TI Spins Motors

Texas Instruments

DRV830x Rev D. Hardware Quick Start Guide

Version 1.0.5 *Motor Solutions*

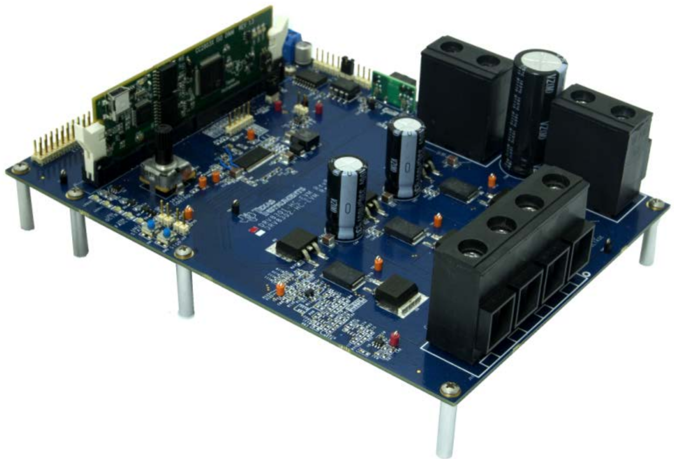


Fig 1: DRV830x EVM with controlCARD

Abstract

The Low Voltage, High Current Motor Drive EVM (DRV8301, Figure 1), provides a great way to learn and experiment with digital control of sub 60 volt three-phase motors to increase efficiency of operation. The board is available in two configurations, the DRV8301 or the DRV8302. This document goes over the typical kit contents and hardware details, and explains the functions and locations of jumpers and connectors present on the board. This document supersedes all the documents available for the kit.

Version: 1.0.5

Revision History:

1.0.5	April 23, 2014	Fixed page 18-20 comments regarding ADC and IQ CURRENT, VOLTAGE, and pole settings
1.04	January 29, 2014	Changed page 8 regarding GPIO to Enable Pin connection with TMDSCNCD28027F
1.03	July 11, 2013	Updated for TMDSCNCD28027F support. See specific instructions on Page 8. Added section on Optimizing Sense Circuitry
1.0.2	March 21, 2013	Added Revision History
1.0.1	February 26, 2013	First release

WARNING

This EVM is meant to be operated in a lab environment only and is not considered by TI to be a finished end-product fit for general consumer use

This EVM must be used only by qualified engineers and technicians familiar with risks associated with handling high voltage electrical and mechanical components, systems and subsystems.

This equipment operates at voltages and currents that can result in electrical shock, fire hazard and/or personal injury if not properly handled or applied. Equipment must be used with necessary caution and appropriate safeguards employed to avoid personal injury or property damage.

It is the user's responsibility to confirm that the voltages and isolation requirements are identified and understood, prior to energizing the board and or simulation. When energized, the EVM or components connected to the EVM should not be touched.

Table of Contents

Getting Familiar with the Kit

Kit Contents

The DRV830x EVM is usually available packaged as a full solution kit:

- MCU controlCARD
- DRV830x EVM board with slot for the controlCARD
- USB Cable
- USB/DVD with CCStudio IDE, GUI, documentation, and link to project software distribution
- Some versions ship with a tabletop 24V 2.5A power supply and 24V Motor with built-in Hall Sensors and Encoder

The DRV830x EVM board can accept many of the TI MCU controlCARDs, but we recommend using the versions that ship with the kits that include the JTAG emulator, USB to serial, and isolation on the controlCARD. It is recommended to always check for any updates to the GUI executable and MCU program.

Board Features:

The board has the following features

- **Three-Phase Power Stage, DRV830x** capable of driving 3-phase brushless DC motors and Permanent Magnet Synchronous Motors.
    - 60V DC max input voltage
    - 60A peak output current per phase
    - Up to 200khz driver switching frequency
    - Integrated 1A buck converter to provide logic and analog power
    - Dual integrated current sense amplifiers
- Isolated CAN and SPI communication (will only work if MCU supports and SW is enabled)
- JTAG connector for external emulators
- Quadrature Encoder Interface and Hall Sensor Interface available for speed and position measurement (only if MCU supports and SW is enabled)
- High precision low-side current sensing using integrated current sense amplifiers in the DRV830x (2-ch) or optional external 3-ch (Starting with DRV8301 RevD)
- Over current protection on the inverter stage by DRV830x
- Hardware Developer's Package that includes schematics and bill of materials
- Closed-loop digital control with feedback using the MCU's on-chip PWM and ADC peripherals

Warning: about low switching frequencies on the DRV830x

When the DRV830x runs at a low switching frequency (e.g. less than 20 kHz with 100 nF bootstrap capacitor), the bootstrap capacitor voltage might not be able to maintain a proper voltage level for the high-side gate driver. A bootstrap capacitor under voltage protection circuit (BST_UVP) will start under this circumstance to prevent the potential failure of the high-side MOSFET. In this circumstance, both the FAULT and OTW pins should pull low and the device should self-protect itself. The motor's inductance and the inverter's bootstrap capacitance will allow the DRV830x to run efficiently until approximately 10 kHz (with margin). Setting the PWM switching frequency below 10 kHz may cause issues on the inverter output and is not recommended. Please reference the datasheet.

Hardware Overview

The example projects made available with the kit may be done with a supplied 24V power supply, but many of the examples will work with an externally supplied laboratory power supply of a different voltage or current limit. The DRV830x EVM has all the power and control blocks that constitute a typical motor drive system for a three-phase system: Communications + Control + Feedback + Feedforward + Drive

Macro Blocks

The motor control board is separated into functional groups that enable a complete motor drive system, these are referred to as macro blocks. Following is a list of the macro blocks present on the board and their functions:

- controlCARD socket – Socket for a controlCARD (preferably using built-in emulation).
- DC Bus Connection
  - "PVDD/GND" Terminals – Connect an external 8-60V DC lab supply here making sure to observe correct polarity..
- DRV830x – This module includes either the DRV8301 or DRV8302 Three Phase Pre-Driver as well as all of the necessary external passive components.
- Current Sense – Low-side shunt current sensing on each half-bridge.
- Quadrature Encoder Connections – Connections are available for an optional shaft encoder to interface to the MCU's QEP peripheral.
- Hall Effect Sensor Connections – Connections are available for optional Hall Effect Sensors.

Fig 2, illustrates the position of these macro blocks on the board. The use of a macro block approach, for different power stages enables easy debug and testing of one stage at a time. All the PWM's and ADC signals which are the actuation and sense signals have designated test points on the board, which makes it easy for an application developer to try out new algorithms and strategies.

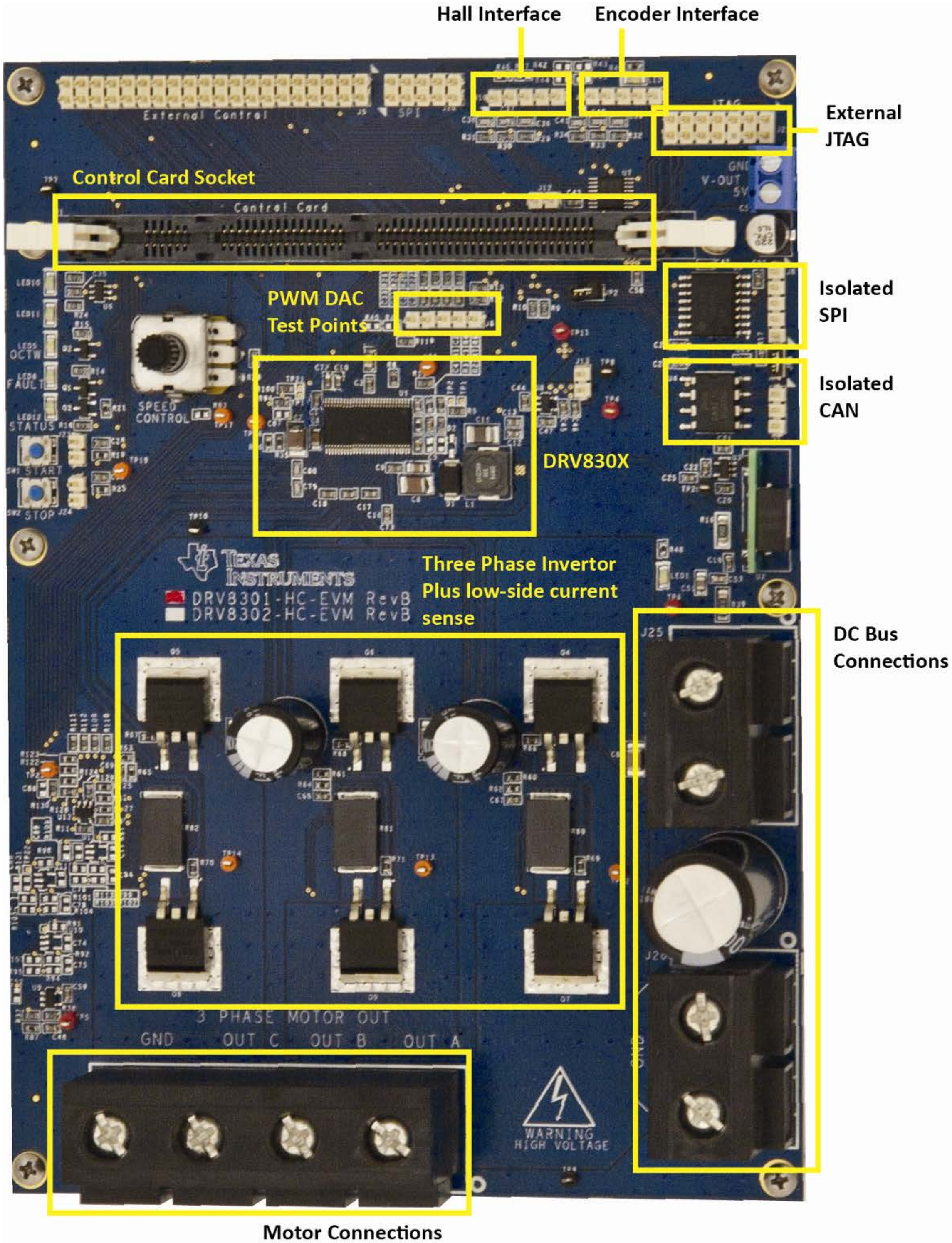


Fig2: DRV830x-EVM Board Macros

Powering the Board

The board is separated into two power domains*, the low voltage Controller Power domain that powers the controller and the logic circuit present on the board, and the medium voltage power delivery line that is used to carry the medium voltage and current like the DC power for the Inverter also referred to as DC Bus.

1) **Controller Power** comprises of the 5V and 3.3V that the board uses to power the controller and the logic and sensing circuit present on the board. This power is regulated from the DC bus by the DRV830x integrated buck converter.

2) **DC Bus Power** is the medium voltage line – up to 60V - that provides the voltage to the inverter stage to generate 3 phases to control the motor

Note: Do not apply power to board before you have verified these settings!

The kit ships with the control card inserted and the jumper and switch settings pre done for connecting with the GUI. However the user must ensure that these settings are valid on the board.

1. Make sure nothing is connected to the board, and no power is being supplied to the board.
2. Insert the controlCARD into the connector if not already populated.

Special Notes Regarding controlCARD Use

- Make sure switches are set properly on the controlCARD according to the appropriate qsg_hw_cncd280xxx.pdf
- Special notes for using controlCARDs with this motor drive board
    - When using TMDSCNCD28027F
        - Connect pin 2 of J12 (GPIO-29) to pin 6 of J5 (EN_GATE).
        - Note, for all MotorWare versions up to _11 this was pin1 of J11. Changed in _12 due to pin conflict.

3. Make sure the following jumpers & connector settings are valid i.e.
    a. JP2 is installed
4. Connect your PC to the kit
    a. controlCARDs with on-card XDS100 USB-JTAG:
        i. connect USB cable from computer to USB connector on control card
    b. controlCARDs without on-card USB-JTAG
        i. connect USB cable from computer to external emulator, and emulator to 14-pin JTAG header (J21)
5. Connect the motor you want to spin to the “MOTOR” terminal block as shown below. The order is not important unless a rotor sensor is used. If ground is available with your motor it should also be used.

6. Connect an 8-60V DC power supply to the PVDD and GND terminals.

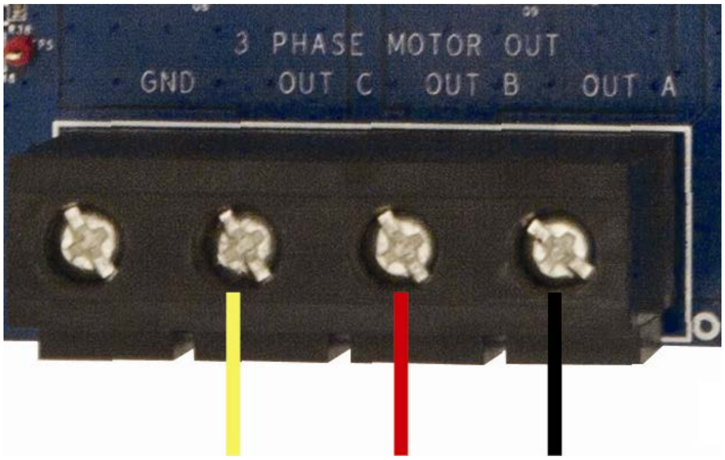


Fig3: DRV830x-HC-EVM Motor Connections

Hardware Resource Mapping

Resource Allocation

J1 Pin no.	**GPIO**	**Signal Name**	**Function** (DRV8301/DRV8302)
23	GPIO-00	PWM_AH	DRV830x Phase AH PWM input
73	GPIO-01	PWM_AL	DRV830x Phase AL PWM input
24	GPIO-02	PWM_BL	DRV830x Phase BH PWM input
74	GPIO-03	PWM_BL	DRV830x Phase BL PWM input
25	GPIO-04	PWM_CH	DRV830x Phase CH PWM input
75	GPIO-05	PWM_CL	DRV830x Phase CL PWM input
26	GPIO-06	DAC_PWM4	PWM DAC
76	GPIO-07	STOP	Push button input
28	GPIO-08	DAC_PWM3	PWM DAC
78	GPIO-09	START	Push button input
29	GPIO-10	DAC_PWM1	PWM DAC
79	GPIO-11	DAC_PWM2	PWM DAC
33	GPIO-12	LED-1	User LED

83	GPIO-13	OCTWn	Over-temperature warning
84	GPIO-14	FAULTn	Over-current fault
34	GPIO-15	LED-2	User LED
38	GPIO-16	SPI-SIMO	Isolated SPI Interface
88	GPIO-17	SPI-SOMI	Isolated SPI Interface
39	GPIO-18	SPI-CLK	Isolated SPI Interface
89	GPIO-19	SPI-STE	Isolated SPI Interface
40	GPIO-20	QEPA	Encoder A
90	GPIO-21	QEPB	Encoder B
41	GPIO-22	STATUS	User LED
91	GPIO-23	QEPI	Encoder Index
35	GPIO-24	SDI	SPI Data In/M_DC
85	GPIO-25	SDO	SPI Data Out/GAIN
36	GPIO-26	SCLK	SPI ClockDC_ADJ
86	GPIO-27	/SCS	/SCS/M_PWM
44	GPIO-30	CAN-RX	Isolated CAN Interface
94	GPIO-31	CAN-TX	Isolated CAN Interface
30	GPIO-40	CAP1	Hall Input 1
80	GPIO-41	CAP2	Hall Input 2
31	GPIO-42	CAP3	Hall Input 3
81	GPIO-43	DC-CAL	Short DC current sense amplifier inputs to ground, calibrate offset
59	ADC-A1	IA-FB	Current sense phase A
61	ADC-A2	I-TOTAL	DC Bus current sense
63	ADC-A3	IC-FB	Current sense phase C
67	ADC-A5	IC-FB	Current sense phase C

71	ADC-A7	ADC-Vhb2	Phase Voltage sense B
7	ADC-B0	TSI	Tach/Pot input
9	ADC-B1	IB-FB	Current sense phase B
11	ADC-B2	VDCBUS	DC Bus voltage sense
13	ADC-B3	IA-FB	Current sense phase A
15	ADC-B4	ADC-Vhb3	Phase Voltage sense C
17	ADC-B5	IB-FB	Current sense phase B
21	ADC-B7	ADC-Vhb1	Phase Voltage sense A

Table 1: Signal mapping to the controlCARD DIMM slot

Jumpers and Connectors

The Tables below show the various connections available on the board.

Connector Reference	# of Pins	Name
J2	2	HEADER2x1
J4	5	HEADER5x1
J5	40	HEADER20x2
J6	5	HEADER5x1
J7	3	HEADER3x1
J8	5	HEADER5x1
J10	5	HEADER5x1
J11	4	TERM BLOCK HEADER 4x1
J12	2	HEADER2x1
J13	2	HEADER2x1
J20	10	HEADER5x2
J21	14	HEADER7x2

J23	2	HEADER2x1
J24	2	HEADER2x1
J25	2	TERM BLOCK HEADER 2X1
J26	2	TERM BLOCK HEADER 2X2

Table 2: List of Connectors

J2 (User Power Access)

Pin #	Signal
1	VCC_5V
2	GND

J4 (Optional Encoder)

Pin #	Signal
1	E1A
2	E1B
3	E1C
4	VCC_5V
5	GND

J6 (PWM DAC)

Pin #	Signal
1	DAC1
2	DAC2
3	DAC3
4	DAC4
5	GND

J7 (CAN)

Pin #	Signal
1	CAN-H
2	CAN-L
3	IGND

J8 (User SPI)

Pin #	Signal
1	iSD-O
2	iCLK-O
3	iSD-I
4	iGPIO
5	IGND

J10 (HALL Sensor)

Pin #	Signal
1	E2A
2	E2B
3	E2C
4	VCC_5V
5	GND

J11 (Motor)

Pin #	Signal
1	Phase A
2	Phase B
3	Phase C
4	GND

J12 (GPIO/SCI)

Pin #	Signal
1	GPIO-28
2	GPIO-29

J13 (User Power Access)

Pin #	Signal
1	VCC_3.3V
2	GND

J20 (DRV8301 SPI))

Pin #	Signal
1	NC
2	GND
3	NC
4	NC
5	SDO
6	NC
7	SCLK
8	SDI
9	/SCS
10	GND

J23 (Push Button)

Pin #	Signal
1	START
2	GND

J24 (Push Button)

Pin #	Signal
1	STOP
2	GND

J21 (External JTAG)

Pin #	Signal
1	TMS
2	TRSTn
3	TDI
4	GND
5	VCC_3.3V
6	NC
7	TDO
8	GND
9	TCK
10	GND
11	TCK
12	GND
13	EMU0
14	EMU1

J25 (Power Input)

Pin #	Signal
1	PVDD
2	PVDD

J26 (Power Input)

Pin #	Signal
1	GND
2	GND

Tables3-17 Individual Connector Pinouts

J5 (External Controller Access)

Pin #	Signal	Pin #	Signal
1	VCC_5V	2	VCC_5V
3	GND	4	GND
5	STATUS	6	EN_GATE
7	QEPA	8	QEPI
9	FAULTn	10	QEPB
11	CAP3	12	OCTWn
13	DC_CAL	14	CAP1
15	DAC_PWM1	16	CAP2
17	DAC_PWM3	18	DAC_PWM2
19	GND	20	GND
21	DACE_PWM4	22	PWM_CL
23	PWM_AL	24	PWM_BL
25	PWM_AH	26	PWM_CH
27	GND	28	PWM_BH
29	ADC-Vhb1	30	GND
31	ADC-Vhb2	32	ADC-Vhb3
33	IC-FB	34	VDCBUS
35	I_TOTAL	36	IB-FB
37	IA-FB	38	TSI
39	GND	40	GND

Table 18: J5 Pinout

Test Points

Test Point	Net Connection
TP1	VCC_5V
TP2	VCC_5V_R5
TP3	PWRGD
TP4	VCC_3.3V
TP5	REF_1.65V
TP6	PVDD
TP7	GND
TP8	GND
TP9	GND
TP10	GND
TP11	VCC_5V
TP12	SH_A
TP13	SH_B
TP14	SH_C
TP15	S02
TP16	IB-FB
TP17	IA-FB
TP18	U10_1
TP19	IC-FB
TP20	IGND
TP21	S01
TP22	U11_1
TP23	I-TOTAL

Jumpers

Reference	Function
JP2	VCC_5V to controlCARD
JP4	CAN termination

Table 20: Testpoints and Jumpers

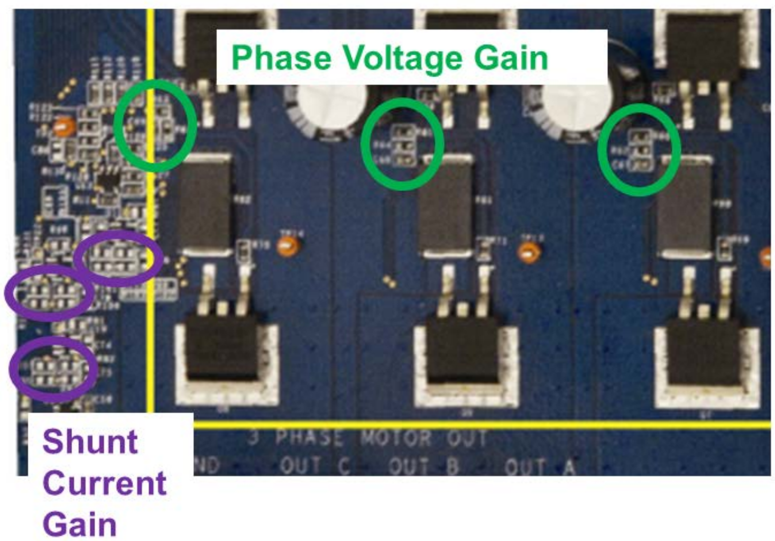
Optimizing Sense Circuitry

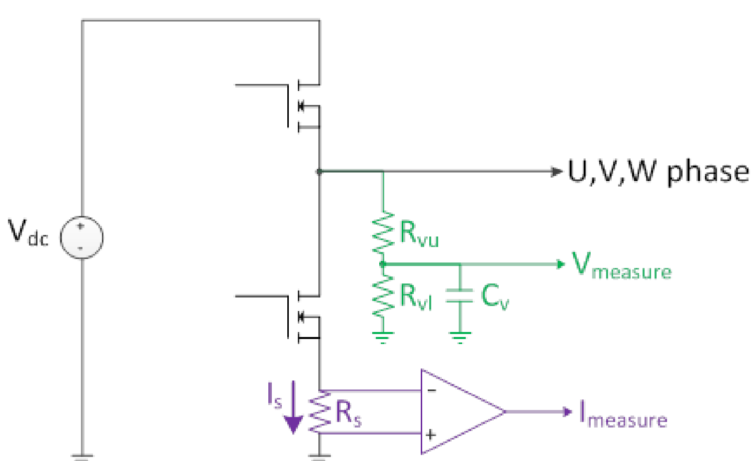
Overview

Proper resolution of motor signals is critical to the performance of any control system, but especially those with software observers attempting to replace the precision of an absolute encoder. Because the DRV83xx are built to work at over 50 Vdc-bus, the resolution of the voltage sensing is not as precise as you would like for motors < 48V. And in the case of the DRV8301 which measures 41.25A, the current resolution may also be unacceptable. This section describes how to update both the hardware and corresponding software to maximize resolution and performance.

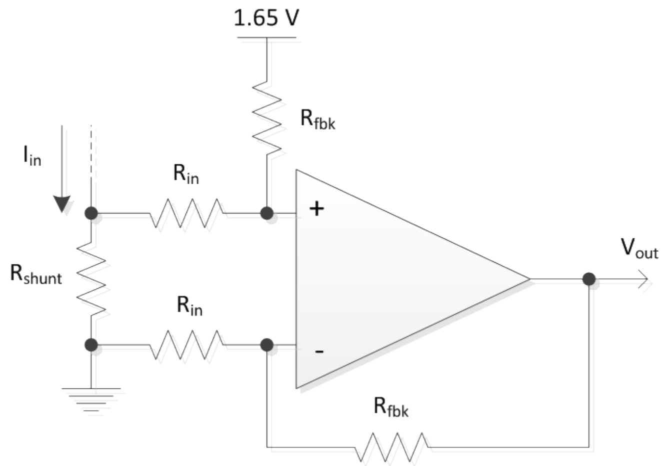
Steps to follow

1. Determine MAXIMUM phase current, adjust current gain to 3.3V ADC
2. Set MAX voltage at +30% margin of motor voltage, adjust voltage gain to 3.3V ADC
3. Configure software to hardware changes





Shunt Current Feedback



$$V_{out} = 1.65 + I_{in} \cdot R_{shunt} \cdot \frac{R_{fbk}}{R_{in}}$$

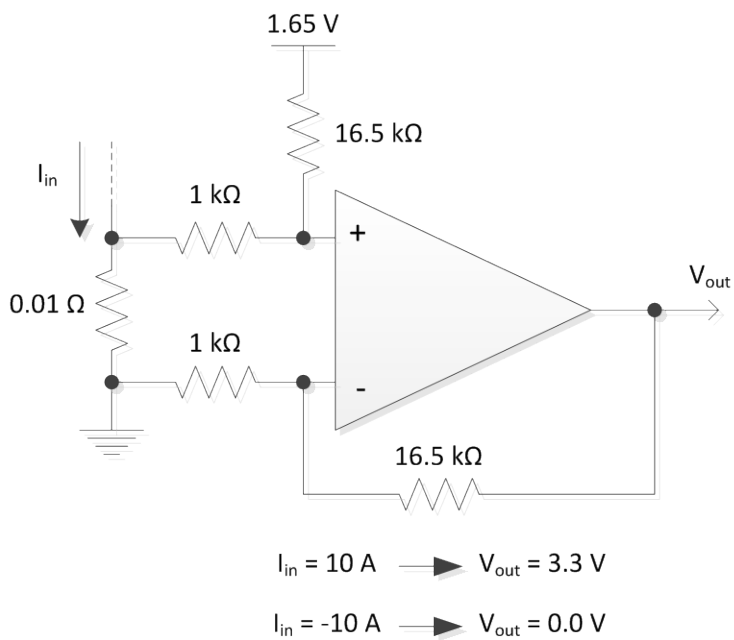
Select resistor values to provide Vout = 3.3V for maximum peak-to-peak phase current

- Ex: For a maximum of 10A, consider a 0.01Ω shunt resistor

$$\frac{R_{fbk}}{R_{in}} = \frac{V_{out} - 1.65}{I_{in} \cdot R_{shunt}} = \frac{3.3 - 1.65}{10 \cdot 0.01} = 16.5$$

  - One possible solution

$$R_{fbk} = 16.5 \cdot R_{in} = 16.5\ \mathrm{k\Omega}\ \text{ with } R_{in} = 1\ \mathrm{k\Omega}$$



- Update the current hardware resistors
  - R_{shunt} = R80, R81, R82
  - R_{fbk} = R107, R95; R108,R105; R113, R103
  - R_{in} = R92, R94; R101, R104; R99, R102

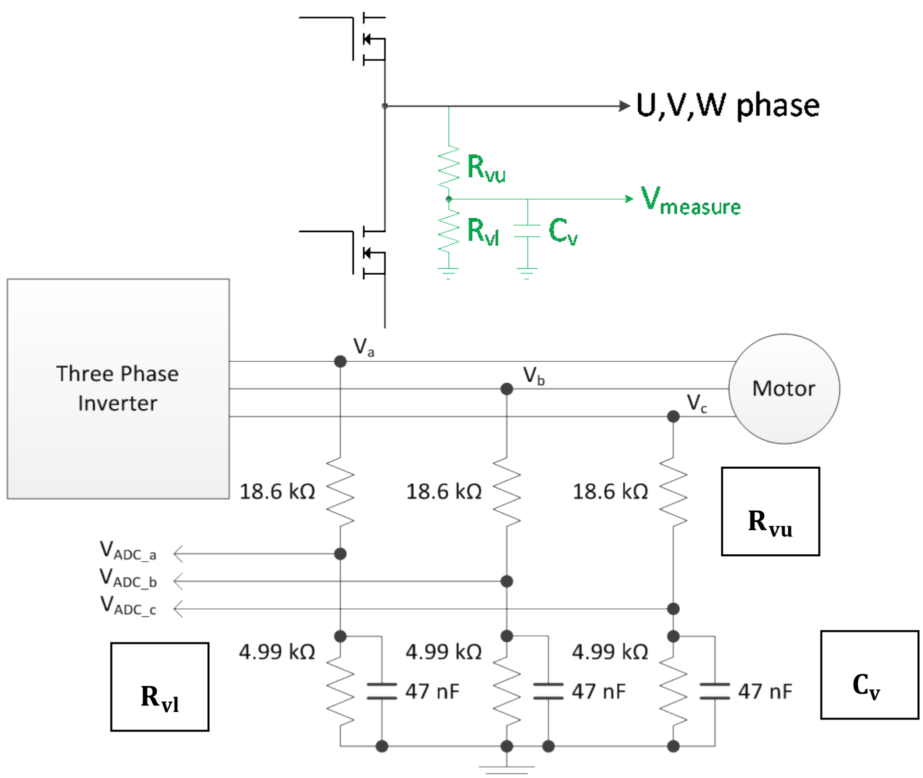
- Update your software settings in user.h; for this example of +/- 10A peak

```
//! \brief  Defines the maximum current at the input to the AD converter
#define USER_ADC_FULL_SCALE_CURRENT_A  (20.0)
```

Insure that your IQ variable is >= 0.5 * the ADC value

```
#define USER_IQ_FULL_SCALE_CURRENT_A  (10.0)
```

Phase Voltage Feedback



- Ex: for a maximum of 12V, add headroom of 30% to set V_a^{max} to 15.6V

$$V_a^{max} = V_{ADC_a}^{max} \cdot \frac{(4.99\ \text{k}\Omega + R_{vu})}{4.99\ \text{k}\Omega}$$

$$15.6V = 3.3\ \text{V} \cdot \frac{(4.99\ \text{k}\Omega + R_{vu})}{4.99\ \text{k}\Omega}$$

$$R_{vu} = \frac{15.6\ \text{V} \cdot 4.99\ \text{k}\Omega}{3.3\ \text{V}} - 4.99\ \text{k}\Omega = 18.6\ \text{k}\Omega$$

- Update the voltage hardware resistors
  - $\mathbf{R_{vu}}$ = R60; R61; R63
  - $\mathbf{R_{vl}}$ = R62; R64; R65

- Update your software settings in user.h; for this example of 15.6V maximum

```
//! \brief  Defines the maximum voltage at the input to the AD converter
#define USER_ADC_FULL_SCALE_VOLTAGE_V  (15.6)
```

In general an IQ value equal to your Voltage bus is effective.

During motor identification – for very small flux motors - you may need to make this value smaller to lower the minimum flux value that can be identified, which is given by:

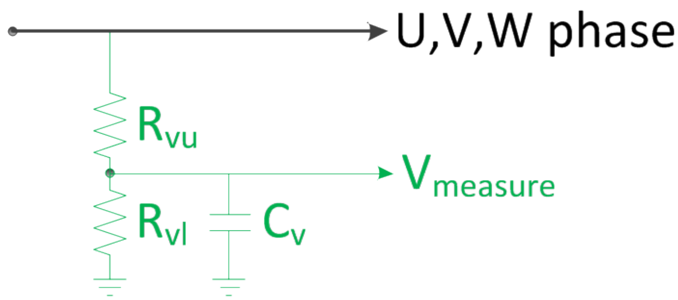
USER_IQ_FULL_SCALE_VOLTAGE_V / Effective Estimator Hz / 0.7

After motor identification - for larger flux motors - you may need to increase this value to insure that the following is true:

USER_IQ_FULL_SCALE_VOLTAGE_V > USER_MOTOR_RATED_FLUX * Maximum_Frequency_Hz (this is the maximum speed you will ever run the motor, including deep field weakening).

```
#define USER_IQ_FULL_SCALE_VOLTAGE_V  (12.0)
```

Phase Voltage Filter Feedback



- See 5.2.4 of the User's Guide
- The voltage filter pole is needed by the FAST estimator to allow an accurate detection of the voltage feedback. The filter should be low enough to filter out the PWM signals, and at the same time allow a high speed voltage feedback signal to pass through the filter
- This pole should be designed to fall between
  200 Hz <= Pole <= USER_IQ_FULL_SCALE_FREQ_Hz / 4 [hard upper limit]
  - **Higher poles are more sensitive to capacitor error and drift, so please recognize the trade-offs in using a higher pole, especially for high frequency motors**

$$F_{filter\_pole} = \frac{1}{2 \cdot \pi \cdot R_{parallel} \cdot C} = \frac{1}{2 \cdot \pi \cdot \left(\frac{\mathrm{R_{vu}} \cdot \mathrm{R_{vl}}}{\mathrm{R_{vu}} + \mathrm{R_{vl}}}\right) \cdot \mathrm{C_v}}$$

- Example
  - 4 pole pairs; 5 kRPM
    - Hz = RPM * Poles / 120 = 5000 * 8 / 120 = 333 Hz
    - Select 400 Hz (> 333 Hz)
  - With our previous $\mathbf{R_{vl}}$ =4.99 kΩ ; $\mathbf{R_{vu}}$ = =18.6 kΩ

$$F_{filter\_pole} = 400\ Hz = \frac{1}{2 \cdot \pi \cdot \left(\frac{18.6\mathrm{k\Omega} \cdot 4.99\ \mathrm{k\Omega}}{18.6\mathrm{k\Omega} + 4.99\ \mathrm{k\Omega}}\right) \cdot \mathrm{C_v}}$$

  - $\mathbf{C_v}$ =101 nF

- Update the hardware capacitors
  - $\mathrm{C_v} = \mathrm{C67; C68; C69}$
- Update your software settings in user.h

```
//! \brief Defines the analog voltage filter pole location, Hz
#define USER_VOLTAGE_FILTER_POLE_Hz (400.0)
```

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