[Module 1, Exercise 2]

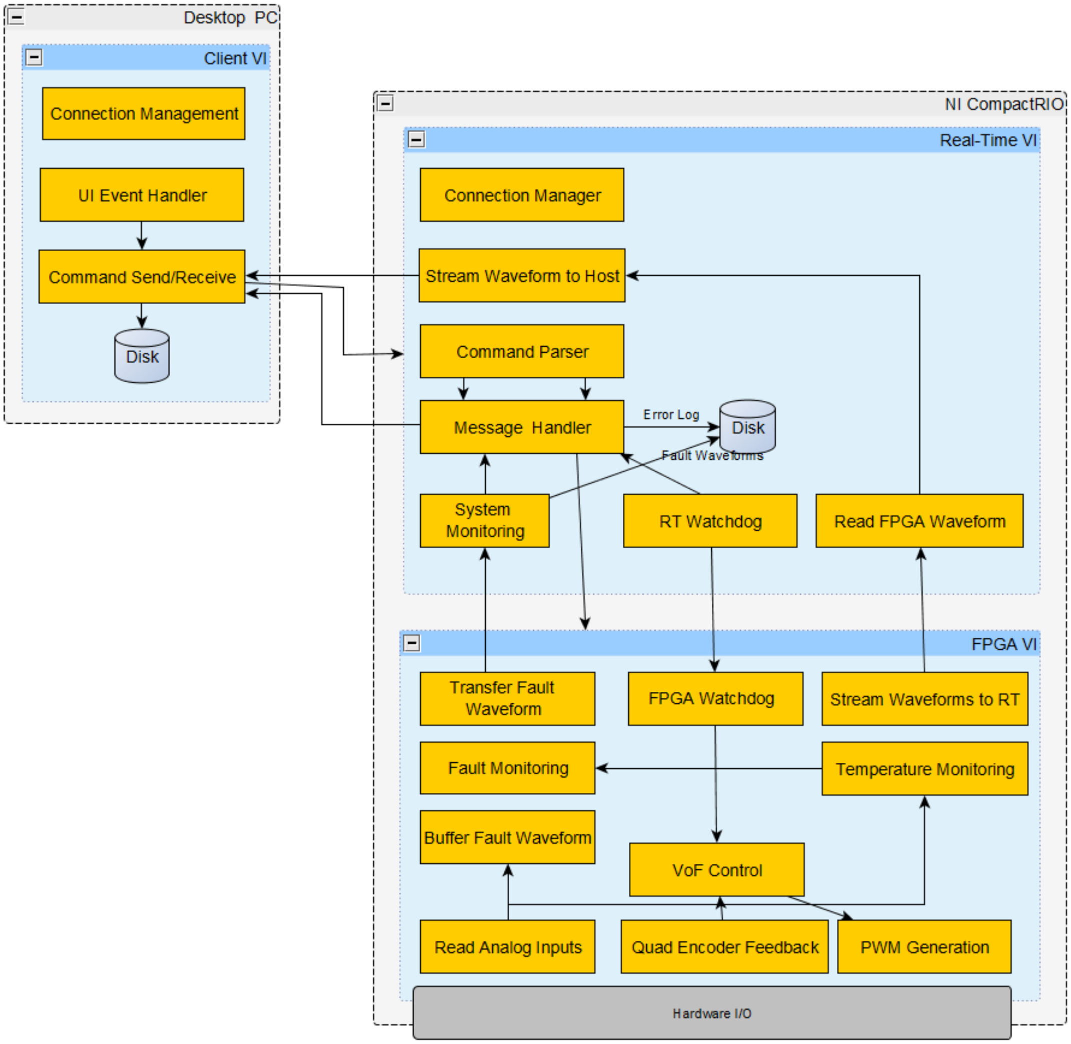
Understanding the GPIC Reference Design Application

Induction Motor Drive (Inverter A) and Grid Synchronized Inverter (Inverter B)

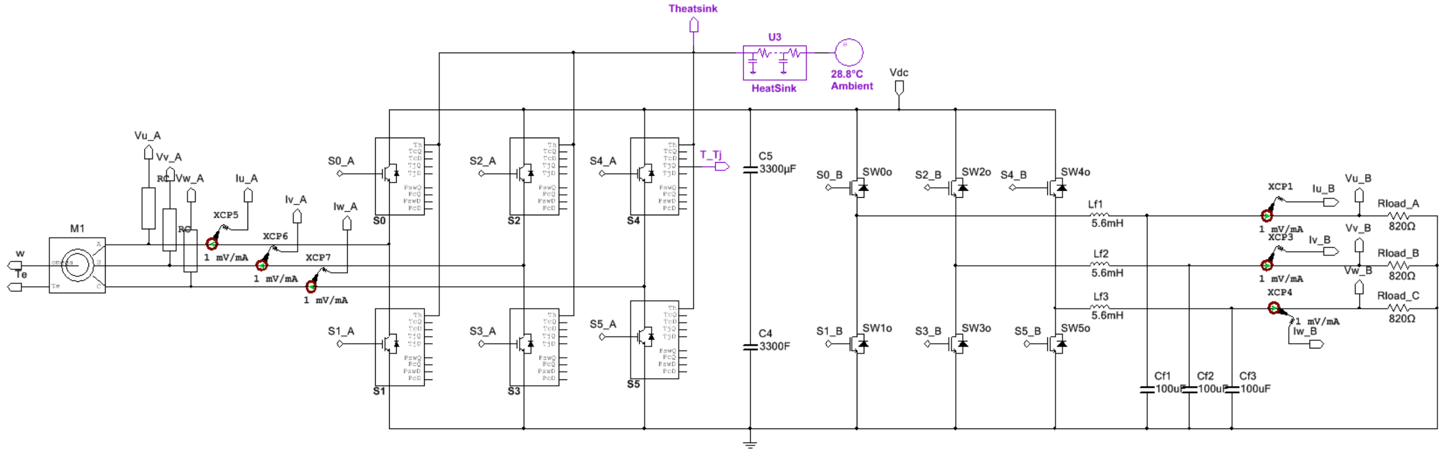
NI GPIC Reference Design Software

- Fully instrumented turnkey control demonstration software with network user interface, live scope display, and configurable control settings
- 10 kHz waveform graphing and data logging with live status display and automatic fault capture (up to 116 kS/s)
- Support for external isolated phase voltage and grid voltage sensors with configurable sensor gain, offsets and filtering
- Datalog and fault log viewing and analysis with Microsoft Excel, The MathWorks, Inc. MATLAB®, NI DIAdem, and NI LabVIEW (including 3-phase power quality analysis)
- Open source reference design code
- Download: ftp://ftp.ni.com/evaluation/powerdev/training/GPICReferenceDesign.zip

Software Block Diagram



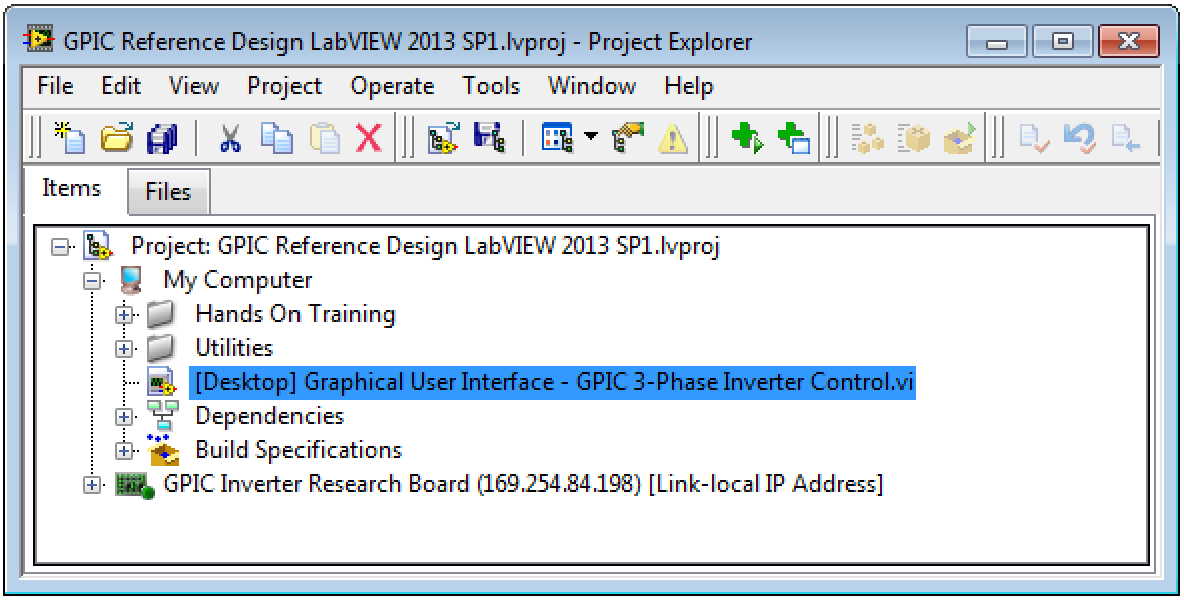
Circuit Schematic



Exercise time: 15-30 minutes

1. Confirm that the LED on your sbRIO GPIC control system is blinking on and off, indicating that the RT and FPGA applications are running and waiting for a network connection. (If not, deploy the startup executable.)

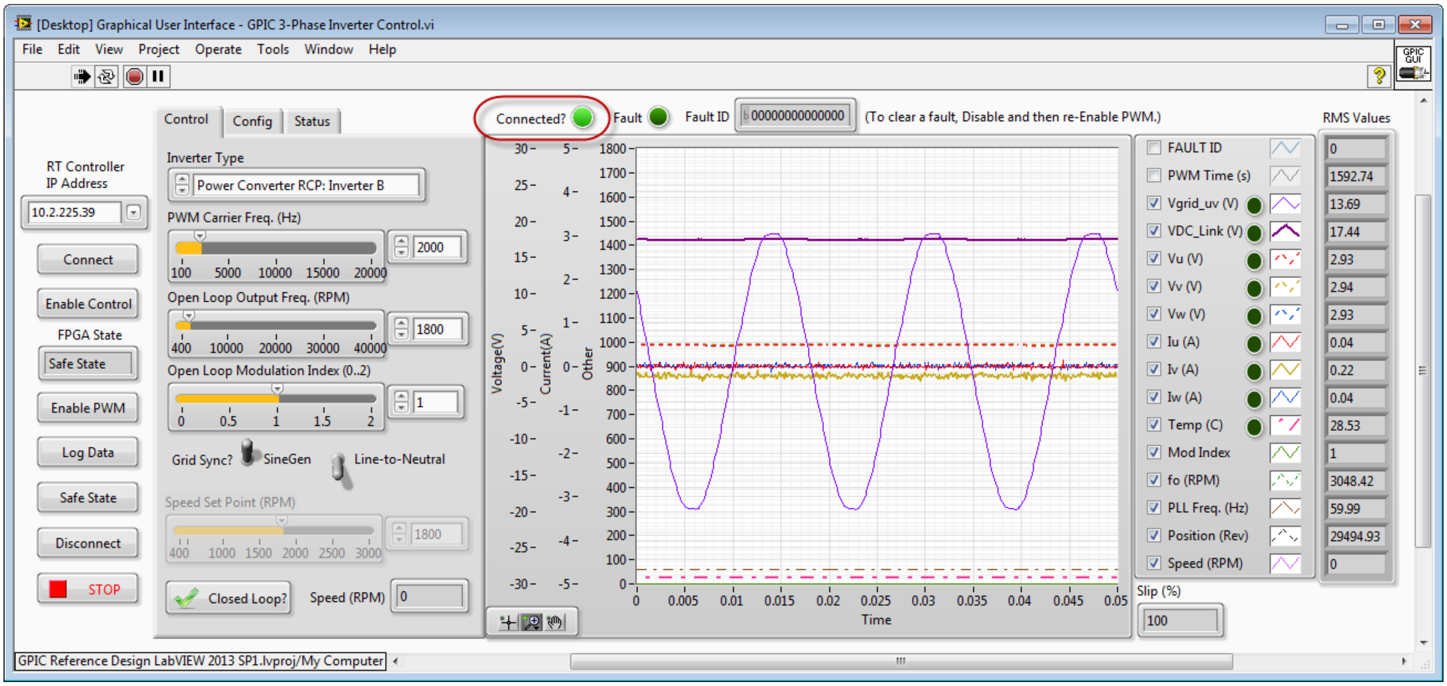
2. Under My Computer, open **[Desktop] Graphical User Interface - GPIC 3-Phase Inverter Control.vi**.



GPIC Reference Design LabVIEW 2013 SP1.lvproj - Project Explorer

Project: GPIC Reference Design LabVIEW 2013 SP1.lvproj
My Computer
Hands On Training
Utilities
[Desktop] Graphical User Interface - GPIC 3-Phase Inverter Control.vi
Dependencies
Build Specifications
GPIC Inverter Research Board (169.254.84.198) [Link-local IP Address]

3. Run the application. It will scan the Ethernet network and populate the **RT Controller IP Address** ring control with NI LabVIEW RIO targets. The **Connected?** indicator should illuminate. If you are not automatically connected, select the appropriate **RT Controller IP Address** and click **Connect**.



[Desktop] Graphical User Interface - GPIC 3-Phase Inverter Control.vi

RT Controller IP Address: 10.2.225.39

FPGA State: Safe State

Inverter Type: Power Converter RCP: Inverter B

PWM Carrier Freq. (Hz): 2000

Open Loop Output Freq. (RPM): 1800

Open Loop Modulation Index (0..2): 1

Speed Set Point (RPM): 1800

Speed (RPM): 0

Fault ID: 00000000000000

(To clear a fault, Disable and then re-Enable PWM.)

	RMS Values
□ FAULT ID	0
□ PWM Time (s)	1592.74
☑ Vgrid_uv (V)	13.69
☑ VDC_Link (V)	17.44
☑ Vu (V)	2.93
☑ Vv (V)	2.94
☑ Vw (V)	2.93
☑ Iu (A)	0.04
☑ Iv (A)	0.22
☑ Iw (A)	0.04
☑ Temp (C)	28.53
☑ Mod Index	1
☑ fo (RPM)	3048.42
☑ PLL Freq. (Hz)	59.99
☑ Position (Rev)	29494.93
☑ Speed (RPM)	0

Slip (%): 100

GPIC Reference Design LabVIEW 2013 SP1.lvproj/My Computer

4. Click **Enable Control**, then **Enable PWM**. You should hear the pre-charge contactor close, and waveforms from the RLC line reactor filter (**Power Converter RCP: Inverter B**) should appear.

5. Try changing the **PWM Carrier Freq. (Hz).** How does a higher carrier frequency impact the power quality (harmonic distortion) of the voltage and current waveforms?

6. Try changing the **Open Loop Output Freq. (RPM)**. Note that an open loop output frequency of 1800 is equivalent to 60 Hz (divide by 30 to convert from RPM to Hz).

7. Try changing the **Open Loop Modulation Index (0..2)**. Are the voltage and current RMS values linearly proportional for the modulation index values ranging from 0 to 1? What about modulation index values greater than 1? (The inverter amplitude response is non-linear when overmodulation is used.) What happens to the voltage and current waveforms when the modulation index is set to 2? (The voltage waveforms approach a square wave. The current waveforms are highly non-sinusoidal.)

8. Try clicking the **Line-to-Neutral** button to go to **Line-to-Line** mode. Note that the labels for the phase voltages change, and the voltage waveform is now bipolar rather than unipolar.

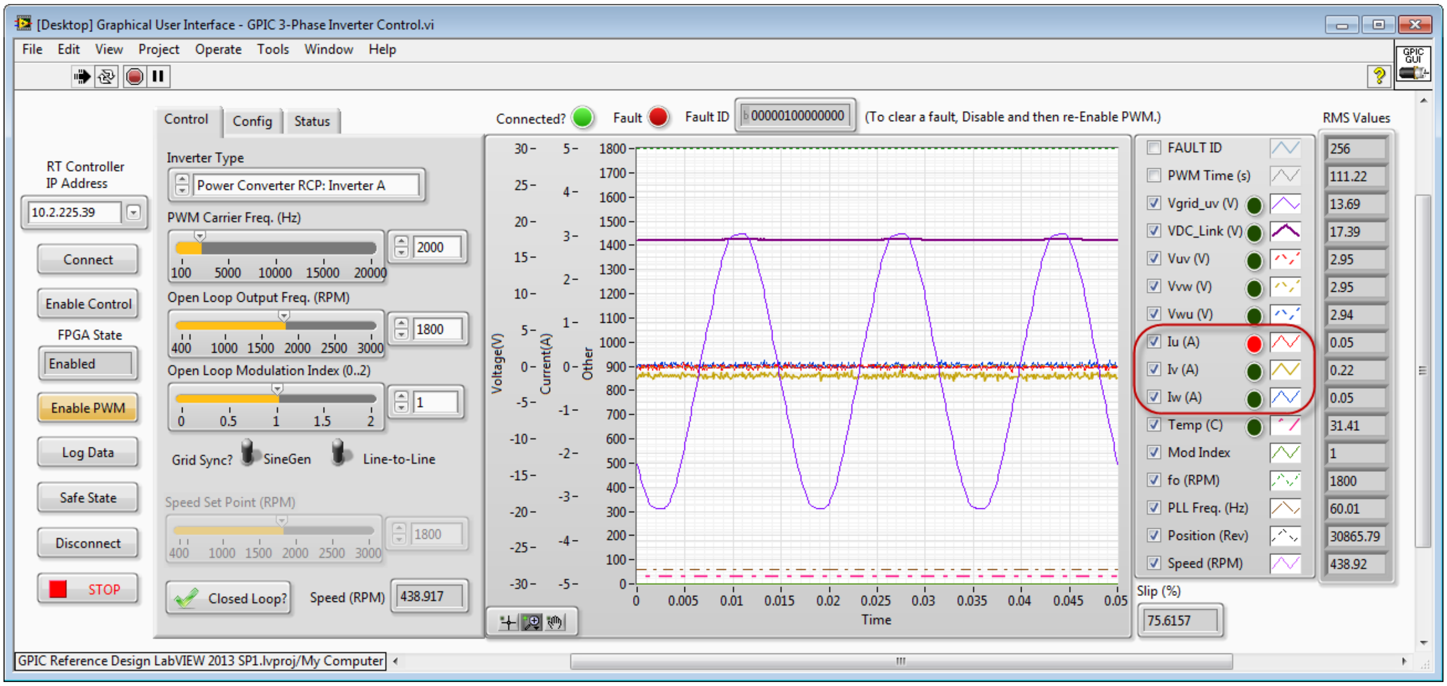
9. Try clicking the **Grid Sync?** button to phase lock the 3-phase inverter with the grid input signal. Which of the three line-to-line inverter output voltages is phased locked with the single phase grid input signal?

10. Change the **Grid Sync?** mode back to **SineGen**. Now change the **Inverter Type** to **Power Converter RCP: Inverter A**. The 3-phase induction motor begins spinning. In some cases, a fault may occur due to overcurrent since you just “hard started” the induction motor. If that occurs, set the **Open Loop Modulation Index (0..2)** to 0, disable and re-enable PWM to clear the fault, and then bring the modulation up slowly from 0 to 1.

11. What is the **Slip (%)** and motor **Speed (RPM)**? This is the difference between the frequency of the excitation voltage from the 3-phase inverter and the motor rotation frequency.

12. Try increasing the **Open Loop Output Freq. (RPM)** in 100 RPM increments. (You can use the up/down arrows on the control.) What is the slip when the excitation frequency is 3000 RPM?

13. To fault the inverter intentionally, try changing the **Open Loop Output Freq. (RPM)** to 1800 RPM in a single step. (Type in the value 1800 and hit enter.) Looking at the LEDs next to the channel labels on the graph, which phase current caused the overvoltage fault? The phase that causes the fault depends on the rotation angle of the motor when you changed the excitation frequency suddenly. A sudden rush of current occurs because the excitation voltage does not match the rotational angle (and rotor flux) of the motor.



[Desktop] Graphical User Interface - GPIC 3-Phase Inverter Control.vi

RT Controller IP Address: 10.2.225.39

FPGA State: Enabled

Inverter Type: Power Converter RCP: Inverter A

PWM Carrier Freq. (Hz): 2000

Open Loop Output Freq. (RPM): 1800

Open Loop Modulation Index (0..2): 1

Speed Set Point (RPM): 1800

Speed (RPM): 438.917

Fault ID: b00000100000000

(To clear a fault, Disable and then re-Enable PWM.)

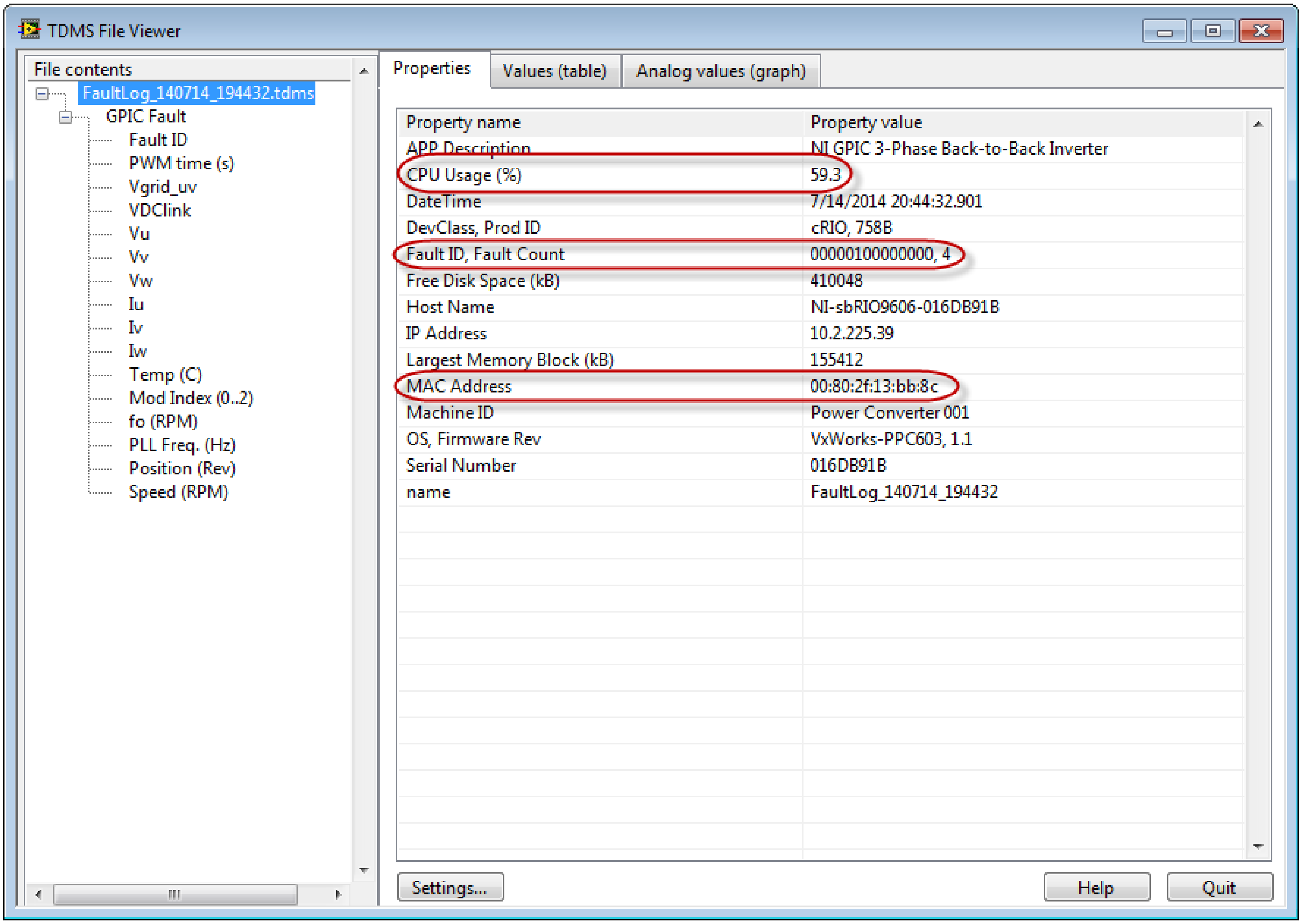
Slip (%): 75.6157

Channel	RMS Values
☐ FAULT ID	256
☐ PWM Time (s)	111.22
☑ Vgrid_uv (V) ●	13.69
☑ VDC_Link (V) ●	17.39
☑ Vuv (V) ●	2.95
☑ Vvw (V) ●	2.95
☑ Vwu (V) ●	2.94
☑ Iu (A) ●	0.05
☑ Iv (A) ●	0.22
☑ Iw (A) ●	0.05
☑ Temp (C) ●	31.41
☑ Mod Index	1
☑ fo (RPM)	1800
☑ PLL Freq. (Hz)	60.01
☑ Position (Rev)	30865.79
☑ Speed (RPM)	438.92

GPIC Reference Design LabVIEW 2013 SP1.lvproj/My Computer

14. A TDMS log file containing the inverter waveform data before and after the fault automatically appears. Note that the Status tab on the GUI application displays the **Fault Data File Path**. This data is saved in FPGA RAM and then transferred to the GPIC RT controller if a fault occurs, and is logged to the non-volatile storage on the sbRIO GPIC system. The desktop GUI application is notified that a fault log file is available and it is retrieved. Then the GPIC RT controller deletes its local copy.

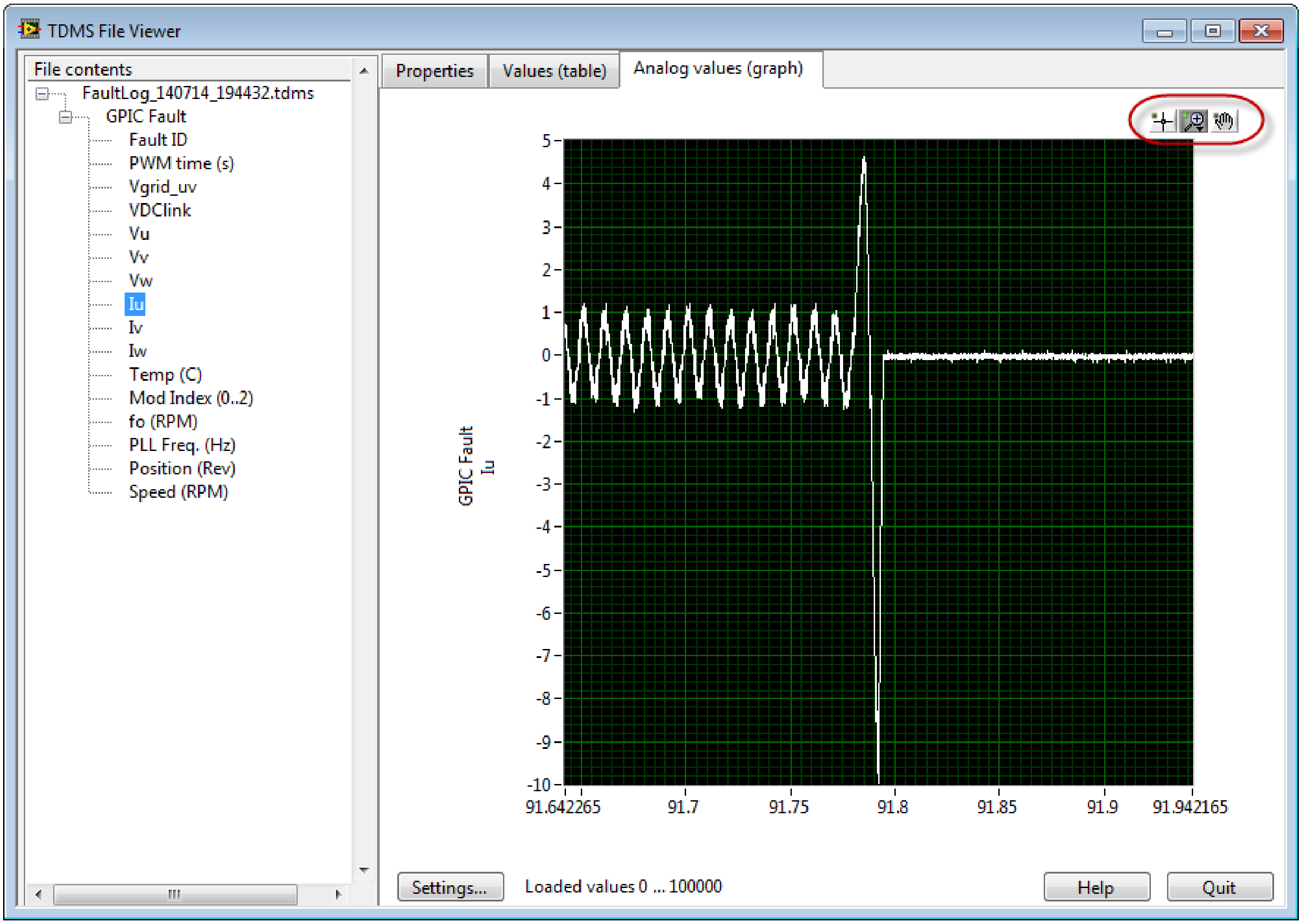
15. Click on the top item in the **File contents** tree to observe the meta data saved with the fault log. What was the GPIC RT **CPU Usage (%)** when the fault occurred. What is the **Fault ID**, and how many faults have previously occurred (**Fault Count**)? Note that the **MAC Address** is listed on a label located on the top of your sbRIO GPIC control board and provides an easy way to identify it.



- FaultLog_140714_194432.tdms
  - GPIC Fault
    - Fault ID
    - PWM time (s)
    - Vgrid_uv
    - VDClink
    - Vu
    - Vv
    - Vw
    - Iu
    - Iv
    - Iw
    - Temp (C)
    - Mod Index (0..2)
    - fo (RPM)
    - PLL Freq. (Hz)
    - Position (Rev)
    - Speed (RPM)

Property name	Property value
APP Description	NI GPIC 3-Phase Back-to-Back Inverter
CPU Usage (%)	59.3
DateTime	7/14/2014 20:44:32.901
DevClass, Prod ID	cRIO, 758B
Fault ID, Fault Count	00000100000000, 4
Free Disk Space (kB)	410048
Host Name	NI-sbRIO9606-016DB91B
IP Address	10.2.225.39
Largest Memory Block (kB)	155412
MAC Address	00:80:2f:13:bb:8c
Machine ID	Power Converter 001
OS, Firmware Rev	VxWorks-PPC603, 1.1
Serial Number	016DB91B
name	FaultLog_140714_194432

16. In the **File contents** tree, click on the current signal corresponding to the phase current that caused the fault. Then select **Analog values (graph)**. Do you observe the current measurement going over the limit? 91% of the time you will not see the actual sample when the fault occurred displayed on the graph. That's because the fault buffer data is being acquired at 10 kHz (100 usec) intervals, whereas the FPGA simultaneous analog input and fault detection logic is execution at 115,942 Hz (8.625 microseconds). The fault buffer contains 3,000 data points, so at 10 kHz this provides 0.3 seconds of data. (Optionally, fault buffer recording can be executed at up to 6 MHz rates, or at slower rates to provide a longer duration of data.)



17. Try zooming in and out on the current waveforms. Also click to view the other signals that were captured. What happened to the DC link voltage (**VDClink**) when the inverter tripped off? Note that **Fault ID** always goes true in the middle of the fault capture waveform, which contains the inverter data before and after the fault.

18. Click the Quit button to close the **TDMS File Viewer**.

19. Back on the GUI application, click the **Log Data** button to continuously log data on your local computer. Then click Enable PWM to disable, and then click again to re-enable. Note that the FPGA application clears the fault on the rising edge of **Enable PWM**.

20. Now click the **Closed Loop?** button to change the FPGA control mode to Voltage-over-Frequency (V/f) control. Does the motor **Speed (RPM)** match your setpoint? Try changing the **Speed Set Point (RPM)** in 100 RPM increments.

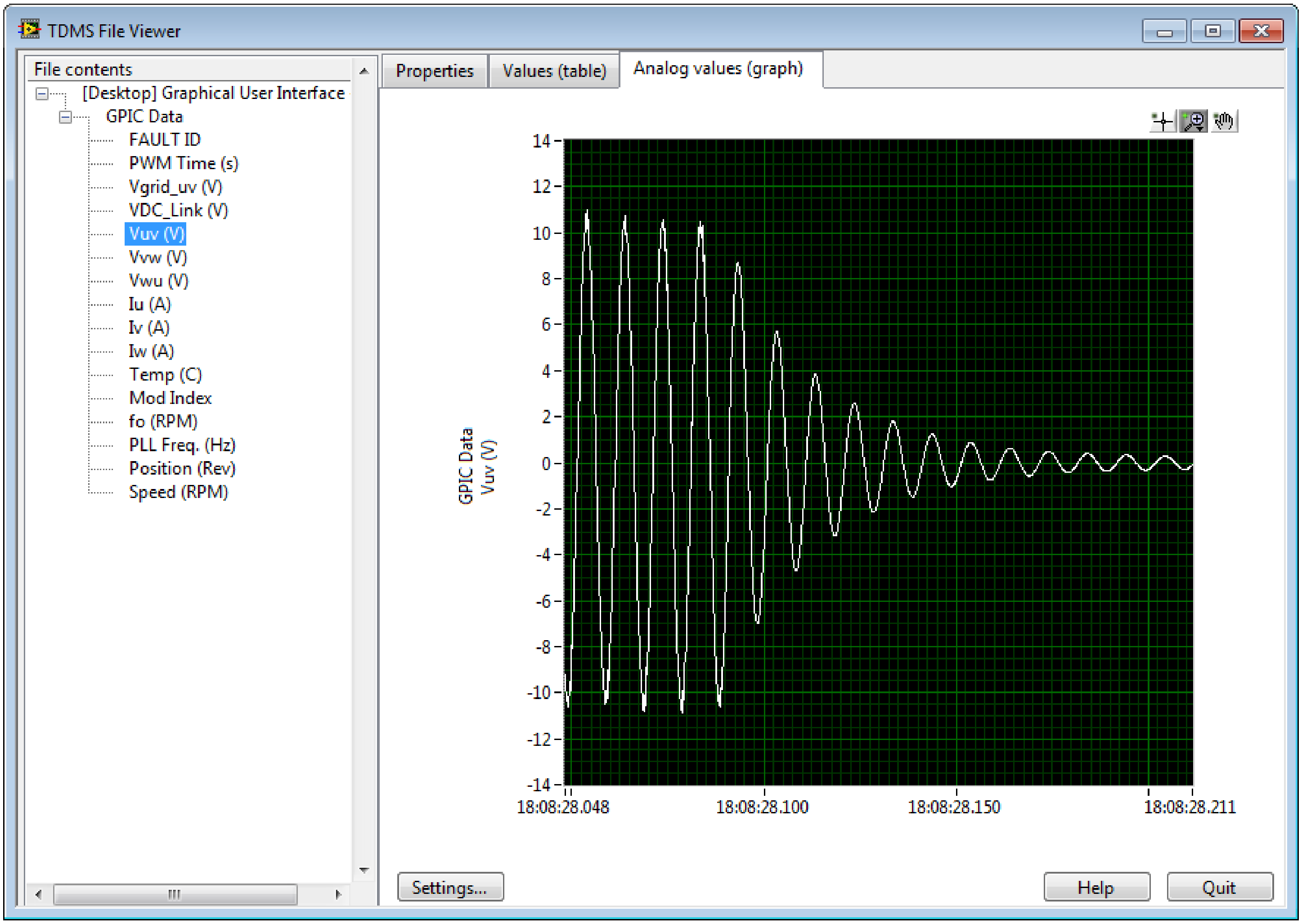
21. What is the inverter excitation frequency, fo (Hz) when the **Speed Set Point (RPM)** is **3000**?

22. Click **Enable PWM** to disable the inverter. Then click the **STOP** button. You should hear the pre-charge contactor open.

23. The **TDMS File Viewer** automatically appears with your data file you recorded.

24. Click on the top item in the **File contents** tree to observe the meta data saved in the TDMS log file. Now expand the tree and click on the **Vuv (V)** waveform data. Since this is a long recording, click on **Settings…** and then select **Load all values** under **Number of values (graph)**.

25. Zoom in to the time period at the end of the waveform when you disabled the inverter. Note that even though you removed the excitation voltages from the induction motor instantaneously, the phase voltages did not decay immediately. The reason is that there are still currents circulating in the rotor of the induction motor, and these induce a decaying back EMF voltage that is observed at the inverter terminals. The time from peak to 63.3% decay is the electrical time constant (tau) of the induction motor. In this case, the time constant is about 45 milliseconds, or 22.2 Hz. From that, we can infer the minimum (10/tau) and recommended (100/tau) control loop rate in Hz, as a rule of thumb, for controlling the rotor flux. (In this case, the recommended control loop rate would be 2222 Hz.)



26. Using the zoom capability of the file viewer, explore the other waveforms. Then click **Quit** to close the **TDMS File Viewer**.

27. This completes the exercise. Let the instructor know you are finished, and ask them if you have any unanswered questions about the GPIC Reference Design GUI Application.