

## Multimeter measurements on variable frequency drives using the new Fluke 289 DMM

### Application Note

**Editor's note:** For similar instructions using the Fluke 87V DMM, reference Fluke article 12345.



In the past, motor repair meant dealing with traditional three-phase motor failures that were largely the result of water, dust, grease, failed bearings, misaligned motor shafts, or just plain old age. But, motor repair has changed in a big way with the introduction of electronically controlled motors, more commonly referred to as variable frequency drives (VFD). Drives present technicians with a unique set of measurement problems that can vex the most seasoned pro.

This application note describes the electrical measurements you can make during the installation and commissioning of a drive, as well as other measurements to aid in diagnosing bad components, and other conditions that may lead to premature motor failure in VFDs.

### Troubleshooting philosophy

There are many different ways to go about troubleshooting an electrical circuit, and a good troubleshooter will always find the problem—eventually. The trick is to track down the problem as quickly as possible, keeping downtime to a minimum.

The most efficient procedure for troubleshooting is to begin at the motor, and then systematically work back toward the electrical source, looking for the most obvious problems first. A lot of time and money can be wasted replacing perfectly good parts when the problem is nothing more than a simple loose connection.

Next, take care to make accurate measurements. Nobody makes inaccurate measurements on purpose of course, but it's easier to do than you may think, especially when working in a high energy, noisy environment like that of an VFD. Choosing the right test tools for troubleshooting, the drive, the motor, and the connections is of the utmost importance. This is especially true when making voltage, frequency and current measurements on the output side of the motor drive. Until now the only meter on the market able to make these measurements accurately was the Fluke 87V Digital Multimeter. Fluke has just introduced the next generation of high performance Multimeter, the new Fluke 289,

incorporating the same selectable low pass filter found in the successful 87V DMM. The filter allows the meter to make accurate drive output measurements that will now agree with the motor drive controller display indications. No longer does the technician have to guess whether the drive is operating correctly and delivering the correct voltage, current, or frequency for a given control setting.



### Drive measurements

**Input side measurements**

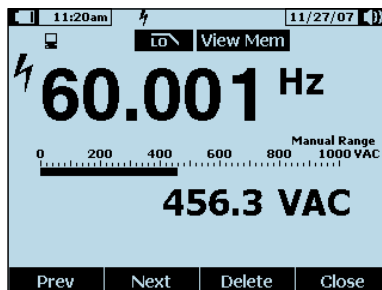
You can use any good quality true rms multimeter to verify proper input power to the drive. The input voltage readings should be within 2 % of one another when measured phase to phase with no load. A significant unbalance may lead to erratic drive operation and should be corrected when discovered.

**Output side measurements**

Measurements on the output side of a pulse width modulated (pwm) motor drive have been difficult or impossible to make, especially accurate measurements, that would agree with the drive controller displayed values. The traditional true rms multimeter will not provide accurate answers. This is because the voltage applied to the motor terminals by the VFD is a pulse width modulated non-sinusoidal voltage.

A true-rms DMM will give an accurate reading of the heating effect of the non-sinusoidal voltage applied to the motor, but will not agree with the motor controller's output voltage reading which is displaying the rms value of the fundamental component only (typically from 30 Hz to 60 Hz). The issues are bandwidth and shielding. Many of today's true rms digital multimeters have a wide bandwidth, sometimes out as far as 20 kHz or more, which allows the meter to respond not only to the fundamental component that the motor really responds to, but also to all of the high frequency components generated by the pwm drive.

In addition, if the dmm is not shielded for high frequency noise, this can also lead to poor measurement performance due to the high noise levels generated by the drive controller. Because of their higher bandwidth and shielding issues, many true rms meters will display readings as much as 20 to 30 % higher than the drive controller is indicating.



289 dual display showing frequency and voltage

Fluke's new 289 multimeter, with its ¼ VGA dot matrix display, has the ability to display multiple parameters at the same time and utilize the selectable low pass filter, giving the troubleshooter or engineer the ability to make accurate voltage, current and frequency measurements on the output side of the drive either at the drive itself or at the motor terminals and also display the filtered output voltage and frequency (motor speed) simultaneously. With the filter selected, the 289 readings for both voltage and frequency (motor speed) should now agree with the associated drive control display indications if they are available. When measuring output current with a clamp accessory, the low pass filter allows for accurate current measurements and frequency measurements simultaneously when using the Hall-effect type clamps. All of these measurements are especially helpful when making measurements at the motor location when the drives displays are not in view.

**Making safe measurements**

Before making any electrical measurements, be sure you understand how to make them safely. No test instrument is completely safe if used improperly, and you should be aware that many test instruments on the market are not appropriate for testing variable frequency drives. Also insure that the appropriate personal protective equipment (PPE) is used in accordance with the specific working environment and the measurements to be made. If at all possible, never work alone.

**Safety ratings for electrical test equipment**

ANSI and the International Electrotechnical Commission (IEC) are the primary independent organizations that define safety standards for test equipment manufacturers. The IEC 61010 second edition standard for test equipment safety states two basic parameters, a voltage rating and a measurement category rating. The voltage rating is the maximum continuous working voltage the instrument is capable of measuring. The category ratings depict the measurement environment expected for a given category. Most three-phase VFD installations would be considered a CAT III measurement environment with power supplied from either 480V or 600V distribution systems. When using a digital multimeter for measurements on these high energy systems, insure that the multimeter is rated at a minimum for CAT III 600V and preferably for CAT IV 600V/CAT III 1000V. The category rating and voltage limit are typically found on the front panel of the multimeter right at the input terminals.



**The new Fluke 289 DMM is dual rated CAT IV 600V and CAT III 1000V.**

Refer to the ABC's of DMM Safety from Fluke for additional information on category ratings and making safe measurements.

**Making the measurements**

Measurements for this procedure will be made on a 480 V three phase drive control at the control panel terminal strips using the new Fluke 289 digital multimeter. These procedures would also be valid for lower voltage 3 phase drives powered by either single or 3 phase supply voltages. For these tests the motor is running at 30 Hz.

**Input Voltage**

To measure the ac voltage supply to the input side of the drive at the drive:

1. Select the 289's ac voltage function.
2. Connect the black probe to one of the three phase input terminals. This will be the reference phase.
3. Connect the red probe to one of the other two phase input terminals and record the reading or save it to the 289's internal memory.
4. Leaving the black probe on the reference phase now move the red probe to the third phase input and record or save this reading to the 289's internal memory.
5. Check to make sure that there is no more than a 2 % difference between these two readings.

The new Fluke 289 also contains internal memory for saving specific individual measurements that can be recalled on screen or downloaded to reports generated by Fluke View Forms® software.

**Input Current**

Measuring the input current requires using a current clamp accessory. This is because it is not practical to "break the circuit" to make an in-line series current measurement. Regardless of the type of clamp used, check to insure that all readings are within 5 % of each other for proper balance.

**Transformer type clamp (Fluke models i200, i400, 80i-400, 80i-600A, i800)**

1. Connect the clamp to the 289's common and 400 mA input jacks.
2. Select the mA/A ac function.
3. Place the clamp around each of the input supply phase cables in succession, recording or saving to internal memory each of the readings as they are taken. Since these clamps output 1 milliamp per amp, the milliamp readings shown on the 289 display are the actual phase current reading in amps.

**Hall Effect type (AC/DC) clamp (i410, i-1010)**

1. Connect the clamp to the 289's common and V/Ω input jacks.
2. Select the 289's mVac voltage function for current measurements up to 500 amps.
3. Since the lowest range on the 289 is 50.000 mVac push the range button once to place the meter in the 500.00 mVac range if the drive current will exceed 50 amps for the measurement.
4. Place the clamp around each of the input supply phase cables in succession, recording each of the readings as they are taken or again save to the 289's internal memory. Since these clamps output 1 millivolt per amp, the millivolt readings shown on the 289 display are the actual phase current reading in amps.



289 with i1010 AC/DC Clamp accessory



Output voltage and motor speed using the low pass filter



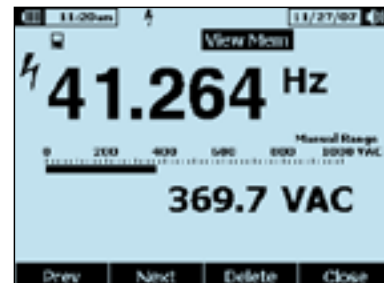
Output voltage reading with low pass filter enabled

### Output voltage and motor speed (Output frequency using voltage as a reference)

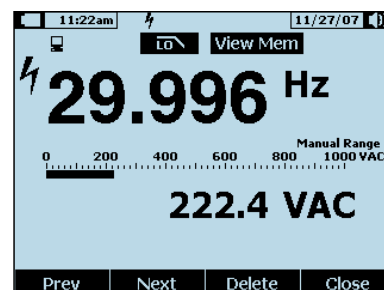
An important new feature on the 289 multimeter is its' ability to simultaneously display both the filtered output voltage and frequency (motor speed) at the same time without having to push additional buttons or change functions.

To measure the ac output voltage and motor speed, either at the drive or at the motor disconnect:

1. Plug the black test lead into the common jack and the red test lead into the V/Ω jack.
2. Select the 289's ac voltage function.
3. Select MENU then (LPF+Hz) to enable the low pass filter and the Hz function.
4. Connect the black probe to one of the three phase output voltage or motor terminals. This will be the reference phase.
5. Connect the red probe to one of the other two phase output voltage or motor terminals and record the reading or save to the 289's internal memory.
6. Leaving the black probe on the reference phase now move the red probe to the third phase output voltage or motor terminal and record or save this reading.
7. Check to make sure that there is no more than a 2 % difference between these two readings. These readings should also agree within these limits with the controller display panel if available.
8. If the low pass filter is not enabled the output voltage readings may be between 10-30 % higher than what is expected and the frequency readings will be inaccurate and unstable.



Output voltage and frequency (motor speed) without the low pass filter (incorrect readings)



Output voltage and frequency (motor speed) using the low pass filter (correct readings)

### Output current and frequency (motor speed)

With the large dot matrix display on the 289 multimeter, it is possible to display both the ac current reading and its' associated frequency simultaneously, allowing the technician or installer to see both the load current and motor speed at the same time, in the same display.

#### Transformer type clamp (i200, i400, 80i-400, 80i-600A, i800)

1. Regardless of the type of clamp used, check to insure that all phase current readings are within 5% of each other for proper balance
2. Connect the clamp to the 289's common and 400 mA input jacks.
3. Select the mA/A ac function. If you want to take advantage of the 289's dual display, then select MENU then Hz.
4. Place the clamp around each of the output phase cables in succession, recording each of the readings as they are taken or save them to internal memory for later use. Since these clamps output 1 milliamp per amp, the milliamp readings shown on the 289 display are the actual phase current reading in amps as well as the frequency of the ac current signal.

#### Hall Effect type (AC/DC) clamp (i410, i-1010)

1. Connect the clamp to the 289's common and V/ $\Omega$  input jacks.
2. Select the 289's mVac voltage function for current measurements up to 500 amps.



Phase current reading + motor speed using i1010 clamp

3. Select MENU then (LPF+Hz) to enable the low pass filter and the Hz function. This will allow the meter to reject all of the high frequency noise generated by the drive controller. Once the low pass filter has been enabled the meter is now in manual range mode.
4. Since the lowest range on the 289 is 50.000 mVac push the range button once to place the meter in the 500.00 mVac range if the drive current will exceed 50 amps for the measurement.
5. Place the clamp around each of the output supply phase cables in succession, recording each of the readings as they are taken or again save to the 289's internal memory. Since these clamps output 1 millivolt per amp, the millivolt readings shown on the 289 display are the actual phase current reading in amps.



### DC Bus measurements

A healthy dc bus is a must for a properly operating motor drive. If the bus voltage is not correct or unstable it may be an indication that the converter diodes or capacitors may be starting to fail. The dc bus voltage should be approximately 1.414 times the phase to phase input voltage. For a 480 volt input, the dc bus should be approximately 679 V dc. The DC Bus is typically labeled as DC+, DC- or B+, B- on the drive terminal strip.

To measure the dc bus voltage:

1. Select the 289's dc voltage function.
2. Connect the black probe to either the DC- or B- terminal.
3. Connect the red probe to the DC+ or B+ terminal.

The bus voltage should agree with the example mentioned above and be relatively stable. You can also check the amount of ac ripple on the bus by simply switching the 289's function switch to the vac function.

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