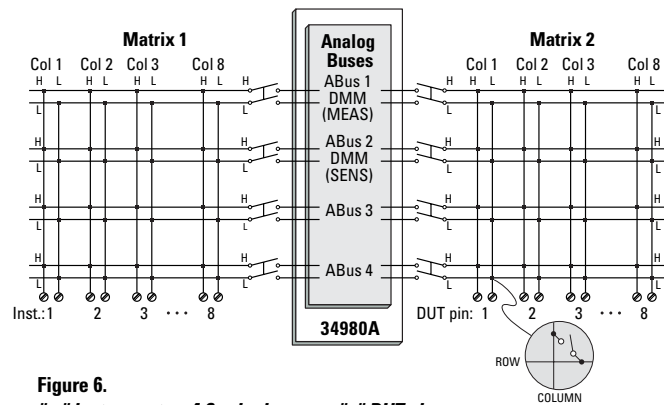
DUT power

In a functional test system, the DUT must receive DC power in order to operate. Often, this supply voltage must be stepped to a number of different levels in order to verify the electronic module's response to low or high battery conditions. In a test system, these steps need to execute quickly so that power supply settling time does not become a bottleneck. It is also sometimes desirable to provide a second supply dedicated to the loads. Other voltages are needed occasionally for line automation control. A good system component, then, must be a small, multi-output programmable supply that can respond to commands quickly and that has outputs that can change quickly. The N6700A power supply fills these requirements admirably.

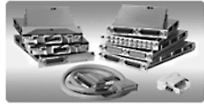| Parameter	Agilent N6700A/N6752A	Typical system DC sources
Command Processing Time	< 1 ms	20 to 50 ms
Output Response Time	< 4 ms to 50 mV	50 to 500 ms to <1%

Figure 7.
The N6700 is an excellent choice for a multi-output programmable DUT power supply

Mass interconnect

Getting the system resources out to the DUT in a way that allows changeover from one DUT to another requires a mass interconnect scheme. This is best implemented using either Mac Panel or Virginia Panel standard connection schemes. Virginia Panel offers a set of pre-assembled cables that can be used to connect the 34980A to their terminal blocks. See **www.vpc.com/agilent/** for details.

Quick, Convenient Connections

VPC provides ready-to-use cable assemblies to connect between standard Agilent instruments and the VPC receiver. One end of the cable is connected to the Agilent instrument; the other is installed into the receiver to make a fast, efficient connection. Use them to mass interconnect your system and make the most out of your Agilent application.

Cable Assemblies for Agilent 34980A Instruments
Download VPC Cable Solutions for Agilent 34980A Instruments

Agilent Card	20" RCVR Cable Assembly	36" RCVR Cable Assembly	Mating ITA Module	36" ITA Patchcord	Patchcord QTY
Multiplexer Modules					
34921A	540 111 040 140	540 111 040 240	510 151 105	720 109 101	102
34922A	540 112 020 140	540 112 020 240	510 151 105	720 109 101	158
34923A	540 111 040 140	540 111 040 240	510 151 105	720 109 101	102
34924A	540 112 020 140	540 112 020 240	510 151 105	720 109 101	158
34925A	540 111 040 140	540 111 040 240	510 151 105	720 109 101	102
Matrix Modules					
34931A	540 111 020 140	540 111 020 240	510 151 105	720 109 101	102
34932A	540 111 020 140	540 111 020 240	510 151 105	720 109 101	102
34933A	540 111 020 140	540 111 020 240	510 151 105	720 109 101	102
General Purpose Modules					
34937A	540 111 030 103	540 111 030 203	510 108 126	720 101 101	94
34938A	540 111 020 103	540 111 020 203	510 108 126	720 101 101	94
RF & Microwave Modules					
34941A	540 129 010 109	540 129 010 209	510 108 132	710 102 137	20
34942A	540 128 010 132	540 128 010 232	510 108 179	710 106 434	20
34945A	540 010 020 101	540 010 020 201	510 108 101	720 101 101	10
34946A	540 130 010 107	540 130 010 207	510 108 111	710 102 137	6
34947A	540 131 010 107	540 131 010 207	510 108 111	710 102 137	9
System Control Modules					
34950A	540 116 020 140	540 116 020 240	510 151 105	720 109 101	158
34951A	540 019 020 101	540 019 020 201	510 108 101	720 101 101	51
34952A	540 019 020 101	540 019 020 201	510 108 101	720 101 101	51
Mainframe (Analog Busses)					
34980A	540 011 020 101	540 011 020 201	510 108 101	720 101 101	10

Figure 8.
Virginia Panel web page[1]

[1] *Used with permission, Virginia Panel Corp. All legal and privacy restrictions apply. See* ***http://www.vpc.com/privacy_statement.htm***

Putting it all together

Figure 9 shows an example of a test system architecture that can be used for many automotive electronic modules. The matrix switch allows many measurement devices to be connected to the DUT via the 34980A's 4-wire differential bus. The armature switches are used for loads, and the isolated DAC cards are used for DC and AC stimulus. The N6700 power supply is used to provide DUT power. In this way, the 34980A forms the core of the system. An external PC would be used to control all devices using LAN. A 3rd party serial communications interface would be used to provide CAN or other serial communications to the DUT. All wires leading to the DUT would pass through a fixture interface such as a Mac or Virginia Panel (not shown for clarity).
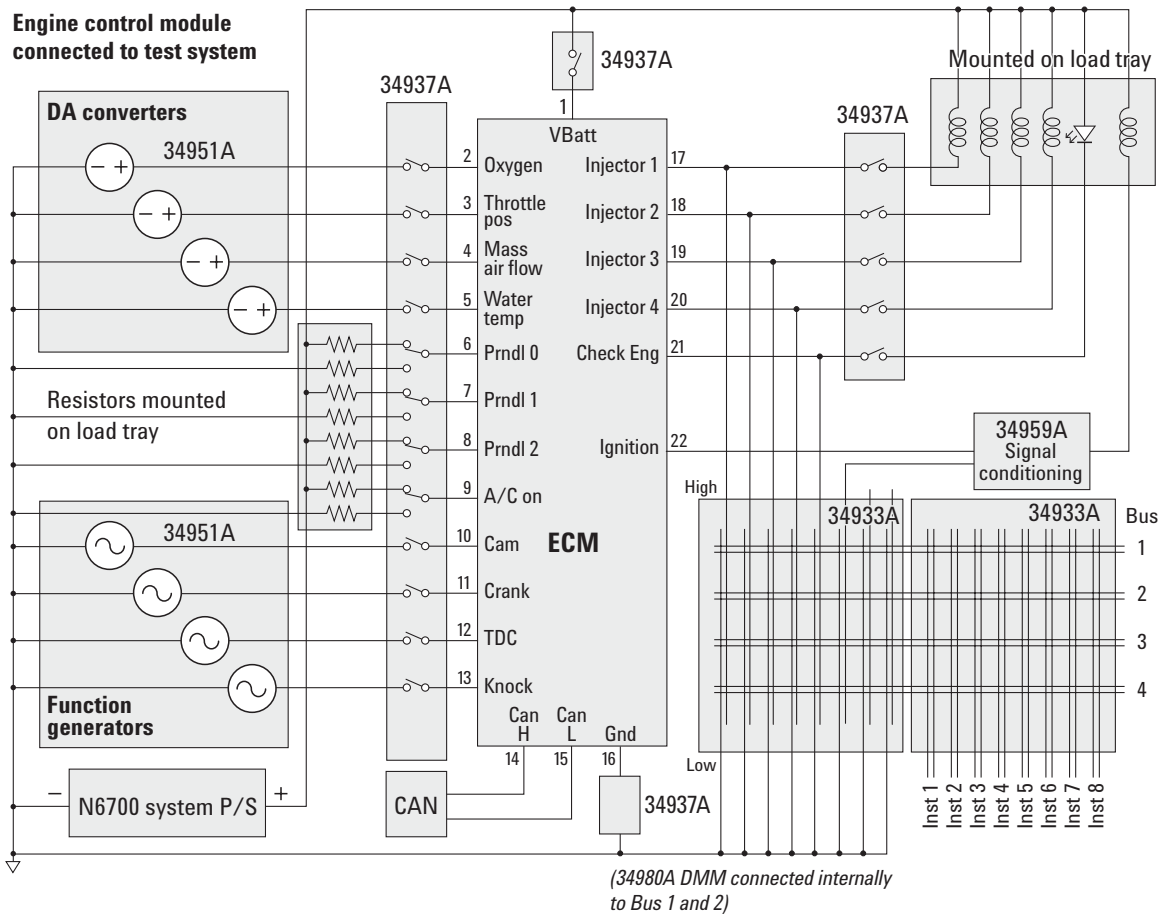

Figure 9.
Typical design of an automotive electronic functional test system. In this example, only one 4x8 bank of relays was shown on the 34933A matrix. Add more banks and more cards to be able to connect to more DUT pins or more instruments. "Inst1-8" can be external instruments or cards internal to the 34980A, such as the counter/timers.

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For more assistance with your test & measurement needs or to find your local Agilent office go to www.agilent.com/find/contactus

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