APPLICATION NOTE

Automotive Electrical Tests with E36150 Series DC Power Supply

Quickly evaluate and gain insight into the performance of your automotive ECU.

KEYSIGHT

Related Products

- Keysight E36154A 800W Autoranging Benchtop Power Supply
- Keysight E36155A 800W Autoranging Benchtop Power Supply
- E36150ADVU Upgrade option for Scope View and Arbitrary Waveform Generation Capabilities
- E36150ATMU Upgrade option for Automotive Standards Testing Capabilities with Enhanced Programming Speed and Preset Waveforms
- Keysight InfiniiVision DSO-X 3054T Digital Storage Oscilloscope
- Keysight N6705C DC Power Analyzer
- Keysight BV9201B PathWave BenchVue Advanced Power Control and Analysis

Introduction

An automotive Electronic Control Unit (ECU) is an embedded system that controls the vehicle's electrical and electronic components, such as fuel injection, spark ignition control, braking, suspension, power steering control, alternator, and more. Modern vehicles, in general, may contain more than 100 ECUs to manage an ever-increasingly sophisticated automotive system. As modern vehicles become progressively more reliant on the ECU, it is vital that those ECUs are thoroughly validated and able to operate in harsh environmental conditions or within a system with high electrical disturbance to ensure reliability and safety to its user.

ISO16750 and ISO7637 automotive electrical test specifications have been developed just for this purpose to systematically guide manufacturers in performing the electrical disturbance immunity test and vigorous test anticipated from the actual environment in which the vehicle will be exposed once deployed. The Keysight E36150 Series Autoranging Bench DC Power Supply supports the new feature that allows you to import or generate complex voltage transients derived from the automotive ISO standards, which is suitable for the automotive electrical test.

This Application Note demonstrates how you can leverage this power supply's new features to help you quickly perform the automotive ISO electrical test to gain insight into your automotive ECU performance.

Key Features at a Glance

The E36150 Series Autoranging Bench DC Power Supply is an extension of Keysight's DC power supplies product family that offers excellent performance at an affordable price. This general-purpose DC power supply is designed for versatility, ease of use, and safety for various power applications. It comes in two models, shown in Table 1, that you can select based on your test requirement.

Figure 1. Keysight E36154A (right) & E36155A (left) 800W Autoranging Benchtop Power Supply

Models	Specification
E36154A	Single channel, 30V, 80A, 800W
E36155A	Single channel, 60V, 40A, 800W

Table 1. DC power supply output specifications

Most importantly, the power supply offered a few key features that can be beneficial for the automotive electrical test, for instance:

- Peak-power handling features can accommodate up to 2400W, three times the 800W rated output for 7ms. This is critical when handling electromechanical components, which typically require a high startup current during the initial boot.
- Quickly generate and customize a variety of power transient waveforms up to 800W using the built-in waveform generators without needing an external AWG.
- Includes pre-configured waveform patterns that you can select, such as sine, step, ramp, pulse, trapezoid, and many more that you can further customize to simulate your application scenarios easily.
- E36150ATMU and E36150ADVU upgrade options enable seven automotive ISO16750 and ISO7637 preset waveforms that you can use when testing your ECU, such as starting profile waveform, motor regen, reset behavior, momentary drop, and more. Additionally, the upgrade option enhanced programming speed up to 750%.
- The E36150ADVU upgrade option enables a built-in oscilloscope feature, eliminating the hassle of connecting the DUT to an external oscilloscope.
- It can be paired with Keysight BV9201B Advanced Power Control and Analysis software to access more advanced features, such as short-term waveform capture with Scope Mode or long-term waveform capture with Data Logger Mode. The software also comes with a Charge-Discharge Depth of Functionality (CCDF) Mode to perform statistical analysis of your data or use the built-in ARB Mode feature to create a complex waveform for your DUT easily.

Performing the Power Transient Immunity Test on an ECU DUT

Power transient immunity test on automotive ECU is typically performed not only on the final product but throughout the development cycle to validate and optimize the product design. Figures 2 and 3 below show the test setup and hardware connections used in the immunity tests. Two types of tests will be performed to showcase two of the new E36150ATMU features utilizing these waveform outputs to simulate vehicle cranking operation:

- E36154A built-in preset ISO16750 Starting Profile standard waveform (Test 1)
- Playback simulation of an imported voltage transient waveform captured from actual power conditions in a real vehicle during engine cranking (Test 2)

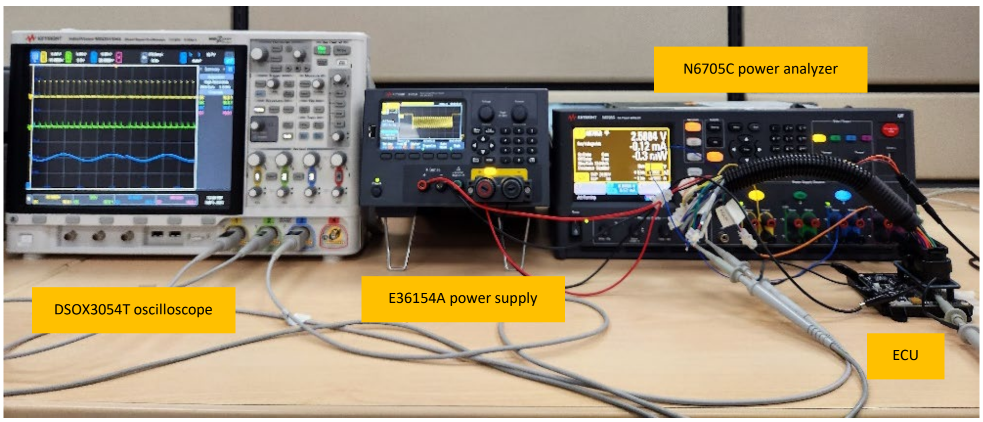


Figure 2. Hardware connection for the bench test.

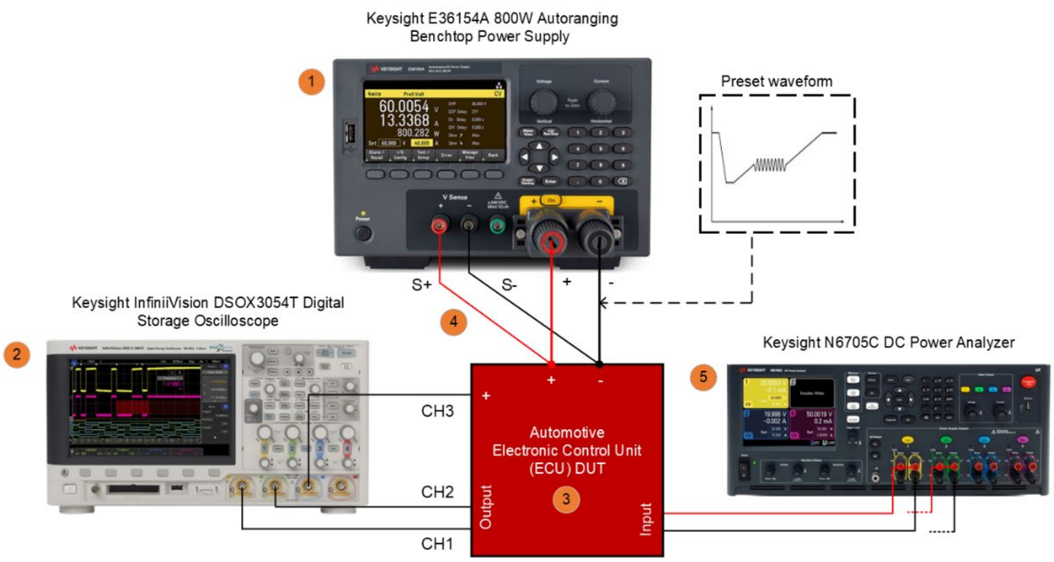


Figure 3. Simplified hardware connection diagram for the bench test.

Item	Description
1	The Keysight E36154A 800W Autoranging Benchtop Power Supply (upgraded with E36150ATMU and E36150ADVU options) provides power to the ECU. Waveforms are generated from this power supply to simulate harsh environmental conditions and electrical disturbances.
2	The Keysight InfiniiVision DSOX3054T Digital Storage Oscilloscope is connected to the ECU to verify the integrity of the input and output signals.
3	An off-the-shelf, 12V input consumer-grade ECU has been selected as an example DUT. The primary function of the ECU is to drive the initial engine startup operation and subsequent operation while monitoring various vehicle sensor inputs such as Manifold Absolute Pressure (MAP), Coolant Temperature (CLT) sensor, Throttle Position Sensor (TPS), and others.
4	The 4-wire connection between the power supplies and ECU was used to increase output accuracy, which improves voltage regulation at the load by compensating voltage drop across wires on the power supply output terminal. It is recommended to use twisted short wires to reduce lead inductance and noise pickup. Use shorter wire lengths (less than a meter) with a size of at least AWG 14 to reduce resistance. The 4-wire configuration also needs to be enabled within the power supplies.
5	Keysight N6705C DC Power Analyzer with N6785A SMU modules on channels 1 and 2. This instrument generates signal stimuli to the ECU to simulate sensor signals.

Table 2. Description of the hardware test components

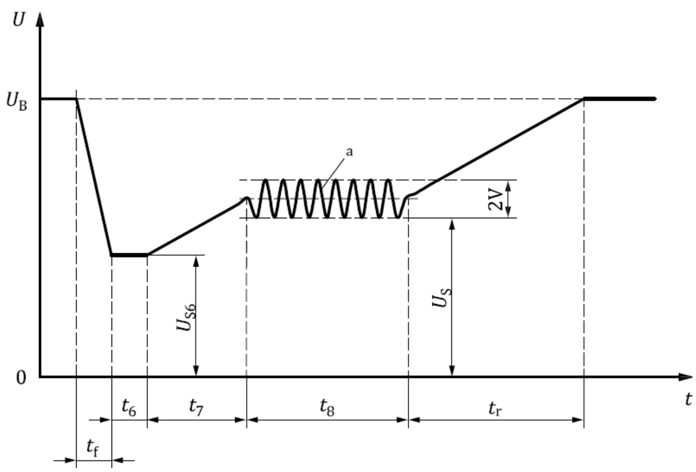
The ECU requires a valid sensor input to calculate the right timing to drive fuel injection and ignition operation. The critical sensor inputs such as MAP, CLT, and TPS, including crank and cam tach signals, can be simulated with the help of Keysight N6705C DC Power Analyzer, paired with Keysight BV9201B PathWave BenchVue Advanced Power Control and Analysis software. Figure 4 below shows the simulated 5V tach signal of 36-1 crank trigger wheels running at 300Hz (V1) and a constant 0.8V (V2) for MAP and Oxygen sensor signal to emulate a specific atmospheric pressure with a lean air-fuel ratio. In this case, the remaining sensor signals, such as MAT, CLT, and TPS, were connected to the ground to prevent the "floating" reading. It is also important to note that all these signals can only be transmitted to the ECU once it has been properly powered up with the E36154A power supply to avoid damaging the ECU.

Figure 4. Emulating Cam tach and MAP/Oxygen sensor signals configured as V1 and V2, respectively, using the BV9201B software

As shown in Figure 3, two of the ECU signal outputs –ignition spark (channel 1) and fuel injector (channel 2) signals, are connected to the Infiniivision oscilloscope as these are the resultant signals of the cranking operation to be probed. The 12V signal from the E36154A power supply is also connected to the oscilloscope's channel 3 to trigger the start of measurement. Once it detects the ISO waveform, the oscilloscope can immediately capture the ignition and fuel injection signals.

Test 1: Internal Preset Waveform

The purpose of the ISO16750-2, 4.6.3 Starting Profile test is to verify the targeted ECU's performance during and after engine cranking, which is a process of energizing the starter motor to spin the engine's crankshaft to start the engine. The 12V/24V battery powers the ECU, starter motor, fuel injector, ignitor, and other relevant components during the cranking operation. As a result, a high current is drawn from the battery during the cranking process. This typically causes disturbance to the ECU's power input and can cause failure on the ECU, particularly those with low disturbance immunity. The ISO16750-2 standard requires sets of waveform profiles that mimic the electrical disturbance to be repetitively applied to the ECU inputs while being able to pass the test with Class A or B for the non-relevant functions and Class A for the relevant function during the cranking operation. For this Application Note, Starting Profile waveform level 1 and 2 profiles, as shown in Table 3, were used to demonstrate the advanced automotive test feature of the Keysight E36154A 800W Autoranging Benchtop Power Supply.



Key

U_B = Supply voltage for generator not in operation

a = 2Hz frequency

Figure 5. ISO16750 Starting Profile waveform.

Parameter		**Level**	
		1	**2**
Voltage (V)	U_{S6}	8	4.5
	U_S	9.5	6.5
Duration (ms)	t_f	5	5
	t_6	15	15
	t_7	50	50
	t_8	1,000	10,000
	t_r	40	100

Table 3. Starting Profile waveform level 1 and 2 parameters for 12V DUT system.

Accessing Preset Waveforms

As shown in Figure 3, you must first establish a hardware connection to proceed with the bench test. The following are quick steps to view and select the available ISO waveforms:

- To view the list of ISO preset waveforms from **Meter View**, use the power supply front panel button and navigate to **Arb** > **Arb** > **Preset Waveform**.

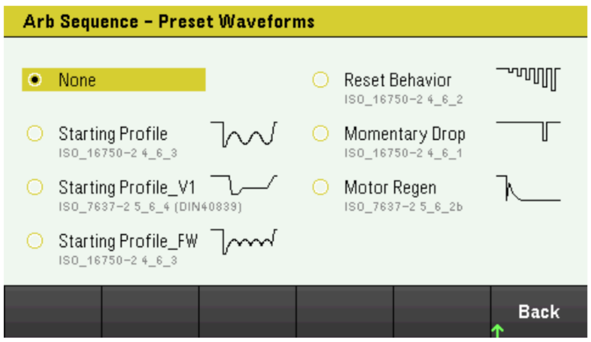


Figure 6. Available ISO waveform presets of the DC power supply.

- Select the *"Starting Profile (ISO_16750-2 4_6_3)"* waveform and press Enter.

Editing and Generating the Arb Waveform

Once a preset waveform is selected, the waveform will be loaded with default settings/values. For user-specific test cases, the default set of voltage and timing parameters can be easily modified to use different ISO waveform level profiles or to meet your test requirements using the power supply's front panel UI. Below are the steps to access this feature:

- From **Meter View**, navigate to **Arb** > **Edit Table** > **Select waveform step** > **Edit**. The instrument will show you the **Arb (Sequence – Voltage)** interface with ISO waveform segmented into steps, as shown in Figure 7 below. Note that the default waveform configuration uses the Starting Profile waveform level 2 of Table 3.

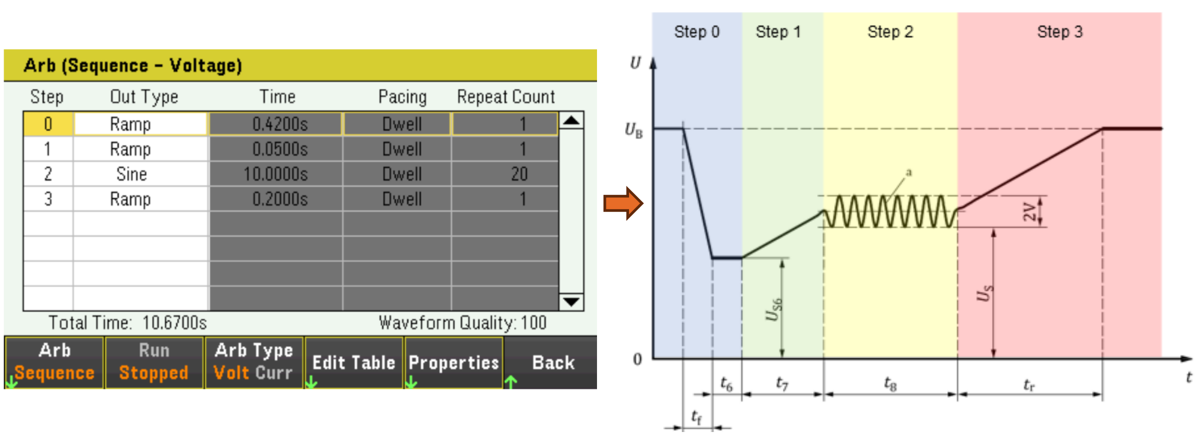


Figure 7. Arb sequence user interface showing segmented ISO waveform into Steps

- Select each one of the waveform steps and press **Edit** to modify the waveform parameter as required. Figure 8 – 11 shows changes to each waveform step to create the Starting Profile waveform level 1 of Table 3. A two-second delay was also added in Step 3 before repeating the cycle to comply with the ISO16750 requirement.

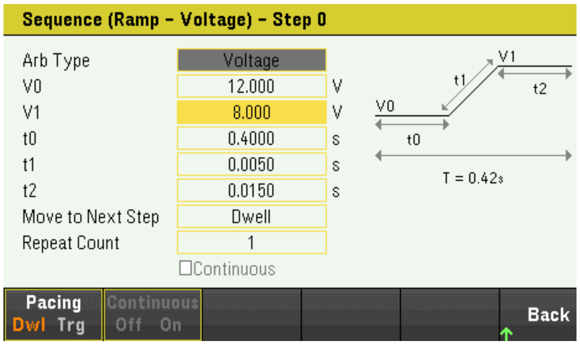


Figure 8. Change V1 from 4.5V to 8V for Step 0

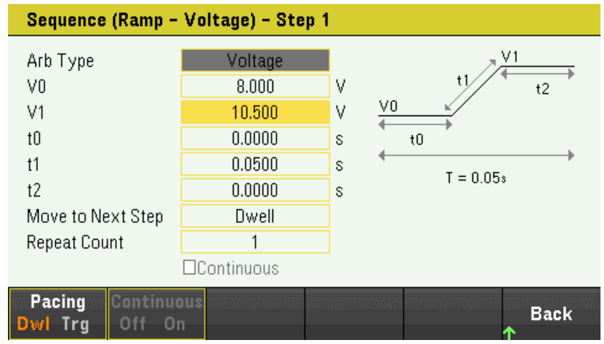


Figure 9. Change V0 and V1 for Step 1

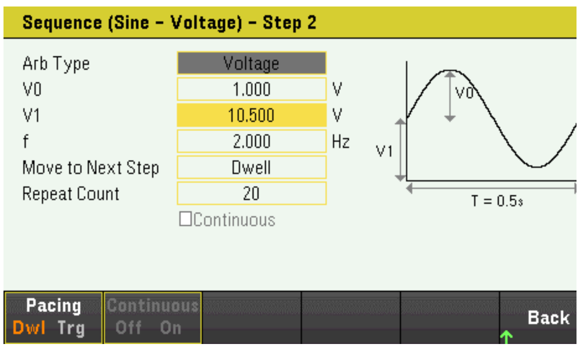


Figure 10. Change V1 from 7.5V to 10.5V for Step 2

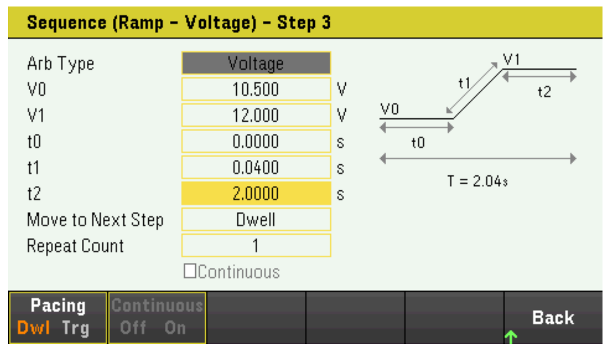


Figure 11. Change V0, t1 and t2 for Step 3

- To run the test for 10 consecutive cycles, from the **Arb (Sequence – Voltage)** section, navigate to **Properties** and modify the Repeat Count setting.

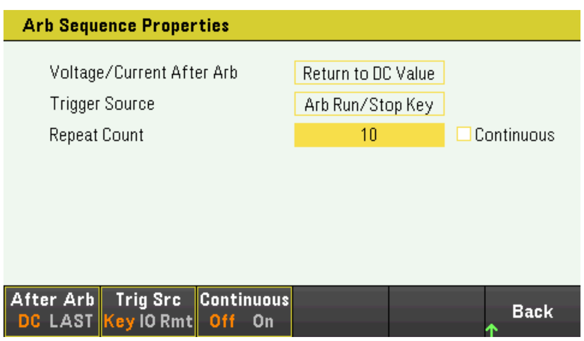


Figure 12. Arb Sequence Properties section

- Press the **On** and **List Run/Stop** button on the power supply's front panel to generate the waveform after modifying the waveform parameters. The ECU will be powered up. Subsequently, the two pre-configured signals in the earlier step, as shown in Figure 3, will be triggered to start feeding the sensor emulation signals to the ECU with Keysight BV9201B PathWave BenchVue Advanced Power Control and Analysis software.

Verifying the Result

You can verify the ECU's performance during and after receiving the ISO waveform. The ISO16750 standard requires relevant features that govern the cranking operation to be fully operational (Class A) during this operation. Figures 13 and 14 below show the ISO waveform captured using the E36154A Data Logger and the output waveform captured from the ECU's output using the InfiniiVision oscilloscope, showing the operational behavior of the ECU during the simulated cranking operation.

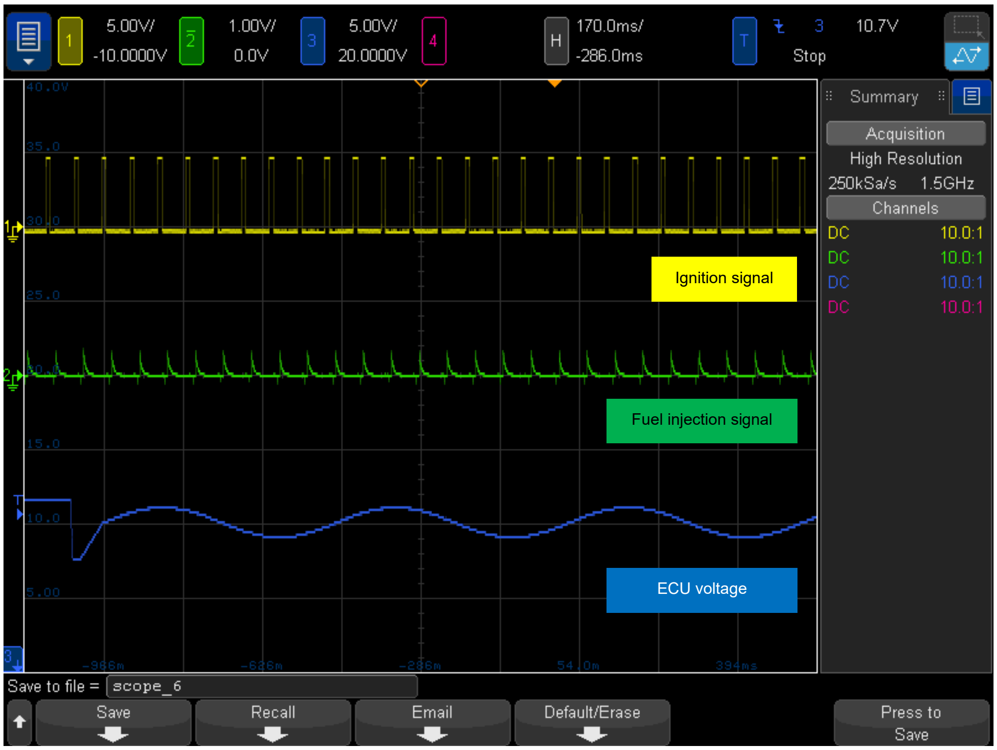


Figure 13. ECU input and output signals captured using the InfiniiVision oscilloscope

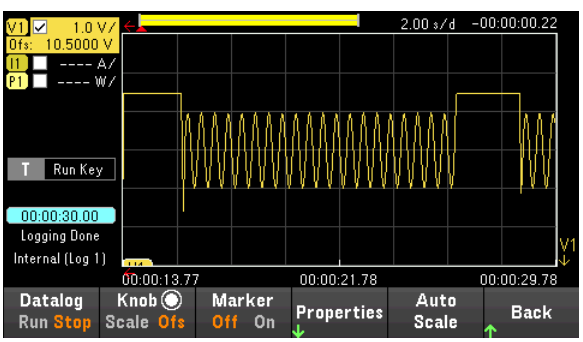


Figure 14. Starting Profile ISO waveforms captured using the E36154A Data Logger.

The three output waveforms captured by the InfiniiVision oscilloscope in Figure 13 represent the Starting Profile waveform (channel 3, blue), fuel injection (channel 2, green), and ignition spark signals coming out from the ECU (channel 1, yellow), during which the Starting Profile ISO waveform is fed into the ECU input power. The fuel injection and ignition spark signal were the outputs of the simulated cranking operation, validating that the ECU passed the immunity test and could drive the operation even with the noisy power input (Class A).

Test 2: External Waveform

Beyond complying with the ISO preset waveform, the Keysight E36150 Series Autoranging Bench DC Power Supply also allows you to import external waveforms and run actual waveform playback simulations with the power supply. This is particularly useful to test your ECU performance with the actual transient and disturbance conditions in the vehicle captured with an oscilloscope. The E36150ATMU and E36150ADVU upgrade options enable up to 10K constant dwell setpoints and enhance the power supply's programming speed, allowing you to capture and run fast transient response waveform with higher fidelity.

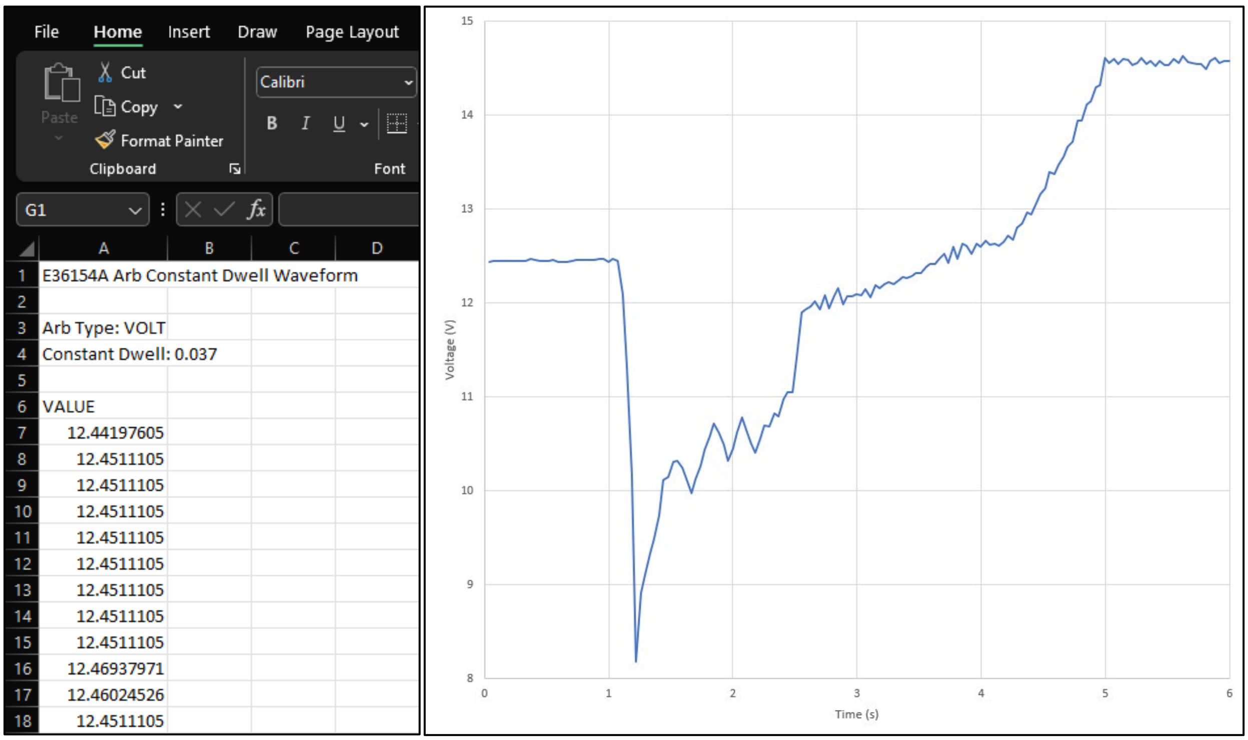


Figure 15. Vehicle voltage transient captured using an oscilloscope (right) and its CSV formatted data (left)

The ISO7637 and ISO16750 standard provides generic guidelines for the manufacturer to achieve adequate power transient immunity; however, the guideline only estimates what the vehicle might experience once deployed. The waveform in Figure 15 (right) is the actual waveform captured with an oscilloscope during the vehicle cranking operation, and the waveform shows a stark difference from the ISO16750-2 –4.6.3—Starting Profile waveform. In particular, the actual cranking operation produces a complex voltage transient waveform, and the voltage typically settles at a higher voltage of around 14.5V when the vehicle's alternator kicks in to charge the battery. It is also possible that the ECU receives a voltage higher than the allowed range, specifically when the alternator's output voltage is not properly regulated, or there is a failure on the voltage regulator component. In this case, an over-voltage protection must be in the ECU circuitry to prevent failure. Figure 15 (left) represents the actual voltage transient in CSV format, readable by the Keysight E36154A 800W Autoranging Benchtop Power Supply. The subsequent subchapter demonstrates steps to import and run the waveform playback using the power supply.

Importing the Waveform

Below are the steps to import external waveform using the power supply's Constant Dwell Arb feature.

- As Figure 15 shows, convert the waveform data captured using the oscilloscope into instrument-readable CSV format.
- To access the **Arb (Constant Dwell – Voltage)** interface from **Meter View**, navigate to **Arb** > **Sequence** > **CDwell.**

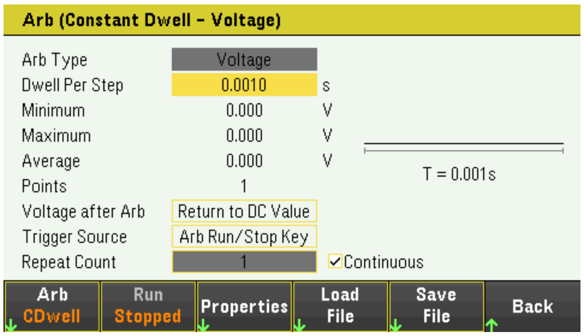


Figure 16. Arb (Constant Dwell – Voltage) section

- Press **Load File** and specify the CSV file location from the drop-down menu. Figure 17 (left) below shows that the CSV-formatted file is in the external USB drive. Press **Load** to proceed with importing the file. Subsequently, the instrument automatically generates a waveform summary based on the imported file, as shown in Figure 17 (right).

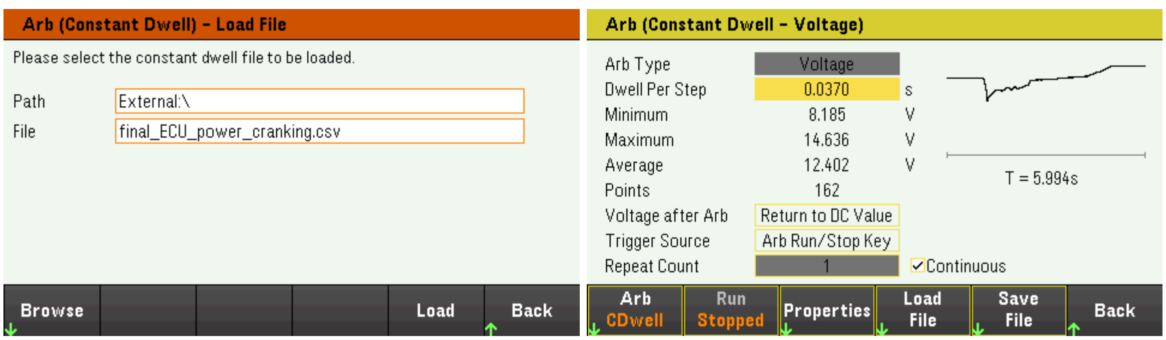


Figure 17. Power supply's file browser section (left) and summary of the imported waveform (right)

Generating and Verifying the Result

Press the **On** and **List Run/Stop** button on the power supply's front panel to run playback of the imported waveform. Doing this will power ECU. Subsequently, emulate various other sensor signals and feed the signals to the ECU with Keysight BV9201B PathWave BenchVue Advanced Power Control and Analysis software.

Figure 18 below shows the voltage transient waveform output captured using Scope Mode of the Keysight E36154A 800W Autoranging Benchtop Power Supply, while Figure 19 shows the ECU's ignition and fuel injection output signals captured using the InfiniiVision oscilloscope. These output signals indicate a successful cranking operation (Class A) with the imported, actual voltage transient waveform. The test also shows that the ECU can receive a slightly higher voltage input of 14.63V and ensure its operation when the vehicle's alternator is running to charge the battery.

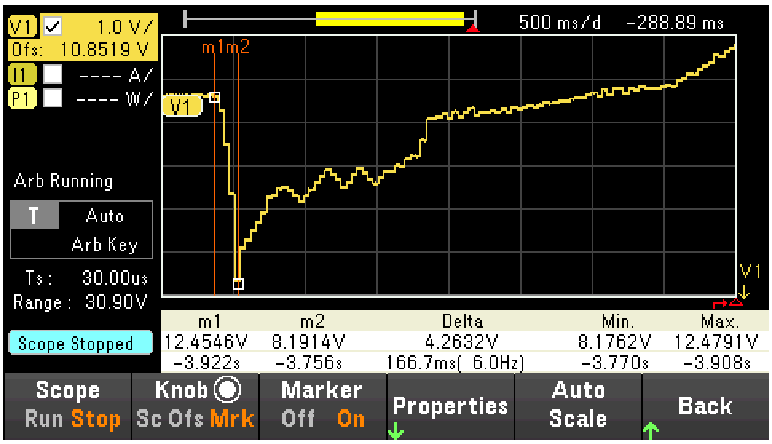


Figure 18. Voltage transient waveform captured using the E36154A power supply's Scope Mode

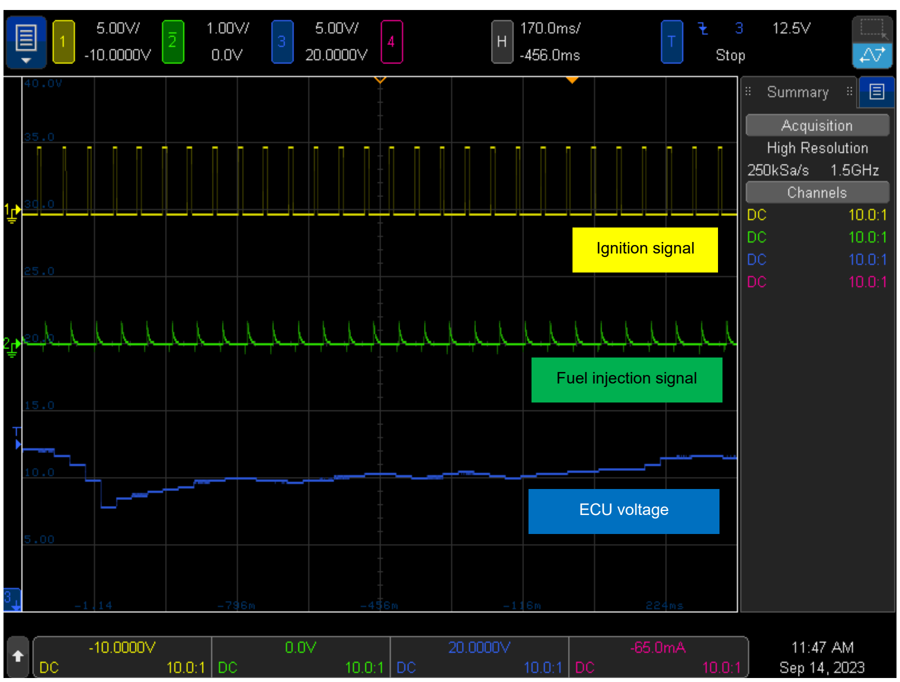


Figure 19. The input voltage, fuel injection, and ignition output signal of the ECU

Conclusion

This Application Note has demonstrated how you can easily perform the ECU bench test using the internal ISO preset waveform and the imported, actual voltage transient waveform with Keysight E36154A 800W Autoranging Benchtop Power Supply. Beyond this, the power supply can generate various other ISO16750 and ISO7637 waveforms –motor regen, reset behavior, momentary drop, etc. –that can help you quickly complete the test without needing sophisticated and expensive hardware setups while helping you to reduce your product development time. Furthermore, the enhanced programming speed and the flexibility to build and edit the preset waveforms enable you to create a more complex waveform and widen your test coverage beyond automotive test applications.

For more information

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