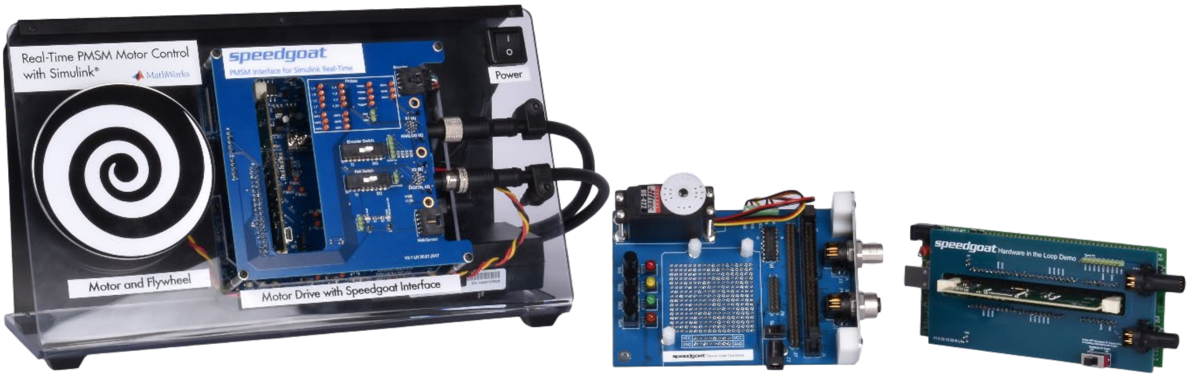
April 2020

IO397 Demo Kits

User Manual



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real-time simulation and testing

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1 Introduction

The demo kits are an excellent starting point to real-time testing and simulation using the MathWorks and Speedgoat workflow. Each demo kit contains the required hardware, Simulink models and documentation to run in real-time. Speedgoat offers demo kits ranging from basic Simulink Real-Time evaluation to advanced motor control and hardware-in-the-loop (HIL) simulations:

1. DUT Demo (also known as Getting Started Demo)
2. PMSM Motor Control Demo
3. HIL Demo with TI microcontroller

These demo kits are also used for the MathWorks Simulink Real-Time training worldwide. Sign up for a Simulink Real-Time training near you at mathworks.com/training.

1.1 DUT Demo (Getting Started Demo)

The Getting Started Demo - also known as the DUT (Device Under Test) Demo- takes you through the typical real-time simulation and testing workflows using Simulink models and Speedgoat real-time target machines by connecting to:

a) an electric servo DC motor via a H-bridge and a potentiometer feedback
b) four pushbuttons
c) four LEDs
d) switches, and LEDs.
e) an RC filter
f) a loopback for I^2C

This demo kit is used for the SLRT Evaluation Kit (DUT Demo) for workshops worldwide. Contact Speedgoat for more information (support@speedgoat.com).

1.2 PMSM Motor Control Demo

The demo kit gets you started with rapid control prototyping of a brushless DC motor and a 3-phase full H-bridge motor driver. The PMSM Demo Kit consists of a complete software/hardware package to run and test Simulink PMSM models on a Speedgoat real-time target machine to control a brushless DC motor using analog and digital I/O. The Simulink model supplied allows the user to immediately start running the motor in open-loop and closed-loop control.

1.3 HIL Demo with TI Microcontroller

Learn how to test your real hardware and controllers in simulated conditions before doing expensive tests in the final product using hardware-in-the-loop (HIL) simulation. With this demo kit you will learn both about hardware-in-the-loop, embedded programming and DC motor control. Having designed your controller using Model-Based Design, you will deploy your Simulink model in a Texas Instruments microcontroller. Afterwards, you will test your TI microcontroller under typical operating conditions using hardware-in-the-loop. The real-time target machine will simulate a Simscape™ brushless DC motor with encoders and sensors in real-time with a sampling rate of a few tens of microseconds.

2 Safety Guidelines

2.1 Intended Use

The IO397 demo kits have been designed, developed, and manufactured for evaluation of the real-time products from MathWorks and Speedgoat. This product was not designed, developed, or manufactured for any use involving serious risks or hazards that could lead to death, injury, serious physical damage or loss of any kind without the implementation of exceptionally stringent safety precautions. In particular, such risks and hazards include the use of these devices to monitor nuclear reactions in nuclear power plants, their use in flight control or flight safety systems as well as in the control of mass transportation systems, medical life support systems or weapons systems.

2.2 Protection Against Electrostatic Discharge

Electrical components that can be damaged by electrostatic discharge (ESD) must be handled accordingly.

2.3 Packaging

2.3.1 Electrical components with housing

Does not require special ESD packaging but must be handled properly.

2.3.2 Electrical components without housing

Must be protected by ESD-suitable packaging.

2.4 Policies and Procedures

Electronic devices are never completely failsafe. If the system fails, the user is responsible for ensuring that other connected devices, e.g. motors, are brought to a secure state.

Safety precautions relevant to industrial control systems (e.g. the provision of safety devices such as emergency stop circuits, etc.) must be observed in accordance with applicable national and international regulations. The same applies for all other devices connected to the system, such as drives.

All tasks such as the installation, commissioning and servicing of devices are only permitted to be carried out by qualified personnel. Qualified personnel are those familiar with the transport, mounting, installation, commissioning and operation of devices who also have the appropriate qualifications (e.g. IEC 60364). National accident prevention regulations must be observed.

Safety notices, connection descriptions (type plate and documentation) and limit values listed in the technical data are to be read carefully before installation and commissioning and must be observed.

2.5 Transport and Storage

During transport and storage, devices must be protected against undue stress (mechanical loads, temperature, humidity, aggressive atmospheres, etc.).

2.6 Installation

- Installation must be performed according to the Speedgoat documentation for the real-time target machine. Devices may only be installed by qualified personnel without voltage applied. Before installation, voltage to the control cabinet must be switched off and prevented from being switched on again.
- General safety guidelines and national accident prevention regulations must be observed.
- Electrical installation must be carried out according to applicable guidelines (e.g. line cross sections, fuses, protective ground connections).

2.7 Operation

2.7.1 Protection Against Touching Electrical Parts

To operate, it may be necessary for certain parts to carry dangerous voltage levels over 42 V_{DC}. Touching one of these parts can result in a life-threatening electric shock. This could lead to death, severe injury or damage to equipment.

Before turning on the real-time target machine, the housing must be properly grounded. Ground connections must be established even when testing/operating devices or the uninterruptible power supply for a short time!

Before turning the device on, all parts that carry voltage must be securely covered. During operation, all covers must remain closed.

2.7.2 Environmental Conditions – Dust, Humidity, Aggressive Gases

Use in very dusty environments should be avoided. Dust accumulation on the devices can affect functionality.

The presence of aggressive gases can also lead to malfunctions. When combined with high temperature and humidity, aggressive gases – e.g. with sulfur, nitrogen and chlorine components – can induce chemical reactions that can damage electronic components very quickly. A sign of the presence of aggressive gases are blackened cable ends on existing equipment.

2.7.3 Viruses and Dangerous Programs

This system is subject to potential risk each time data is exchanged or software is installed from a data medium (e.g. USB flash drive, etc.), a network connection or the Internet. The user is responsible for assessing these dangers, implementing preventive measures such as virus protection, firewalls, etc. and making sure that software is only obtained from trusted sources.

3 Handling Instructions

3.1 ESD Protection

The Demo kits are sensitive to static electricity. Packing, unpacking and all other module handling has to be done with the appropriate care.

3.2 Firmware Damage

Only use the IO397 Demo Kits with Speedgoat library 8.21 or later. Using an earlier release could potentially erase the firmware from the IO397 I/O module requiring factory repair.

4 Prerequisites

4.1 Hardware

The hardware required for running the demo is the following:

1. Baseline real-time target machine with a IO397 I/O module installed
2. Ethernet cable to connect your real-time target machine with your development computer
3. The external power supply plus the power cord to supply the real-time target machine.
4. A DisplayPort cable or adapter to connect your real-time target machine with a target screen. (not included in delivery)
5. Two 17-pin M12 cables to connect your demo hardware with the IO397 I/O module
6. A power cord to supply the demo hardware (only PMSM demo)

Refer to the pictures below if unclear

Figure 1: Baseline

Figure 2: Ethernet cable

 Figure 3: external power supply	 Figure 4: 17Pin M12 cable

4.2 Software

The following software is required to use the IO397 Demo Kits:

1. Speedgoat library 8.21 or later. Download the library from the Speedgoat Customer Portal: **speedgoat.com/login**

   Warning: Using an earlier release could potentially erase the firmware from the IO397 I/O module requiring factory repair.

2. FPGA bitstreams for each demo. Download the latest models from the Speedgoat Customer Portal: **speedgoat.com/login**
   - DUT Demo: speedgoat_IO397_50k_CI_IO397_DUT_DEMO.zip
   - PMSM Motor Control Demo: speedgoat_IO397_50k_CI_IO397_PMSM_DEMO.zip
   - HIL Demo: speedgoat_IO397_50k_CI_IO397_HIL_DEMO.zip

3. Simulink Models for each demo. Download the latest models from the Speedgoat Customer Portal: **speedgoat.com/login**
   - DUT Demo: IO397_DUT_SLRT_MODELS.zip
   - PMSM Motor Control Demo: IO397_PMSM_SLRT_MODELS.zip
   - HIL Demo: IO397_HIL_SLRT_MODELS.zip

4. MATLAB Release 17b or later including the following products:
   - MATLAB
   - Simulink Real-Time
   - Simulink
   - Simulink Coder
   - Embedded Coder

   DUT and PMSM demo are also compatible with MATLAB Release 17a.

   Refer to the Software Configuration Guide for details on how to setup the target computer (speedgoat.com/help).

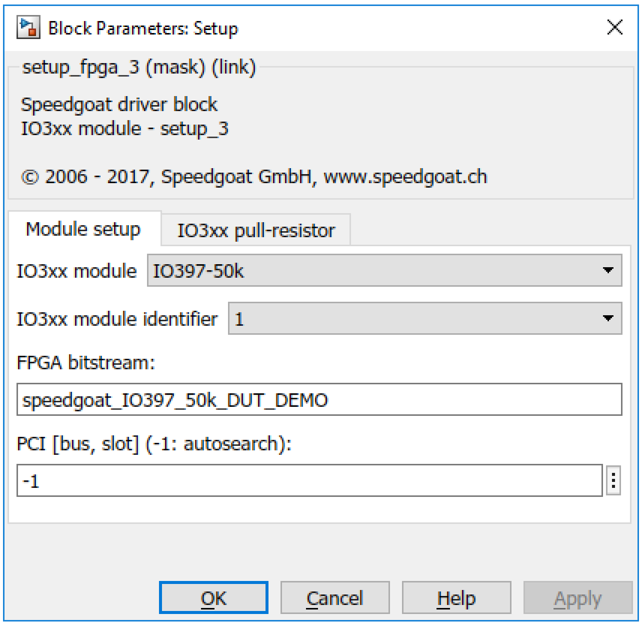
5. Texas Instruments Code Composer Studio 5.5 (HIL demo only)

5 Using the Demos

Setup your Baseline real-time target machine as per the Quick Start Guide supplied or the user manual. The Baseline user manual is available in the Customer Portal: speedgoat.com/login

There are Simulink Real-Time models for at least one function for each demo. To ensure that the model runs correctly, check that the correct I/O module (IO397-50k) and appropriate bitstream is selected in the setup block:

- DUT Demo: speedgoat_IO397_50k_CI_IO397_DUT_DEMO
- PMSM Motor Control Demo: speedgoat_IO397_50k_CI_IO397_PMSM_DEMO
- HIL Demo: speedgoat_IO397_50k_CI_IO397_HIL_DEMO



5.1 DUT Demo (Getting Started Demo)

5.1.1 Extract the Simulink Model and Bitstreams

Setup the folder structure as follows:

1. Extract the contents of the zip file with the Simulink Real-Time models (IO397_DUT_SLRT_MODELS.zip) in a desired folder. The extracted content has a folder named IO397_DUT_SLRT_MODELS containing the Simulink Real-Time models.

2. Extract the contents of the zip file (*speedgoat_IO397_50k_CI_IO397_DUT_DEMO.zip*) with the associated bitstream in a desired location. The folder contains the bitstream, a test model and documentation.

3. Copy the bitstream *speedgoat_IO397_50k_CI_IO397_DUT_DEMO.mat* to the folder containing the Simulink Real-Time models (step 1 above)

5.1.2 Connecting the Demo

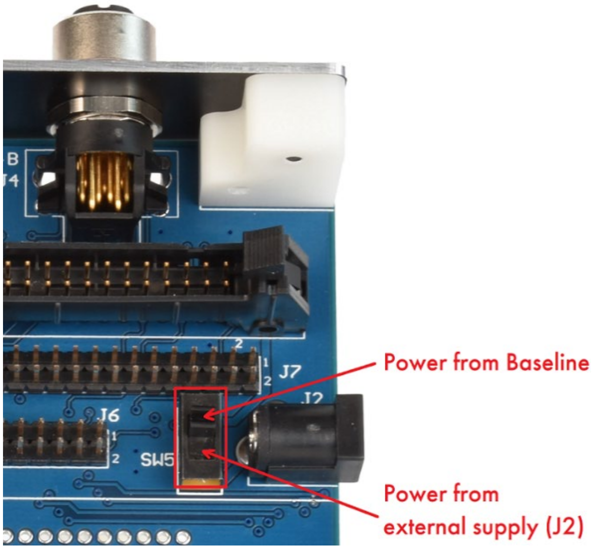
Prepare the demo hardware with the following three steps:

1. **Connect to the Baseline:** The DUT Demo hardware can be connected to the IO397 I/O module either by:

    - Using the M12 cables provided or
    - Directly plugging the DUT Demo hardware into the M12 connectors of the Baseline real-time target machine (see image below).

2. **Power the Demo:** While the DUT demo requires a 5 V_{dc} power supply, the Baseline real-time target machine includes a 5 V_{dc} power supply. Set the power switch SW5 upwards to use the Baseline power supply. <u>No external power supply should be connected.</u>

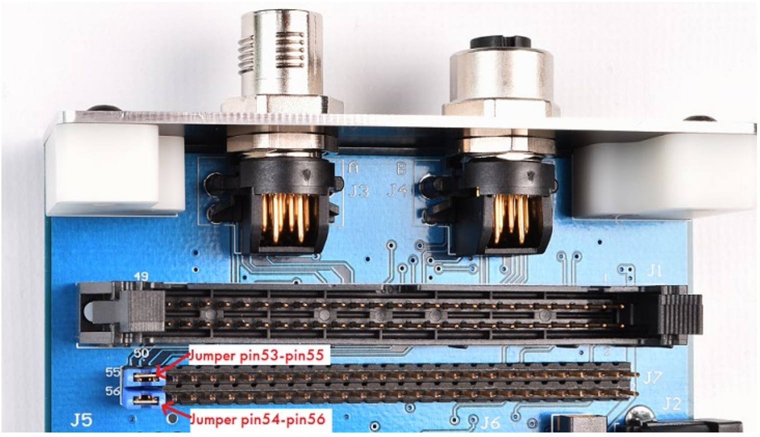
    Alternative power options (not recommended): By setting the power switch SW5 downwards, it is possible to use an external power supply from J2. To use an external power supply connect a regulated 5 V_{dc} power supply using a 5.5mm/2.1mm 5 V_{dc} Barrel Jack connector (not included with DUT demo).



3. **Check I^2C loopback:** If you want to use the I^2C loopback, verify that there are jumpers:

    a. linking J7-pin 53 and J7-pin 55

    b. linking J7-pin 54 and J7-pin 56

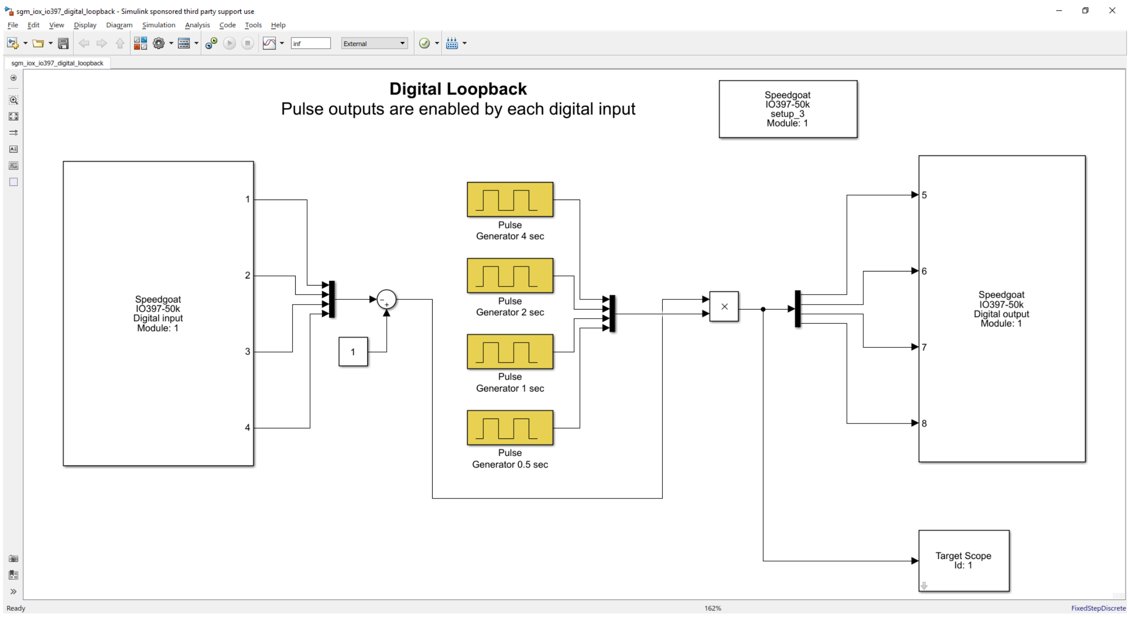


5.1.3 Running the Simulink Real-Time models

For the DUT Demo, the *speedgoat_IO397_50k_CI_IO397_DUT_DEMO.mat* bitstream must be used. This bitstream provides 8 GPIOs, one PWM output, one I^{2}C master, one I^{2}C slave port and 4 analog outputs and 4 analog inputs. Pin mappings for the DUT demo can be found in the [pinouts section]7.1.

Digital I/O

For the digital IOs the model *sgm_iox_io397_digital_loopback.slx* can be used. The model configures GPIOs 1 to 4 as inputs and GPIOs 5 to 8 as outputs.



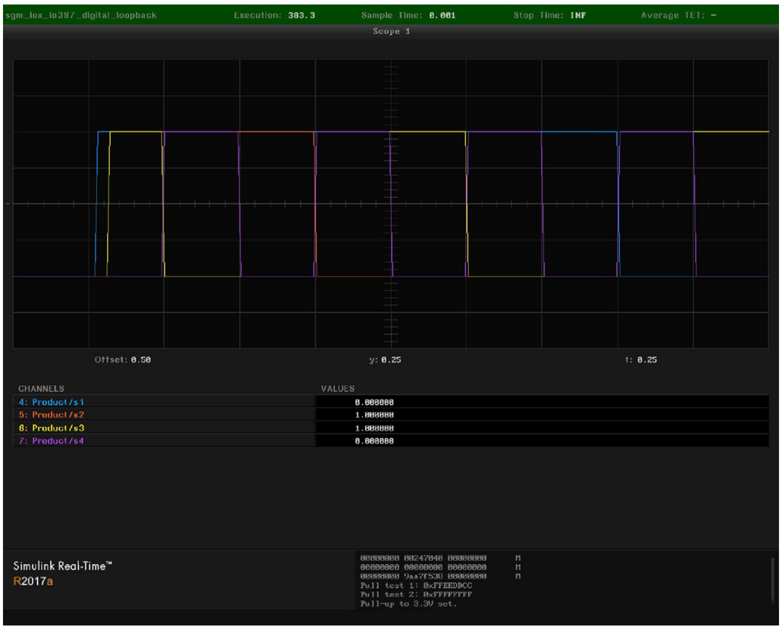
Test the digital I/O Simulink Real-Time model by:

a. Building the model in external mode

b. Connecting to the target

c. Running the model

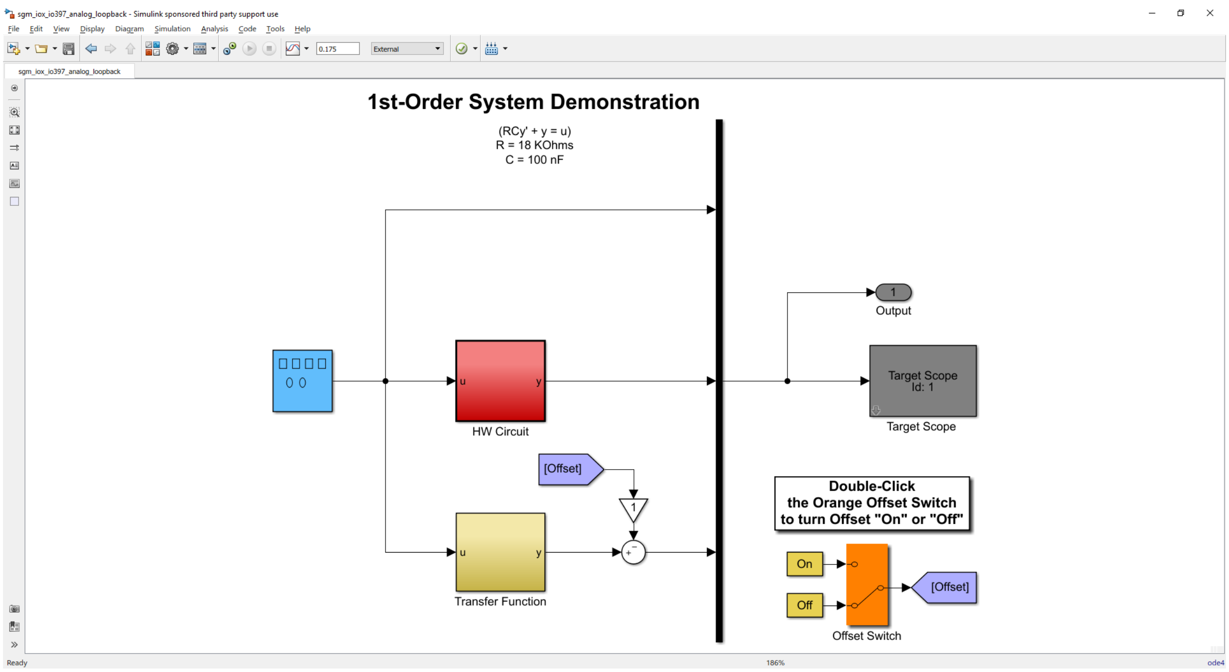
d. Pushing the pushdown buttons one by one



When a pushdown button is pressed down, the led in front of it should start to blink. For all buttons pressed, all lights will blink (at different frequencies) and the target screen output should be similar to the one in the figure above.

Analog I/O

For the analog IOs the model *sgm_iox_io397_analog_loopback.slx* can be used. The model implements a Filter of the 1st-Order, using the analog output 1 (DAC1) and the analog input 2 (ADC2).

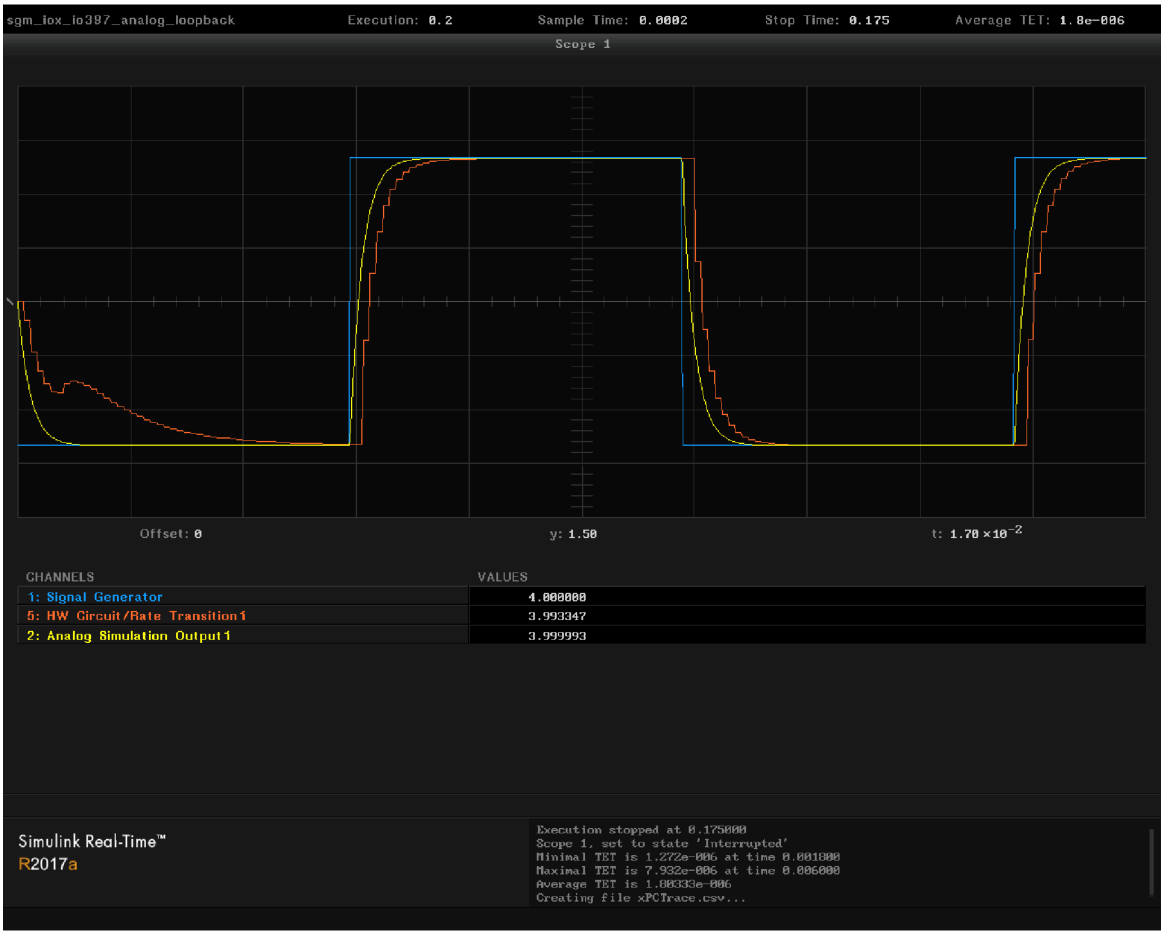


Test the analog I/O Simulink Real-Time model by:

a. Building the model in external mode

b. Connecting to the target

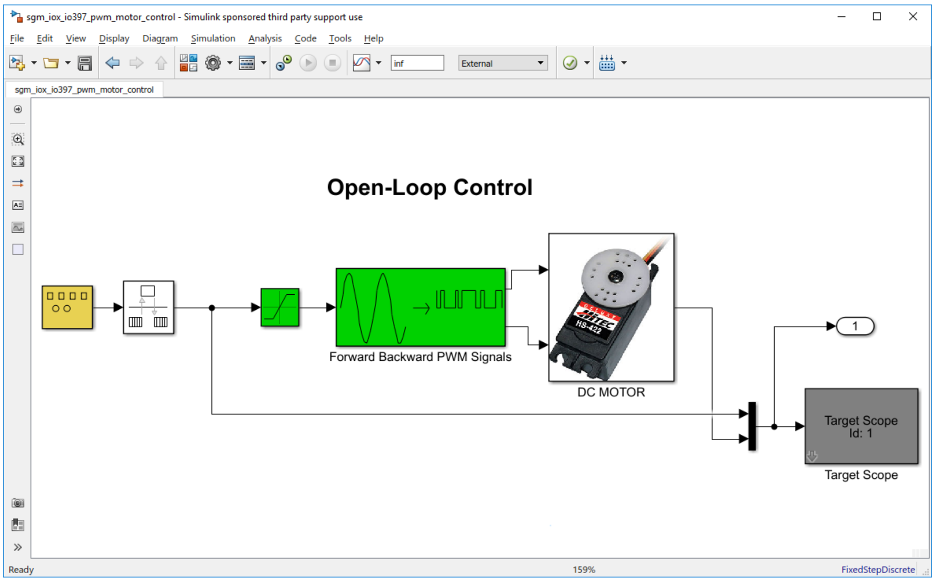
c. Running the model



As the model runs, the DAC1 sends a square signal; and ADC2 reads the same signal once it went through the RC filter. The expected target screen output is shown in the figure above.

Servo Motor Control

For the servo-motor control the model *sgm_iox_io397_pwm_motor_control.slx* can be used. The model generates a forward and backward PWM signal rotating the servo-motor back and forth. Using analog input 1 (ADC1), the position gets read back via the servo potentiometer. The PWM signal is generated using the PWM FPGA Code Module with a 13.33 ns resolution.



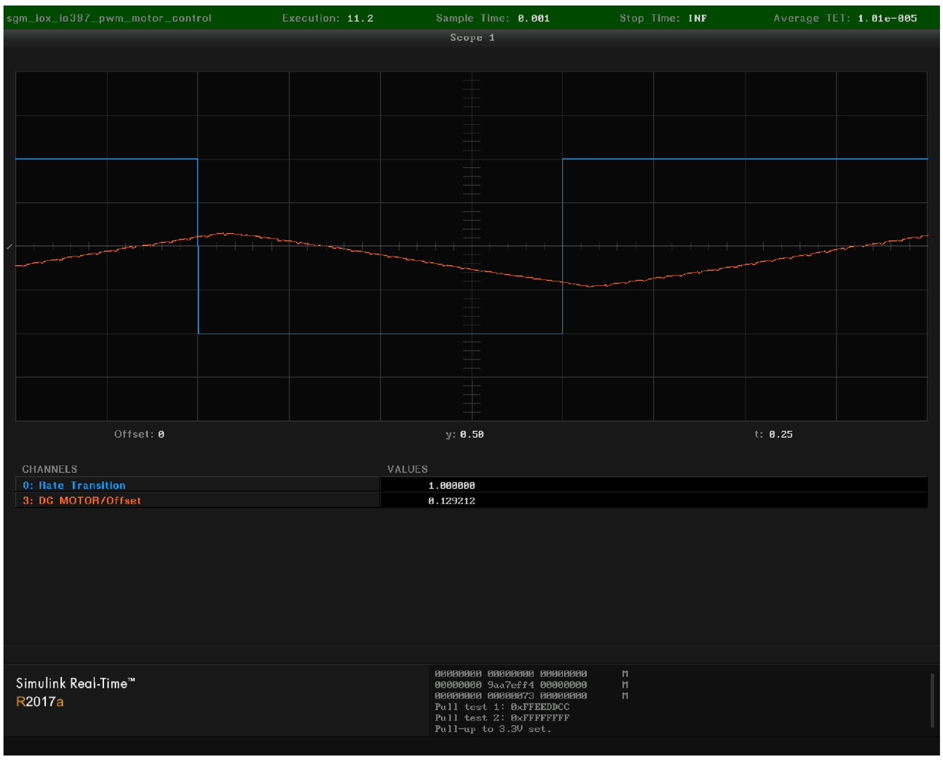
Test the servo motor I/O Simulink Real-Time model by:

a. Building the model in external mode

b. Connecting to the target

c. Running the model

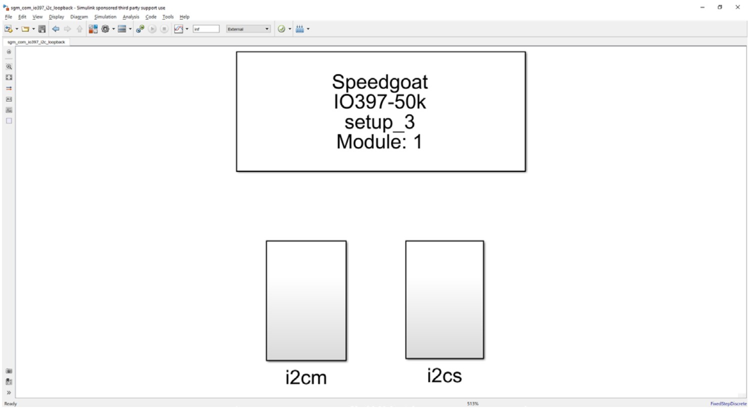
The servo-motor should start rotating back and forth. The measured servo-motor potentiometer voltage is displayed on the target screen like in figure below.



I²C

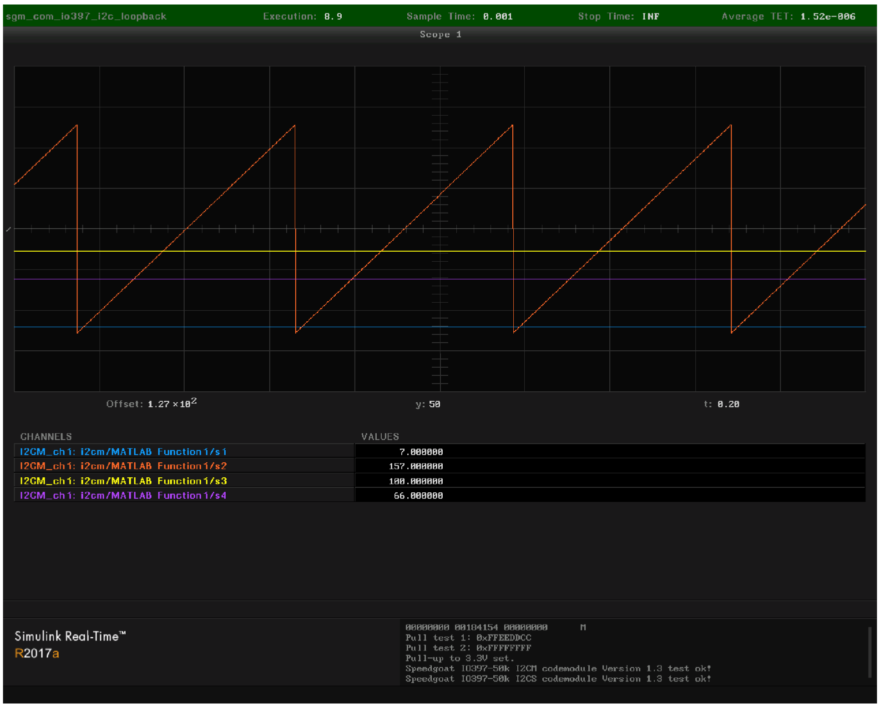
For the I²C IOs the model *sgm_com_io397_i2c_loopback.slx* can be used. The model configures the I²C master and slave loopback: sent via the I²C slave are read via the I²C master. The I²C slave writes 4 registers in a single channel. The registers are:

1. Constant: 7
2. Sawtooth wave
3. Constant: 100
4. Constant: 66



Test the I²C loopback I/O Simulink Real-Time model by:

a. Building the model in external mode
b. Connecting to the target
c. Running the model



A sample of the target output can be seen in the figure above.

5.2 PMSM Motor Control Demo

5.2.1 Extract the Simulink Model and Bitstreams

Setup the folder structure as follows:

1. Extract the contents of the zip file with the Simulink Real-Time models (IO397_PMSM_SLRT_MODELS.zip) in a desired location. The extracted content has a folder named IO397_PMSM_SLRT_MODELS containing the Simulink Real-Time models.

2. Extract the contents of the zip file (*speedgoat_IO397_50k_CI_IO397_PMSM_DEMO.zip*) with the associated bitstream in a desired location. The folder contains the bitstream, a test model and documentation.

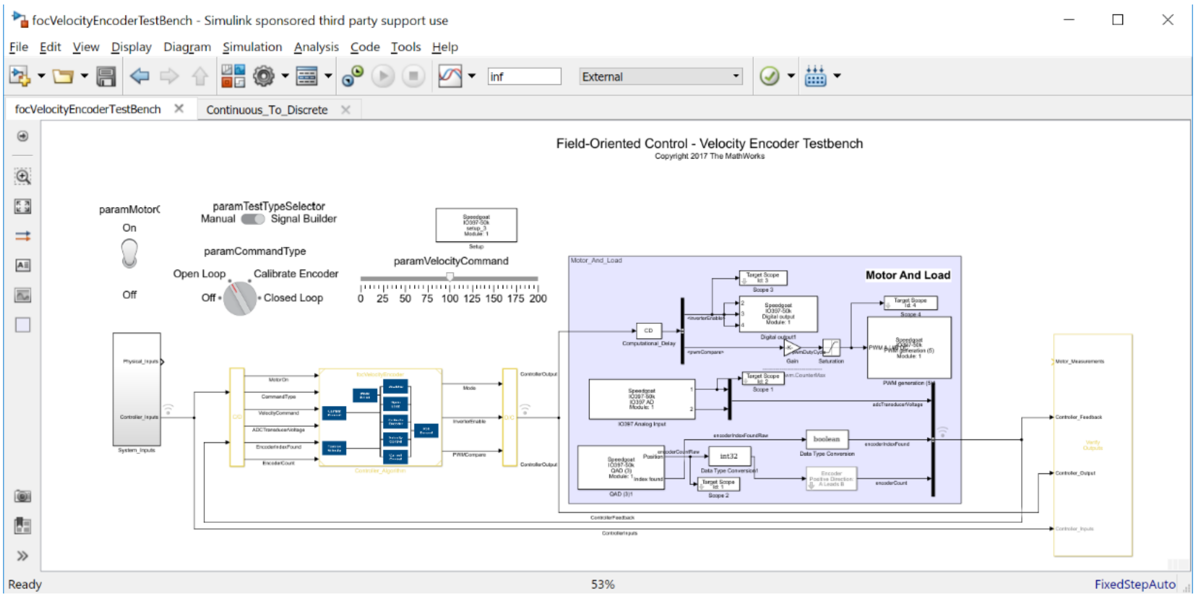
3. Copy the bitstream *speedgoat_IO397_50k_CI_IO397_PMSM_DEMO.mat* to the folder containing the Simulink Real-Time models (step 1 above)

5.2.2 Connecting the Demo

The PMSM demo hardware can only be connected with the IO397 by using the M12 cables provided. The PMSM demo also includes an AC/DC adapter and power plug. Once the demo is connected to the Baseline and a power source, use the power button on the top right to switch on the hardware to enable the motor and the associated 3-phase H-bridge motor driver.

5.2.3 Running the Simulink Real-Time Models

For the PMSM demo, the *speedgoat_IO397_50k_PMSM_DEMO.mat* bitstream must be used. This bitstream provides 4 GPIOs, 3 PWM outputs, 3 CAP inputs, 3 QAD outputs and 4 analog outputs and 4 analog inputs. Pin mappings for the PMSM demo can be found in the pinouts section 7.2. The PWM outputs, CAP inputs and QAD outputs use FPGA Code Modules. The example uses PWM outputs with a 25 kHz frequency with a 13.33 ns resolution.

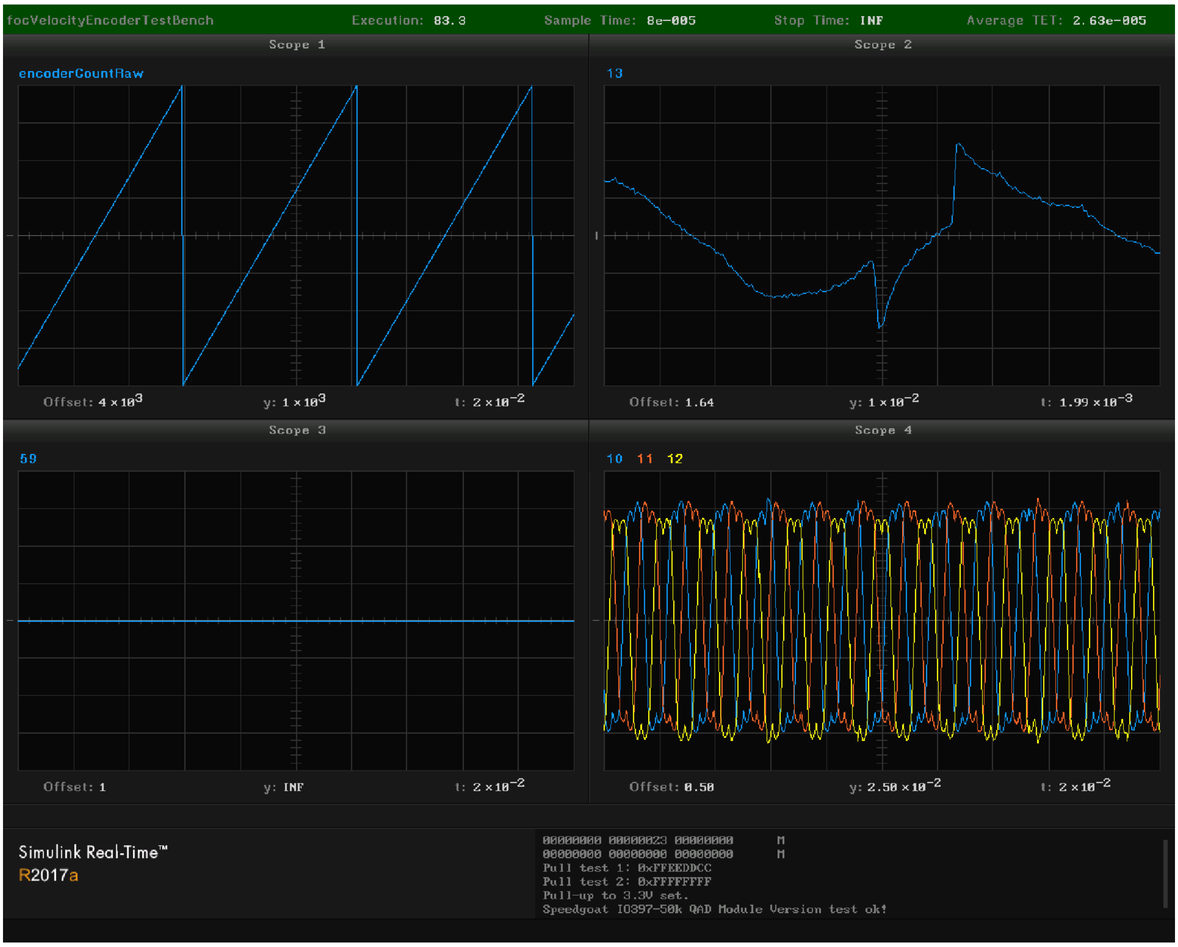


To demonstrate the open or closed looped motor control the *focVelocityEncoderTestBench.slx* Simulink model can be used. When running the model on the real-time target machine, the motor should spin counter-clockwise for around 2 seconds.

Run the model with the following steps:

1. Open the Simulink model "focVelocityEncoderTestBench.slx"
2. Build the model in External Simulation mode
3. Connect to the target and run the model. The motor will spin counterclockwise for a very short period
4. To start continuous rotation in closed-loop use the instruments in the Simulink Editor as follows:
   a. Set the paramTestTypeSelector switch to Manual. The motor starts to spin counterclockwise in Open Loop control.
   b. Set the paramMotorOn switch to "Off"
   c. Set the paramCommandType rotary block to "Closed Loop"
   d. Set the paramMotorOn switch to "On". Rotation should start
   e. Adjust the speed using the paramVelocityCommand slider (it can take 3-5 seconds to respond).

The target screen output should look like in the figure below. Scope 1 corresponds to the encoder count measurement, Scope 2 displays the measured current on one phase A, Scope 3 displays the reset status of the H-bridge (should be 1 when active) and Scope 4 displays the duty cycle sent to each of the three PWM output signals.


focVelocityEncoderTestBench
Execution: 83.3
Sample Time: 8e-005
Stop Time: INF
Average TET: 2.63e-005
Scope 1
encoderCountRaw
Offset: 4 x 10^3
y: 1 x 10^3
t: 2 x 10^-2
Scope 2
13
Offset: 1.64
y: 1 x 10^-2
t: 1.99 x 10^-3
Scope 3
59
Offset: 1
y: INF
t: 2 x 10^-2
Scope 4
10 11 12
Offset: 0.50
y: 2.50 x 10^-2
t: 2 x 10^-2
Simulink Real-Time™
R2017a
00000000 00000023 00000000 M
00000000 00000000 00000000 M
Pull test 1: 0xFFEEDDCC
Pull test 2: 0xFFFFFFFF
Pull-up to 3.3V set.
Speedgoat IO397-50k QAD Module Version test ok!

5.3 HIL demo

5.3.1 Extract the Simulink Model and Bitstreams

Setup the folder structure as follows:

1. Extract the contents of the zip file with the Simulink Real-Time models (IO397_HIL_SLRT_MODELS.zip) in a desired location. The extracted content has a folder named IO397_HIL_SLRT_MODELS containing the Simulink Real-Time models.

2. Extract the contents of the zip file (*speedgoat_IO397_50k_CI_IO397_HIL_DEMO.zip*) with the associated bitstream in a desired location. The folder contains the bitstream, a test model and documentation.

3. Copy the bitstream *speedgoat_IO397_50k_CI_IO397_HIL_DEMO.mat* to the folder containing the Simulink Real-Time models (step 1 above)

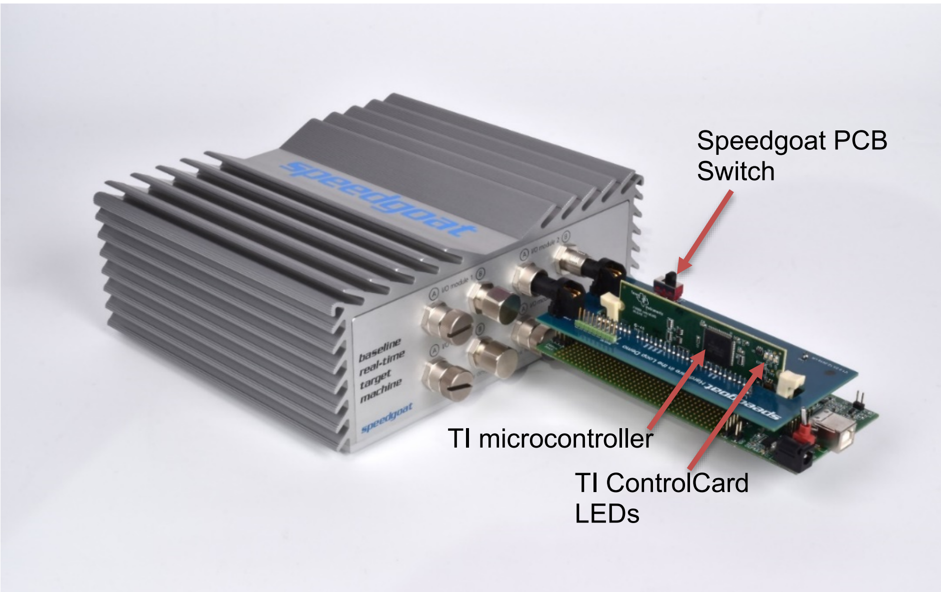
5.3.2 Connecting the Demo

Prepare the demo hardware with the following three steps:

1. **Connect to the Baseline:** The HIL demo hardware can be connected to the IO397 I/O module either by:

    - Using the M12 cables provided or

    - Directly plugging the HIL hardware in the M12 connectors of the Baseline real-time target machine.



2. **Power the Demo:** While the HIL demo requires a 5 V_{dc} power supply, the Baseline real-time target machine includes a 5 V_{dc} power supply. To provide power to the demo set the power switch labelled “Speedgoat 5V Supply” to the ON position to use the Baseline power supply. No external power supply or USB cable should be connected to the HIL demo.

    Alternative power supply options (not recommended): Setting the power switch labelled “Speedgoat 5V Supply” to the OFF position, it is possible to power the HIL demo either (1) using the USB cable provided or (2) using an external 5Vdc regulated power supply with a

5.5mm/2.1mm 5 V_{dc} Barrel Jack connector (not included with HIL demo). The JP2 switch next to the USB connector should be set according to the external power supply used.

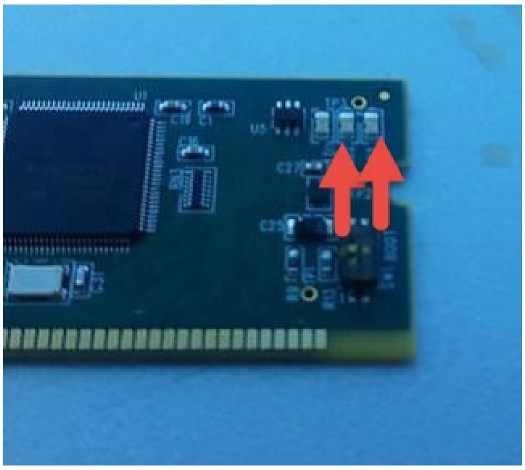
To start using the HIL demo, turn ON the switch on the top PCB of the HIL demo (marked as “Speedgoat PCB Switch” in the image below). The TI ControlCard with the TI microcontroller will power on. If the LED1 is solid green and LED3 is blinking on the TI ControlCard, it means that the motor controller is running in the TI microcontroller. In that case, you may skip the next section and run the Simulink Real-Time model in Section 6.3.4. If the LEDs do not blink, load the motor controller into the TI microcontroller by following the steps in Section 6.3.3.

5.3.3 Load the Motor Control to the TI Microcontroller

Within the HIL demo, there is a Piccolo TI microcontroller embedded in a DIM100 Control Card (looks like a computer RAM card). This card is connected to the HIL demo. We will use Code Composer Studio from Texas Instrument and a USB cable (provided) to load the motor control to the Piccolo TI microcontroller.

The file FOCEncoderF28069.out contains the motor control program and it is included in the IO397_HIL_SLRT_MODELS.zip root directory. Follow the steps below to load the program into the microcontroller.

1. On the control card, make sure that both Switch 1 (SW1) and Switch 2 (SW2) are in the "ON" position. You need to peel back the plastic film to access the switches:

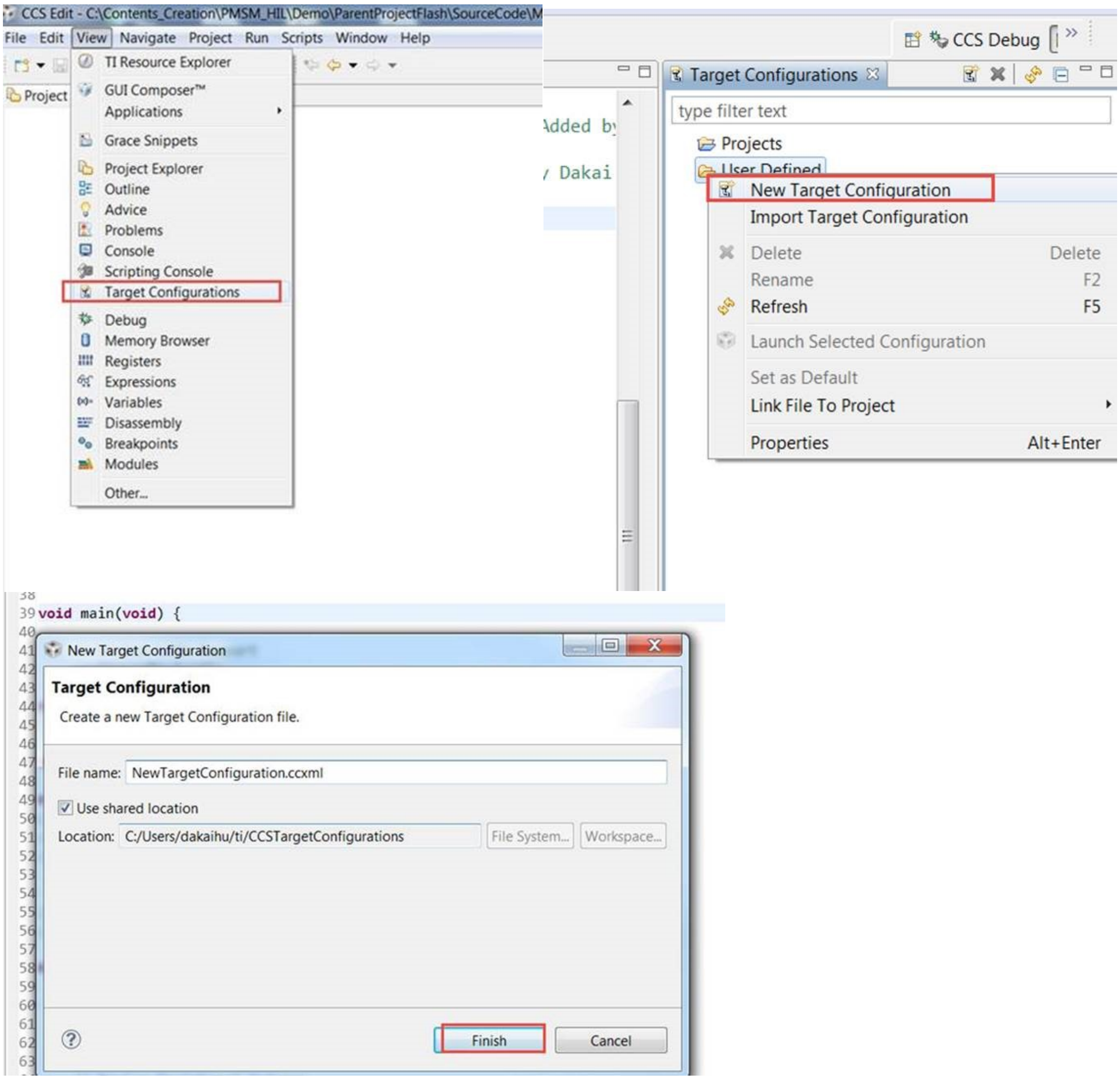


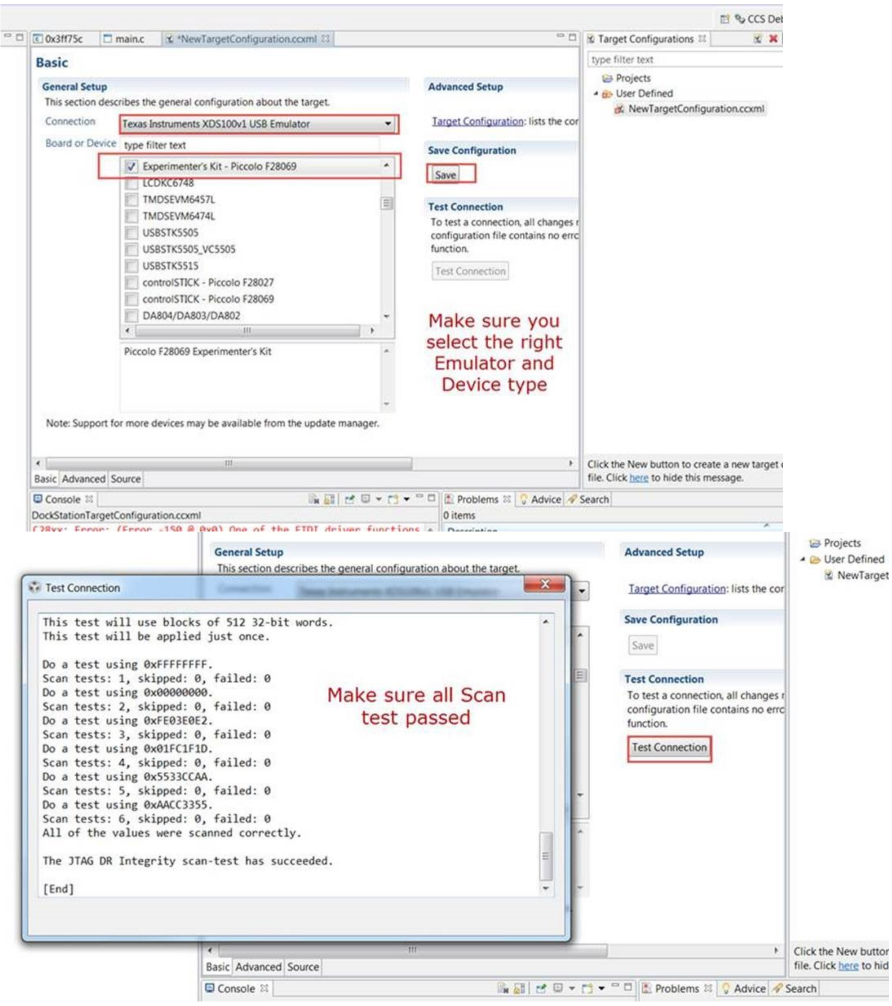
2. Connect the HIL demo to the development computer using the USB-A to USB-B cable provided.

3. Set silver switch with pink base (on HIL demo) to "USB". That will power the lights on the ControlCard. If the lights in LED1 is green and the LED3 is flashing red, then you already have the motor control program loaded on the HIL demo. You can then continue to [Section 6.3.4.]()

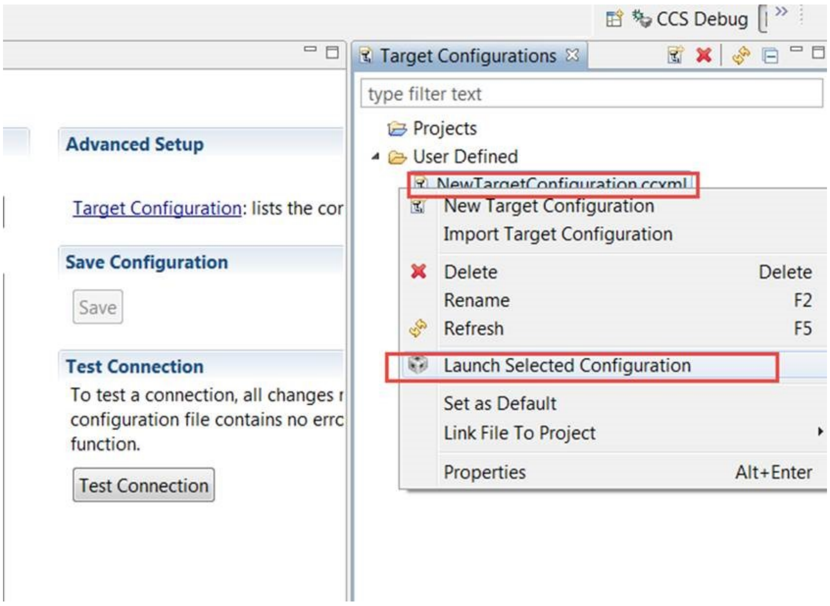
4. Install Code Composer Studio version 5.5.0 on the development computer. This software is available for free from the Texas Instrument download webpage (http://processors.wiki.ti.com/index.php/Download_CCS)

5. Open Code Composer Studio and build a new target configuration.

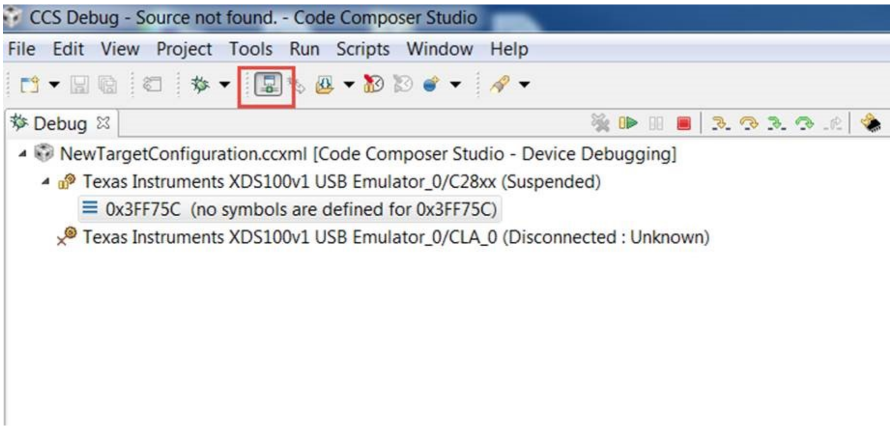




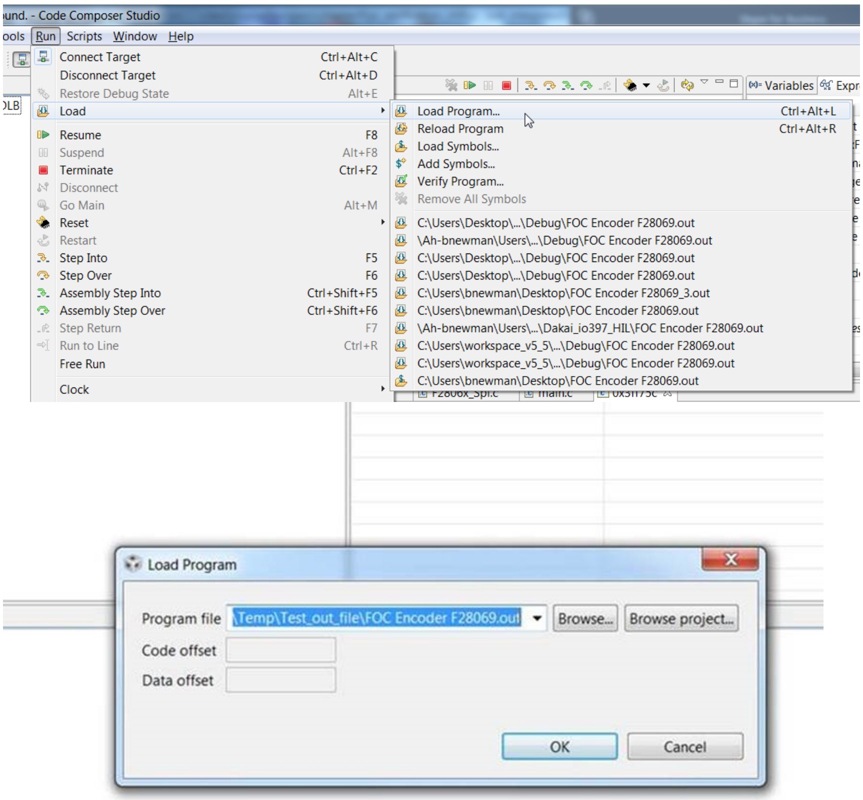
6. Launch the newly created target configuration.



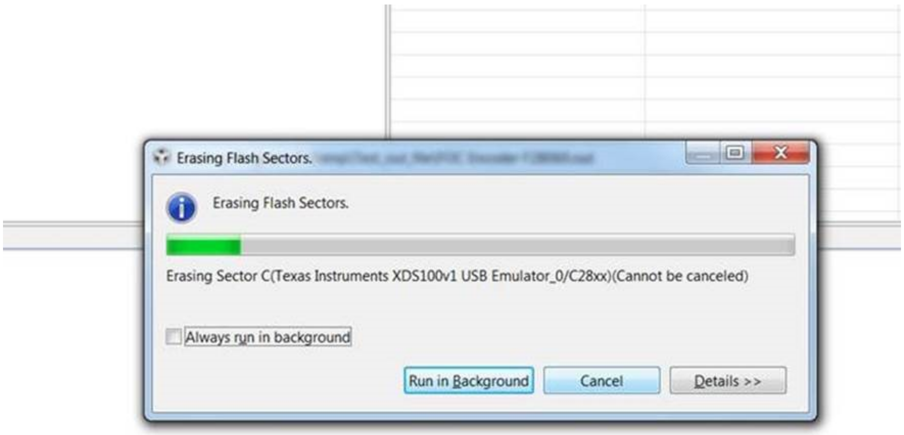
7. Connect to the microcontroller (make sure that the HIL demo is connected via the USB cable and powered on)



8. In the Run menu, select “Load program” and choose the motor control program file FOCEncoderF28069.out in the root director of the extracted folder from IO397_HIL_SLRT_MODELS.zip.



You'll see that the old flash is being erased and the new program is being loaded:



9. After loading the motor control program (FOCEncoderF28069.out), power off the HIL demo by switching off using the silver switch with pink base.

10. Verify that the transfer was successful by turning the power in the HIL demo back on. You'll see that one of the background tasks (Blinking LED3) is being executed, which indicates that the motor control program loading was successful. LED1 (green) should be solid.

5.3.4 Running the Simulink Models

For the hardware-in-the-loop, the *speedgoat_IO397_50k_HIL_DEMO.mat* bitstream must be used. This bitstream provides 4 GPIOs, one SPI interface, three CAP inputs, one QAE interface and 4 analog outputs and 4 analog inputs (refer to pinout in the appendix). Pin mappings for the HIL demo can be found in the [pinouts section](#)7.3.

The HIL demo is mainly composed of two parts (a) a motor control running in a TI microcontroller and (b) a motor real-time simulation running in the Speedgoat real-time target machine. Get started with the hardware-in-the-loop (HIL) demo in a few steps:

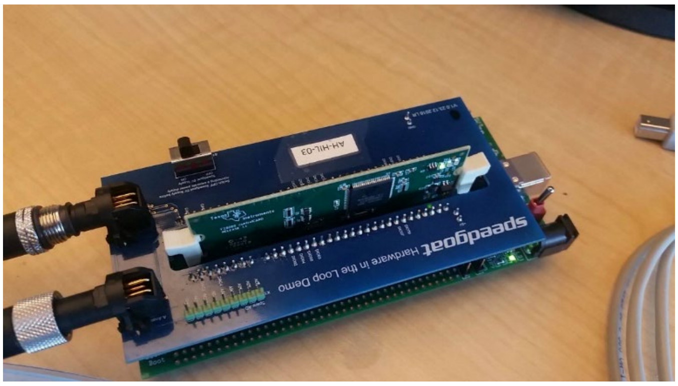
1) Power on the Baseline real-time target machine

2) Attach a monitor to the DisplayPort of the Baseline to view signals during execution (optional).

3) Disconnect the HIL demo from the USB cable

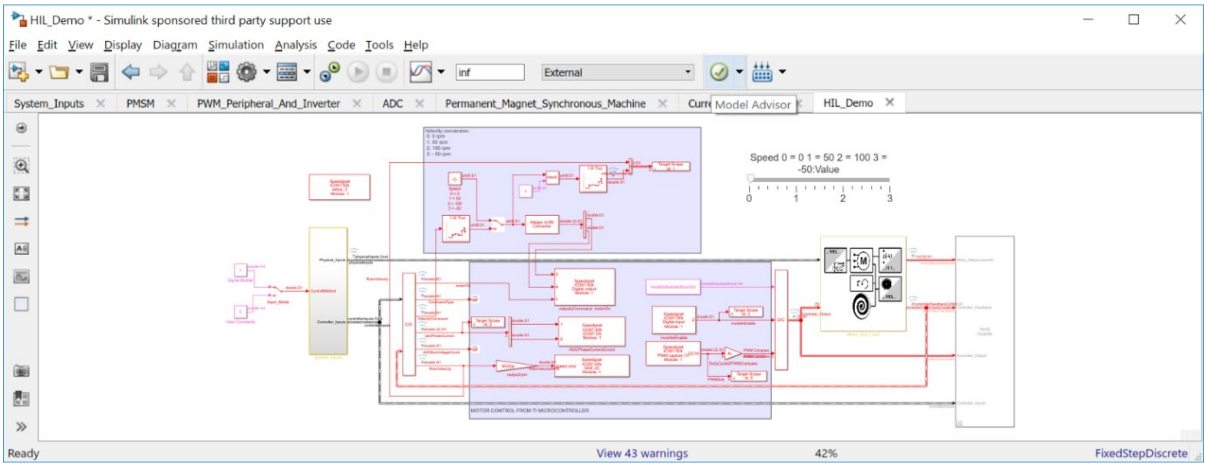
4) Connect the HIL demo directly to the Baseline using the M12 connectors

5) Set the black switch on top of the HIL demo to "ON". Make sure the blinking red LED continues without interruption.



6) Go to the root of the extracted folder and run addSLRPToPath.m from the MATLAB command line

7) Open the HIL_Demo.slx Simulink model.



8) Build the model in external mode

9) Connect to the target.

10) Run the model in external mode. The model may take around 40 seconds to start.

11) Adjust the speed command using the slider and watch for speed changes in the target monitor.

The target screen output should look like in the figure below (transition from 0rpm to 100 rpm). Scope 1 displays the measured and target speeds in rad/s, Scope 2 displays the voltage transducer outputs corresponding to phase A and B currents, Scope 3 displays the status of the H-bridge inverter (should be “1” for enabled) and Scope 4 displays the 3-phase duty cycle inputs from the TI microcontroller.

6 Pin Mappings

6.1 DUT Demo (Getting Started Demo)

Table 1 - Connection A: Analog I/O

Functionality	IO397 pin	M12, A	PCB signal	Description
ADC1+	1	1	POS_FBK	POS_FBK - Motor feedback+
ADC1-	2	2	GND	POS_FBK - Motor feedback-
ADC2+	3	3	RC_SIG	RC_SIG - RC Circuit Feedback+
ADC2-	4	4	GND	RC_SIG - RC Circuit Feedback-
ADC3+	5	5	EXP_39	Spare ADC
ADC3-	6	6	EXP_40	Spare ADC
ADC4+	7	7	EXP_41	Spare ADC
ADC4-	8	8	EXP_42	Spare ADC
DAC1	9	9	RC_PWR	RC_PWR - RC Circuit source
DAC2	10	10	EXP_29	Spare DAC
DAC3	11	11	EXP_30	Spare DAC
DAC4	12	12	EXP_32	Spare DAC
GND	13	13	GND	RC & Motor Circuit ground
GND	14	14	GND	

Table 2 - Connection B: Digital I/O

Functionality	IO397 pin	M12, B	PCB signal	J6 pin header	Description
GND	N/A	1	GND	13	Power supply GND
VDC	N/A	2	VDC2	15 (via switch SW5)	Power supply 5V 1A
DIO01	15	3	SWITCH 1	1	DI, Switch 1
DIO02	16	4	SWITCH 2	2	DI, Switch 2
DIO03	17	5	SWITCH 3	3	DI, Switch 3
DIO04	18	6	SWITCH 4	4	DI, Switch 4
DIO05	19	7	LED 1	5	DO, LED 1
DIO06	20	8	LED 2	6	DO, LED 2
DIO07	21	9	LED 3	7	DO, LED 3
DIO08	22	10	LED 4	8	DO, LED 4
DIO09	23	11	DRIVE_P	9	PWM, DRIVE_P Motor Drive 1
DIO10	24	12	DRIVE_N	10	PWM, DRIVE_N - Motor Drive 2
DIO11	25	13	J7 -pin 53	N/A	I2C Master CLK
DIO12	26	14	J7 - pin 54	N/A	I2C Master Data
DIO13	27	15	J7 - pin 55	N/A	I2C Slave CLK
DIO14	28	16	J7 - pin 56	N/A	I2C Slave Data
GND	29	17	GND	14	Digital Ground

6.2 PMSM Motor Control Demo

Table3 - Connection A: Analog I/O

Functionality	IO397 pin	M12, A	Speedgoat PCB	Description\
ADC1+	1	1	J5-37	IA_FB - Current Phase A+
ADC1-	2	2	GND	IA-FB - Current Phase A-
ADC2+	3	3	J5-35	IB_FB - Current Phase B+
ADC2-	4	4	GND	IB-FB - Current Phase B-
ADC3+	5	5	J5-36	ADC-Vhb1 - Voltage Phase A+
ADC3-	6	6	GND	ADC-Vhb1 - Voltage Phase A-
ADC4+	7	7	J5-33	ADC-Vbus - Bus voltage +
ADC4-	8	8	GND	ADC-Vbus - Bus voltage -
DAC1	9	9	S. AD/DA pin 17	Spare DAC
DAC2	10	10	S. AD/DA pin 19	Spare DAC
DAC3	11	11	S. AD/DA pin 21	Spare DAC
DAC4	12	12	S. AD/DA pin 23	Spare DAC
GND	13	13	GND	DRV8312 Ground
GND	14	14	GND	Ground

Table4 - Connection B: Digital I/O

Functionality	IO397 pin	M12, B	Speedgoat PCB	SG PCB Probe	Description
GND	N/A	1	GND		Power supply GND
VDC	N/A	2	S. DIO pin 40		Spare 5V supply
DIO01	15	3	J5-13		~FAULT - DI, Fault signal DRV8312
DIO02	16	4	J5-26	PWMA	PWM_A - PWM for half-bridge A
DIO03	17	5		TriggerP	PWM_A Trigger from IO397
DIO04	18	6	J5-25	PWMB	PWM_B - PWM for half bridge B
DIO05	19	7	J5-28	PWMC	PWM_C – PWM for half bridge C
DIO06	20	8	J5-6	RSTA	~RESET_A - DO, Enable H-bridge A
DIO07	21	9	J5-9	RSTB	~RESET_B - DO, Enable H-bridge B
DIO08	22	10	J5-12	RSTC	~RESET_C - DO, Enable H-bridge C
DIO09	23	11	QEP-1	QEPA	QEPA-QAD, Quadrature Encoder A
DIO10	24	12	QEP-2	QEPB	QEPB-QAD, Quadrature Encoder B
DIO11	25	13	QEP-3	QEPI	QEPI - Quadrature Encoder Index
DIO12	26	14	CAP-1	CAP1	CAP1 - CAP, Hall Sensor Phase A
DIO13	27	15	CAP-2	CAP2	CAP2 - CAP, Hall Sensor Phase B
DIO14	28	16	CAP-3	CAP3	CAP3 - CAP, Hall Sensor Phase C
GND	29	17	GND		Digital Ground

6.3 HIL with Microcontroller

Table 5 - Connection A: Analog I/O

Functionality	IO397 pin	M12, A	controlCARD	Description
ADC1+	1	1	N/A	Spare ADC
ADC1-	2	2	N/A	Spare ADC
ADC2+	3	3	N/A	Spare ADC
ADC2-	4	4	N/A	Spare ADC
ADC3+	5	5	N/A	Spare ADC
ADC3-	6	6	N/A	Spare ADC
ADC4+	7	7	N/A	Spare ADC
ADC4-	8	8	N/A	Spare ADC
DAC1	9	9	ADC-A1	IA_FB - Current Phase A
DAC2	10	10	ADC-B1	IB_FB - Current Phase B
DAC3	11	11	ADC-A3	Vhb1 - Voltage Phase A
DAC4	12	12	ADC-B3	Vbus - Bus voltage
GND	13	13	GND	Ground
GND	14	14	GND	Ground

Table 6 - Connection B: Digital I/O

Functionality	IO397 pin	M12, B	controlCARD	Docking station	Description
GND	N/A	1	GND	GND header	Power supply GND
VDC	N/A	2	+5V in	5V header	Power supply 5V 1A
DIO01	15	3	GPIO-03	J4 pin 18	SPI MISO
DIO02	16	4	GPIO-00	J5 pin 22	CAP_A, Signal for emulated H-bridge A
DIO03	17	5	GPIO-06	J5 pin 19	Spare GPIO
DIO04	18	6	GPIO-02	J5 pin 21	CAP_B, Signal for emulated H- bridge B
DIO05	19	7	GPIO-04	J5 pin 20	CAP_C, Signal for emulated H- bridge C
DIO06	20	8	GPIO-01	J4 pin 19	DI, Enable signal for emulated H-bridge
DIO07	21	9	GPIO-18	J5 pin 8	SPI CLK
DIO08	22	10	GPIO-19	J4 pin 6	SPI SS
DIO09	23	11	GPIO-20	J5 pin 7	QAE - A, Emulated quadrature Encoder signal A
DIO10	24	12	GPIO-21	J4 pin 5	QAE - B, Emulated quadrature Encoder signal B
DIO11	25	13	GPIO-23	J4 pin 4	QAE - I , Emulated quadrature Encoder Index signal
DIO12	26	14	GPIO-05	J4 pin 17	SPI MOSI
DIO13	27	15	GPIO-07	J4 pin 16	Spare GPIO
DIO14	28	16	GPIO-09	J4 pin 15	Spare GPIO
GND	29	17	GND	GND header	Digital Ground

7 Further reading

Speedgoat (2018), "Documentation of Speedgoat Library", Speedgoat - The Quickest Path to Real-Time Simulation and Testing, http://www.speedgoat.com/help

MathWorks (2018), "MATLAB Documentation", MathWorks - Makers of MATLAB and Simulink", http://www.mathworks.com/help

Speedgoat/MathWorks (Nov 2017) "Evaluation Kit – Setup and Tutorials".

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