HILINK

REAL-TIME HARDWARE-IN-THE-LOOP CONTROL PLATFORM FOR MATLAB/SIMULINK

Quick Reference

release 1.7

May 1, 2016

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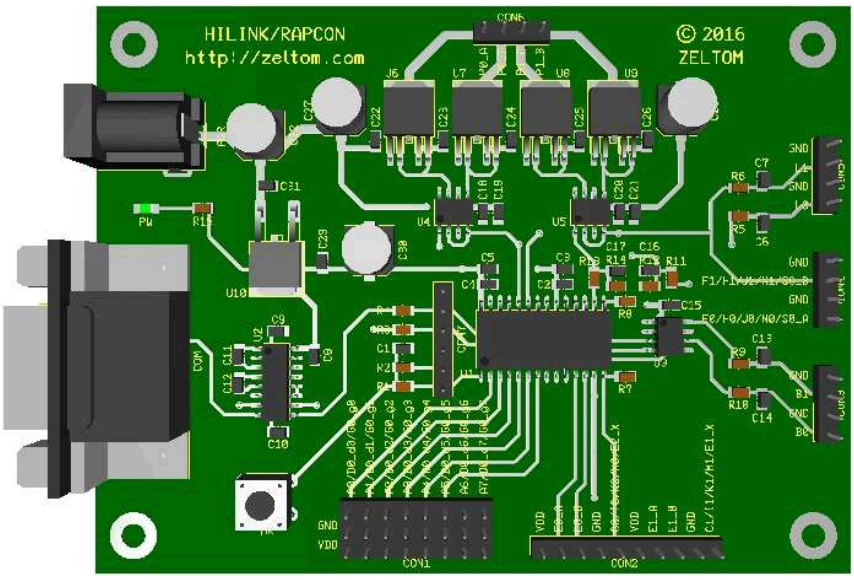
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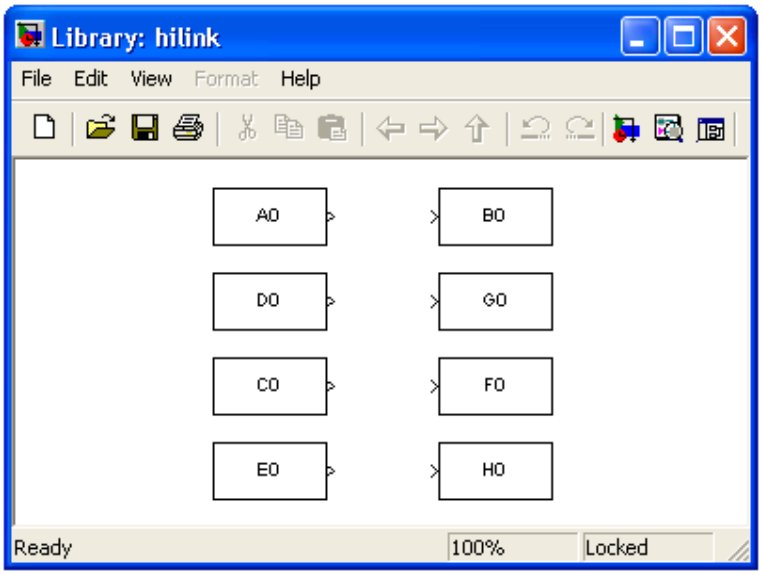
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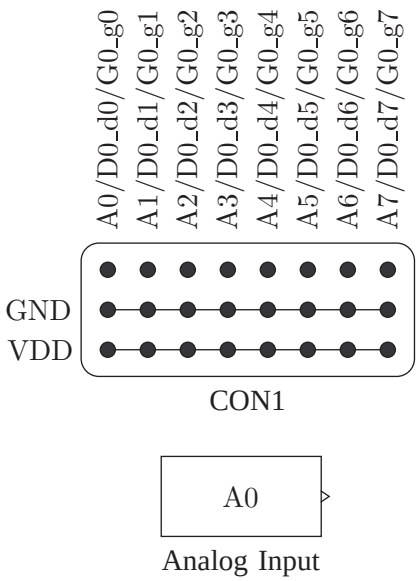
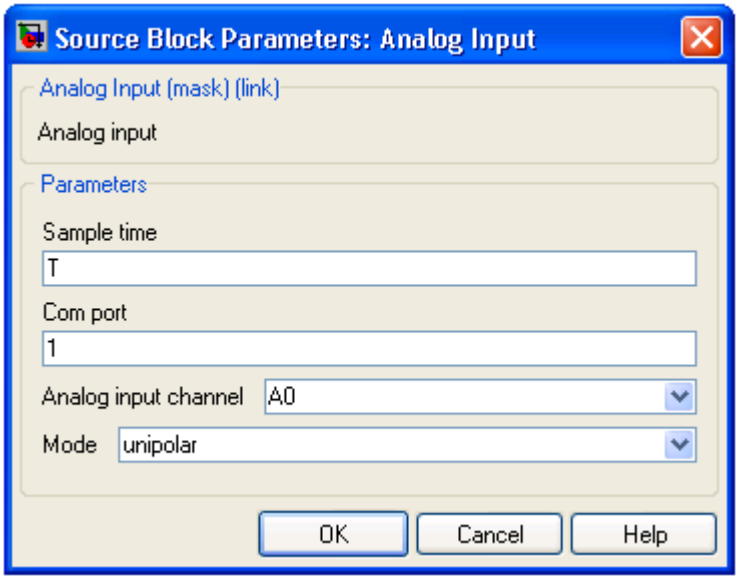
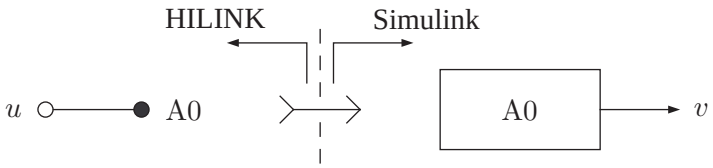
1. Analog Input

- 8 analog input channels $A0 - A7$
- Board input: $0 - 5$ V analog signal
- Block output: unipolar or bipolar amplitude of analog signal
- Resolution: 12 bit
- Sampling rate: 28.7891 kHz (internal)
- 610.3516 μV maximum unipolar amplitude quantization error and 1220.7031 μV maximum bipolar amplitude quantization error





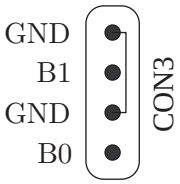


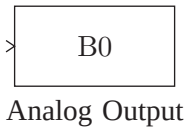
$$\text{unipolar mode} \quad \Rightarrow \quad v \approx \begin{cases} 5, & u \geq 5 \\ u, & 0 < u < 5 \\ 0, & u \leq 0 \end{cases}$$

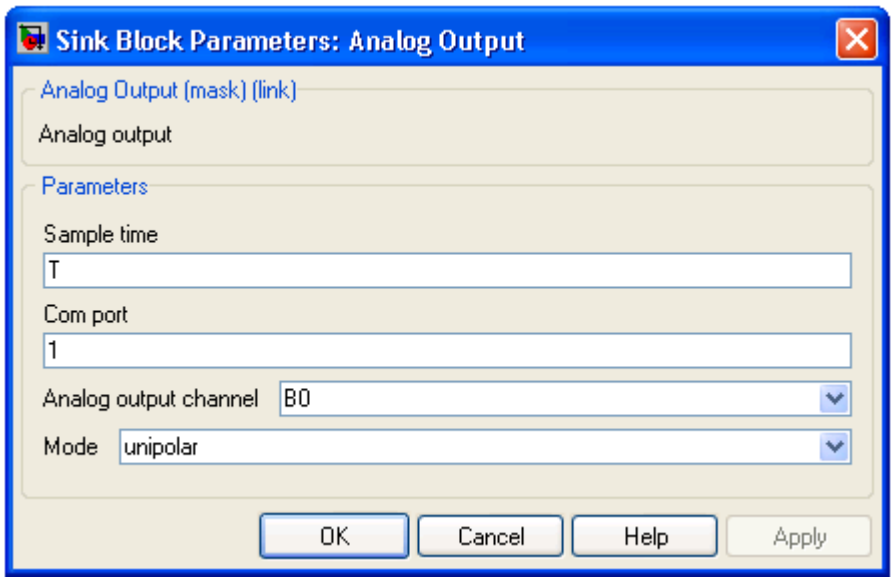
$$\text{bipolar mode} \quad \Rightarrow \quad v \approx \begin{cases} +5, & u \geq 5 \\ 2u - 5, & 0 < u < 5 \\ -5, & u \leq 0 \end{cases}$$

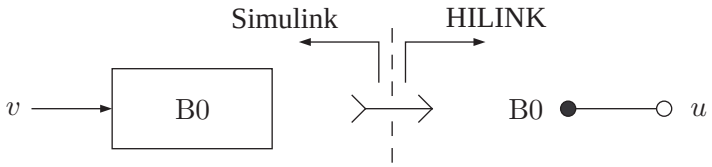
2. Analog Output

- 2 analog output channels $B0 - B1$
- Block input: unipolar or bipolar amplitude of analog signal
- Board output: $0 - 5$ V analog signal
- Resolution: 12 bit
- Settling time: 4.5 μs
- 500.0000 μV maximum unipolar amplitude interpolation error and 1000.0000 μV maximum bipolar amplitude interpolation error







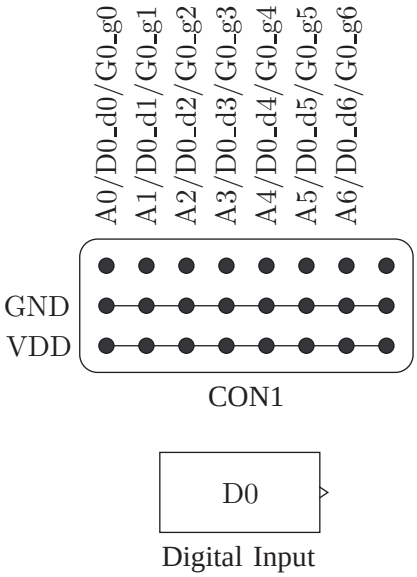


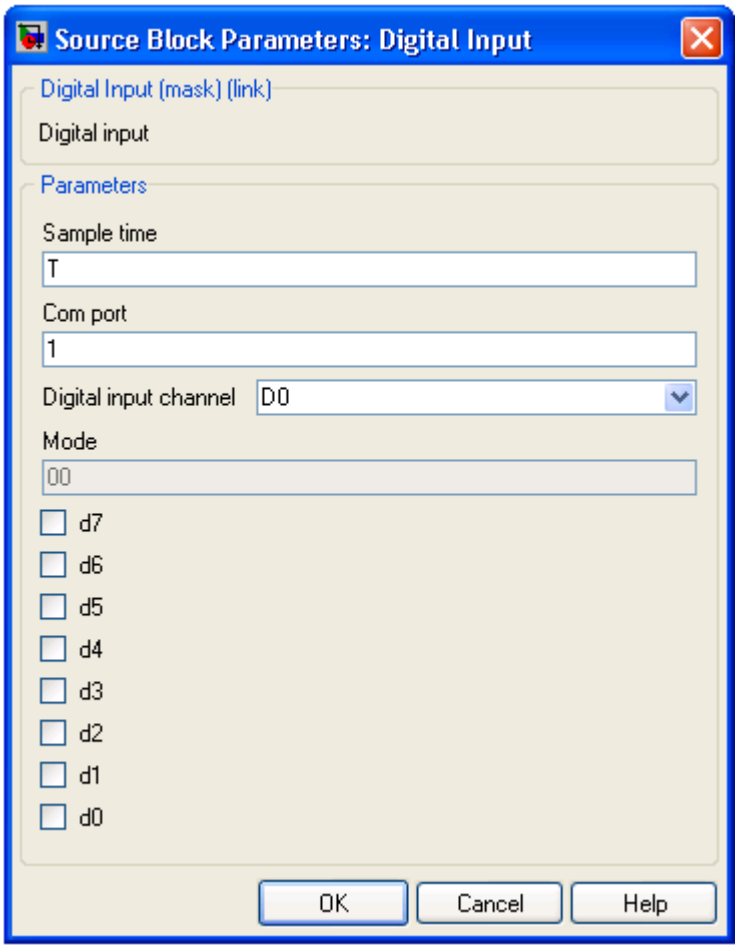
$$\text{unipolar mode} \quad \Rightarrow \quad u \approx \begin{cases} 4.096, & v \geq 4.096 \\ v, & 0 < v < 4.096 \\ 0, & v \leq 0 \end{cases}$$

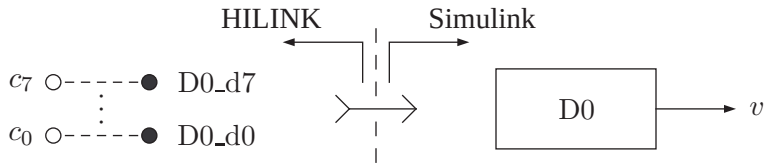
$$\text{bipolar mode} \quad \Rightarrow \quad u \approx \begin{cases} 4.096, & v \geq +4.096 \\ v/2 + 4.096/2, & -4.096 < v < +4.096 \\ 0, & v \leq -4.096 \end{cases}$$

3. Digital Input

- 1 digital input channel D0 with 8 digital input lines D0_d0 – D0_d7
- Board input: 0 – 5 V digital signal
- Block output: decimal representation of digital signal





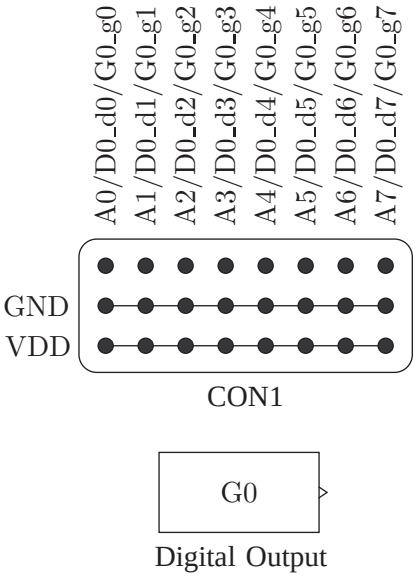


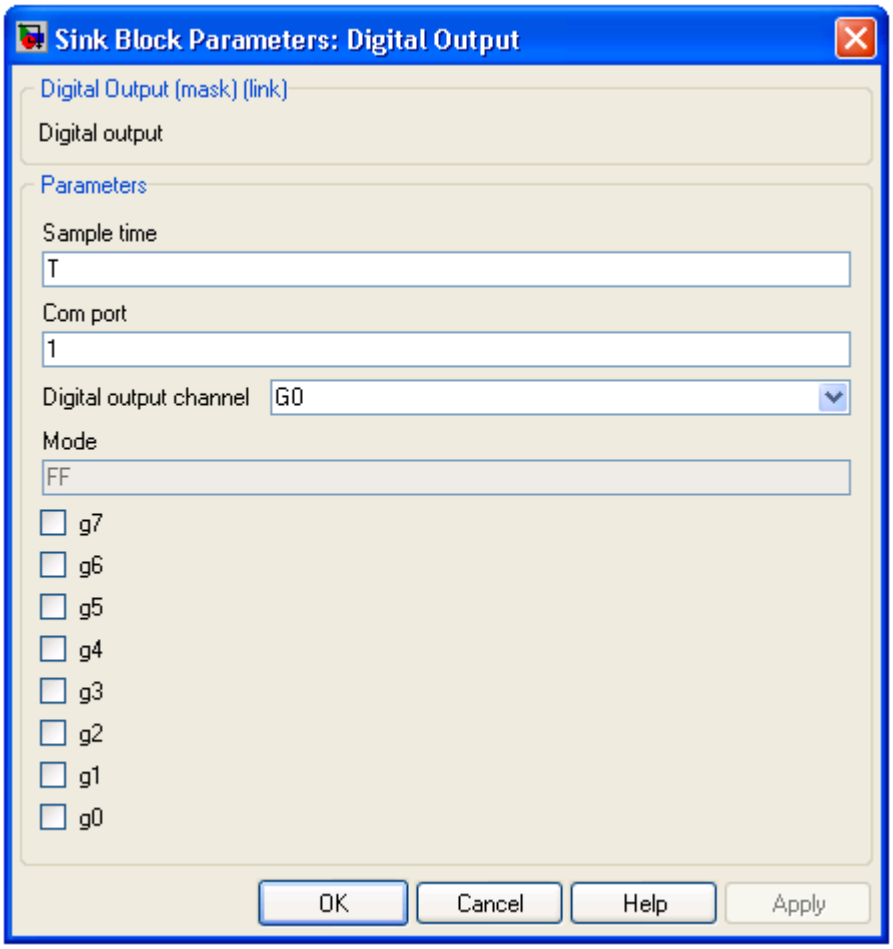
$$v = 128\,d_7 + 64\,d_6 + 32\,d_5 + 16\,d_4 + 8\,d_3 + 4\,d_2 + 2\,d_1 + 1\,d_0$$

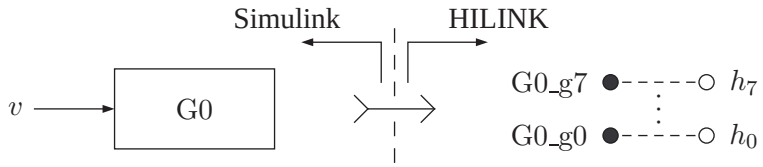
$$d_i = \begin{cases} c_i \text{ (1 or 0)}, & \text{Ai is not used and D0\_di is used (di is checked)} \\ 0, & \text{Ai is used, or Ai, D0\_di and G0\_gi are not used} \\ h_i \text{ (1 or 0)}, & \text{Ai and D0\_di are not used, but G0\_gi is used with output } h_i \end{cases}$$

4. Digital Output

- 1 digital output channel G0 with 8 digital output lines G0_g0 – G0_g7
- Block input: decimal representation of digital signal
- Board output: 0 – 5 V digital signal





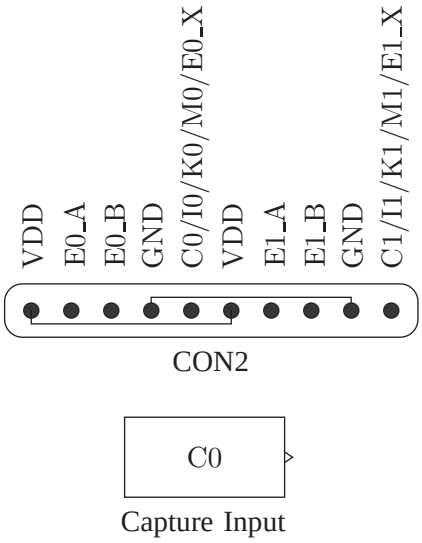


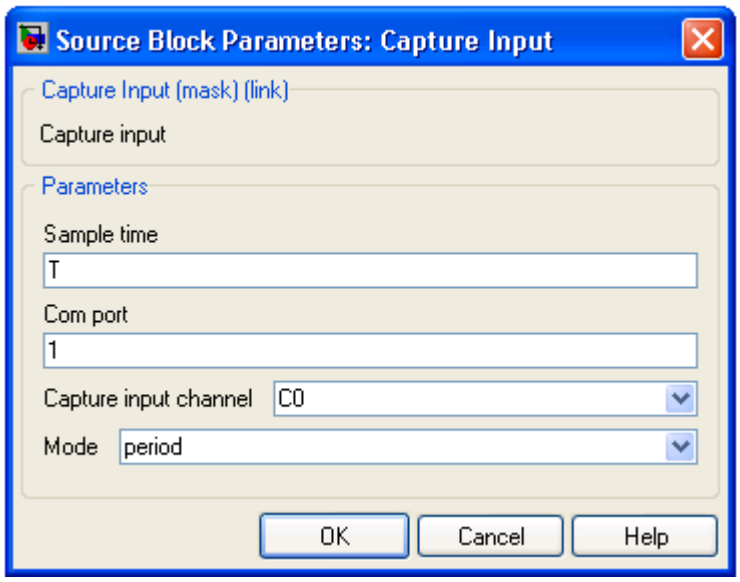
$$128\,g_7 + 64\,g_6 + 32\,g_5 + 16\,g_4 + 8\,g_3 + 4\,g_2 + 2\,g_1 + 1\,g_0 = v \;\&\; 0\times 00\text{FF}$$

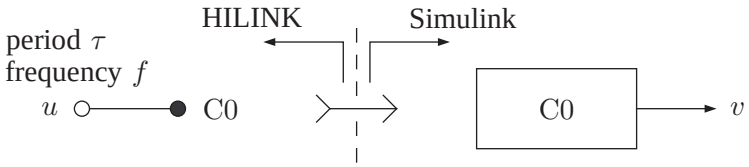
$$h_i = \begin{cases} g_i \text{ (1 or 0)}, & \text{Ai and D0\_di are not used, and G0\_gi is used (gi is checked)} \\ \text{(analog input)}, & \text{Ai is used, or Ai, D0\_di and G0\_gi are not used} \\ c_i \text{ (1 or 0)}, & \text{Ai is not used and D0\_di is used with input } c_i \end{cases}$$

5. Capture Input

- 2 capture input channels $\mathrm{C0} - \mathrm{C1}$
- Board input: $0 - 5$ V digital signal
- Block output: period or frequency of digital signal
- Resolution: 16 bit
- Accuracy: 8.6839 μs
- 8.6839 μs maximum period quantization error and $f - 115156.25/\lfloor 115156.25/f \rfloor$ Hz maximum frequency quantization error (f is the actual input frequency)





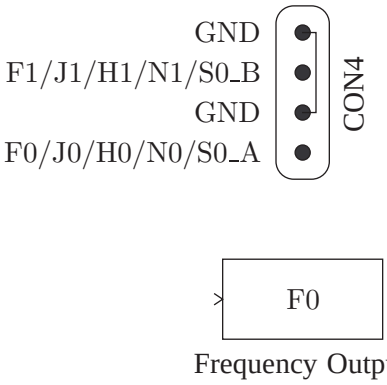


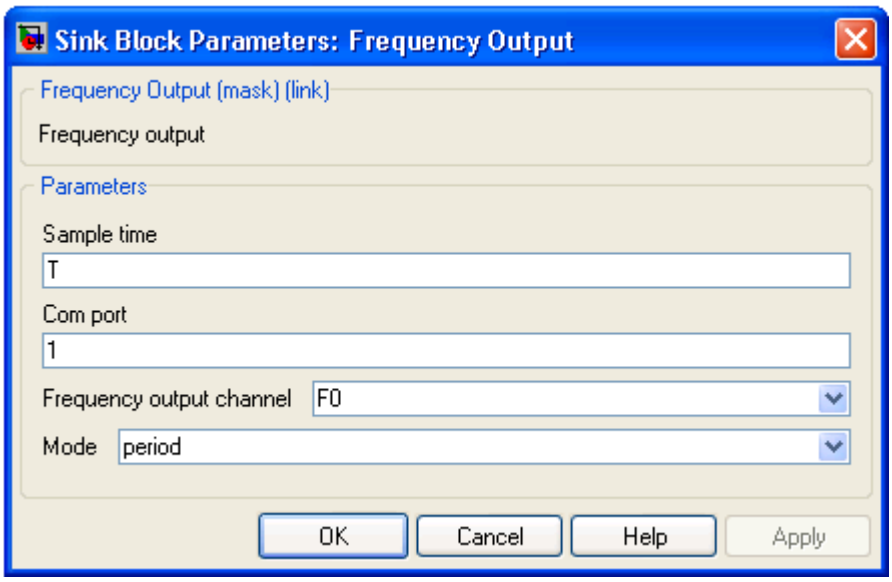
$$\text{period mode} \quad \Rightarrow \quad v \approx \begin{cases} 569.0963 \times 10^{-3}, & \tau \geq 569.0963 \times 10^{-3} \\ \tau, & 34.7354 \times 10^{-6} < \tau < 569.0963 \times 10^{-3} \\ 34.7354 \times 10^{-6}, & \tau \leq 34.7354 \times 10^{-6} \end{cases}$$

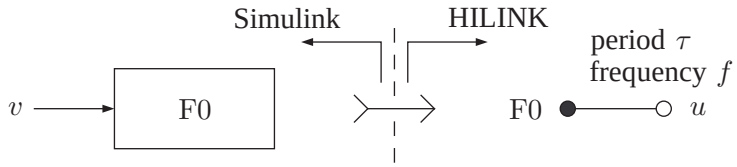
$$\text{frequency mode} \quad \Rightarrow \quad v \approx \begin{cases} 28789.0625, & f \geq 28789.0625 \\ f, & 1.7572 < f < 28789.0625 \\ 1.7572, & f \leq 1.7572 \end{cases}$$

6. Frequency Output

- 2 frequency output channels $\mathrm{F0} - \mathrm{F1}$
- Block input: period or frequency of digital signal
- Board output: $0 - 5$ V digital signal
- Resolution: 16 bit
- Accuracy: 8.6839 μs
- 8.6839 μs maximum period interpolation error and $f - 115156.25/\lfloor 115156.25/f \rfloor$ Hz maximum frequency interpolation error (f is the desired output frequency)





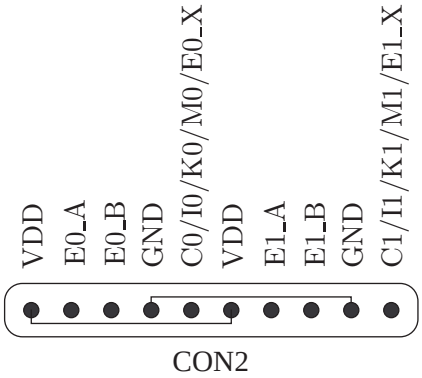


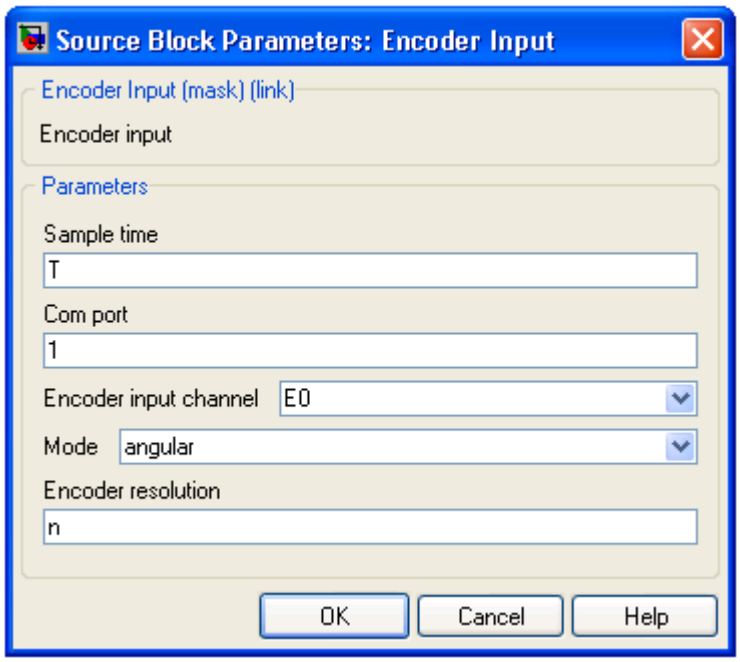
$$\text{period mode} \quad \Rightarrow \quad \tau \approx \begin{cases} 569.0963 \times 10^{-3}, & v \geq 569.0963 \times 10^{-3} \\ v, & 34.7354 \times 10^{-6} < v < 569.0963 \times 10^{-3} \\ 34.7354 \times 10^{-6}, & v \leq 34.7354 \times 10^{-6} \end{cases}$$

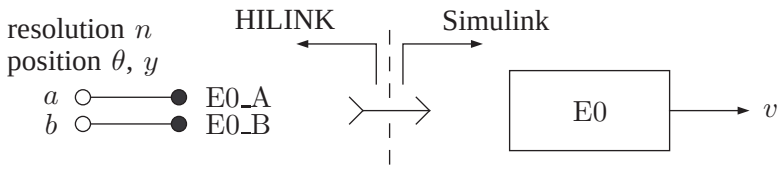
$$\text{frequency mode} \quad \Rightarrow \quad f \approx \begin{cases} 28789.0625, & v \geq 28789.0625 \\ v, & 1.7572 < v < 28789.0625 \\ 1.7572, & v \leq 1.7572 \end{cases}$$

7. Encoder Input

- 2 encoder input channels $\mathrm{E0} - \mathrm{E1}$ with quadrature inputs E0_A, E0_B – E1_A, E1_B
- Board input: $0 - 5$ V digital encoder signals
- Block output: position or velocity of encoder
- Resolution: 16 bit per sampling interval
- Scan rate: 307.0833 kHz
- $\pi/2/n$ rad maximum position quantization error and $153541.6667\,\pi/n$ rad/s maximum measurable angular speed (n is the encoder resolution)





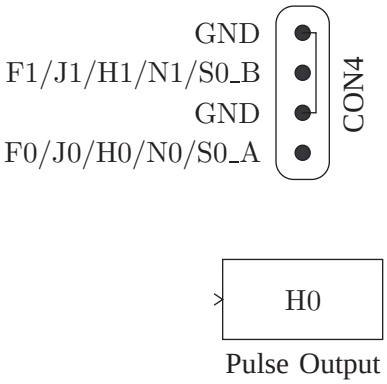


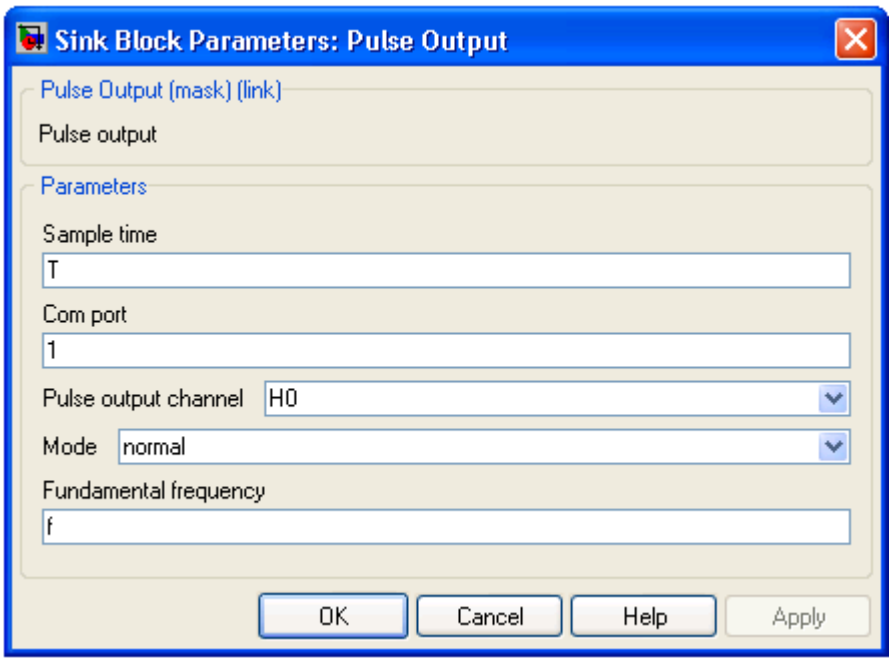
$$\text{angular mode} \quad \Rightarrow \quad v \approx \begin{cases} +32767\pi/2/n, & \theta \geq 32767\pi/2/n \\ \theta, & -32768\pi/2/n < \theta < +32767\pi/2/n \\ -32768\pi/2/n, & \theta \leq -32768\pi/2/n \end{cases}$$

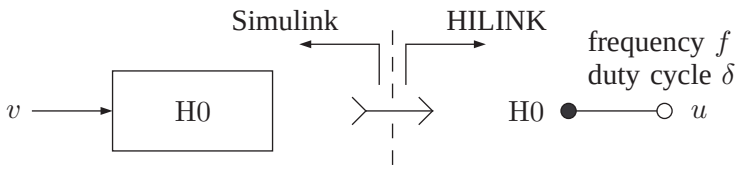
$$\text{linear mode} \quad \Rightarrow \quad v \approx \begin{cases} +32767/400/n, & y \geq 32767/400/n \\ y, & -32768/400/n < y < +32767/400/n \\ -32768/400/n, & y \leq -32768/400/n \end{cases}$$

8. Pulse Output

- 2 pulse output channels $\mathrm{H0} - \mathrm{H1}$
- Block input: normal or shifted duty cycle of digital signal
- Board output: $0 - 5$ V digital signal
- Resolution: 16 bit
- Frequency range: $449.8360 \text{ Hz} \leq f \leq 115156.25 \text{ Hz}$
- $33.9213 \times 10^{-9} f$ maximum normal duty cycle interpolation error and $67.8426 \times 10^{-9} f$ maximum shifted duty cycle interpolation error (f is the desired output frequency)





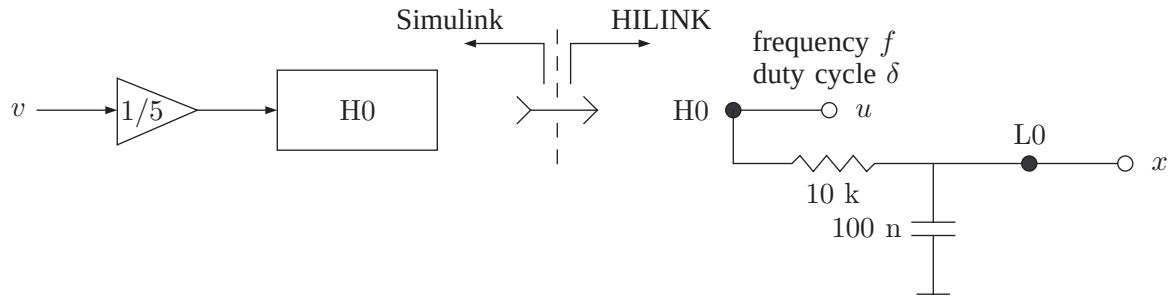


$$\text{normal mode} \quad \Rightarrow \quad \delta \approx \begin{cases} 1 \ (u \text{ is high}), & v \geq 1 \\ v, & 0 < v < 1 \\ 0 \ (u \text{ is low}), & v \leq 0 \end{cases}$$

$$\text{shifted mode} \quad \Rightarrow \quad \delta \approx \begin{cases} 1 \ (u \text{ is high}), & v \geq +1 \\ v/2 + 1/2, & -1 < v < +1 \\ 0 \ (u \text{ is low}), & v \leq -1 \end{cases}$$

9. Filtered Pulse Output

- 2 filtered pulse output channels $\mathrm{L0} - \mathrm{L1}$
- Board output: $0 - 5$ V analog signal
- Bandwidth: 159.1549 Hz
- Filtered pulse outputs can be used as analog outputs

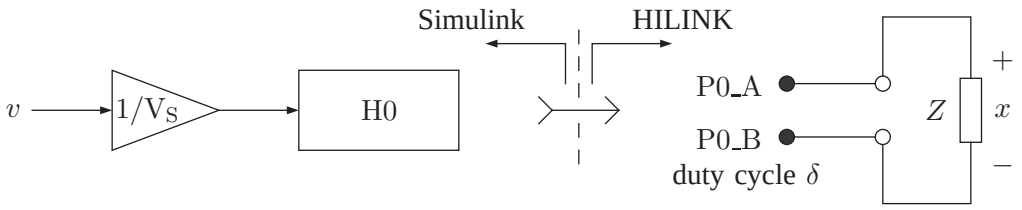


lowpass equivalent of $u \approx \delta\, 5$

$$f >> 159.1549 \text{ Hz and H0 in normal mode} \quad \Rightarrow \quad x \approx \begin{cases} 5, & v \geq 5 \\ v, & 0 < v < 5 \\ 0, & v \leq 0 \end{cases}$$

10. H-bridge Power Output

- 2 H-bridge power output channels $\mathrm{P0} - \mathrm{P1}$ with power outputs $\mathrm{P0\_A}$, $\mathrm{P0\_B} - \mathrm{P1\_A}$, $\mathrm{P1\_B}$
- Board output: $0 - V_S$ V digital power signals (V_S is the power supply voltage)
- Capacity: 5 A
- H-bridge power outputs can be used as power amplifiers to drive heavy loads



lowpass equivalent of $x \approx (2\delta - 1)V_S$

$$\text{H0 in shifted mode} \quad \Rightarrow \quad \text{lowpass equivalent of } x \approx \begin{cases} +V_S, & v \geq +V_S \\ v, & -V_S < v < +V_S \\ -V_S, & v \leq -V_S \end{cases}$$

11. Sampling Rate

$$\begin{array}{l}\text{number of input channels } n_i \leq 16 \\ \text{number of output channels } n_o \leq 16\end{array} \quad \Rightarrow \quad \text{sampling rate } f = \frac{1}{T} \leq \frac{11520}{2\max(n_i, n_o) + 1}$$

12. Usage

- Set up the real-time control board with the desired external connections and construct a Simulink model with the desired blocks.
- Define the sample time T ($T = 1/f$, where f is the sampling rate) and the stop time S at the command prompt in the Matlab command window.
- Build the model by clicking on "Tools $\rightarrow$ Real-Time Workshop $\rightarrow$ Build Model..." or by pressing Ctrl+B.
- Click on the "Connect to target" button  to connect the board to the model and then click on the "Start real-time code" button  to run the model.
- Click on the "Stop real-time code" button  to stop the model or click on the "Disconnect from target" button  to disconnect the model from the board.
- If the real-time execution is terminated by clicking on the "Stop real-time code" button  , the model can be modified, rebuilt and rerun by following the above steps again.
- If, however, the real-time execution is terminated by clicking on the "Disconnect from target" button  , the board must be reset before rerunning the model even without any modification since the code is still running on the real-time board.
- Pressing the reset button on the board also stops the real-time execution.

13. Guidelines

- Refer to the examples that come with the platform for setting up the configuration parameters under "Simulation $\rightarrow$ Configuration Parameters..." for your model.
- Refer to the Matlab help files for setting up the configuration parameters under "Tools $\rightarrow$ External Mode Control Panel..." for your model.
- Refer to the Real-Time Windows Target help files for setting up the "Scope parameters" for external data collection.
- Confine all your project files to the HILINK installation directory and make sure that the "Current Directory" of Matlab is your HILINK installation directory.
- Make sure that the com port number of each HILINK block (default is 1) matches with the com port you are using.
- Rebuild your model whenever you make any changes in the parameters of the HILINK blocks in your model (even when Matlab does not warn you to do so).
- Some inputs and outputs are multiplexed and can not be used together (refer to the User Guide to determine the multiplexed inputs and outputs, and their priority).
- All relevant physical quantities (board and block inputs, outputs and parameters) cited in this document are in SI units for convenience.
- The given quantization and interpolation errors are based on the nominal values of components used on the HILINK board and are provided only for reference purpose (not guaranteed).
- Do not excessively load (actively or passively) the inputs and outputs of the board beyond their normal operating ranges.
- Refer to the data sheets of the components used on the board for their absolute maximum ratings and safe operating areas.

14. Applications

- Real-time signal analysis, synthesis, processing and visualization
- Parameter tuning and optimization
- Modeling, analysis and design of control systems
- Real-time control
- Hardware-in-the-loop simulation
- Real-time rapid control prototyping
- Teaching concepts and carrying out experiments in signals and systems labs
- Real-time data acquisition

15. Specifications

- Power supply: $6 - 15$ V, minimum 0.15 A, regulated, (VPS is $+$ and GND is $-$)
- Interface: 115200 baud, 8 bit data, no parity, 1 stop bit
- Analog inputs: $\mathrm{A0} - \mathrm{A7}$, $0 - 5$ V analog, 12 bit resolution
- Analog outputs: $\mathrm{B0} - \mathrm{B1}$, $0 - 5$ V analog, 12 bit resolution
- Digital inputs: $\mathrm{D0\_d0} - \mathrm{D0\_d7}$, $0 - 5$ V digital, 8 lines
- Digital outputs: $\mathrm{G0\_g0} - \mathrm{G0\_g7}$, $0 - 5$ V digital, 8 lines
- Capture inputs: $\mathrm{C0} - \mathrm{C1}$, $0 - 5$ V digital, 16 bit resolution
- Frequency outputs: $\mathrm{F0} - \mathrm{F1}$, $0 - 5$ V digital, 16 bit resolution
- Encoder inputs: $\mathrm{E0\_A}, \mathrm{E0\_B}, \mathrm{E0\_X} - \mathrm{E1\_A}, \mathrm{E1\_B}, \mathrm{E1\_X}$, $0 - 5$ V digital, 16 bit resolution
- Pulse outputs: $\mathrm{H0} - \mathrm{H1}$, $0 - 5$ V digital, 16 bit resolution
- Filtered pulse outputs: $\mathrm{L0} - \mathrm{L1}$, $0 - 5$ V analog
- H-bridge power outputs: $\mathrm{P0\_A}, \mathrm{P0\_B} - \mathrm{P1\_A}, \mathrm{P1\_B}$, $0 -$ (supply voltage) V digital, 5 A
- Voltage regulator output: VDD, 5 V, 0.25 A, regulated power supply
- Ground: GND, 0 V
- Sampling rate: up to 3.8 kHz
- Size: 10.16 cm $\times$ 7.62 cm
- Weight: 43.9 g

16. Requirements

- PC with Windows XP or later and an available serial port or an expansion slot for a serial card
- Matlab R2007b or later with Simulink, Real-Time Workshop (Matlab Coder and Simulink Coder) and Real-Time Windows Target (Simulink Desktop Real-Time)
- HILINK hardware (real-time control board) 1.5 or later
- HILINK software 1.5 or later
- Serial crossover cable
- Power supply (regulated, $6 - 15$ V and at least 0.15 A)

17. Absolute Maximum Ratings

- Power supply voltage: minimum 3 V, maximum 16 V
- Each analog, digital, capture and encoder input: minimum -0.3 V, maximum $+5.3$ V
- Each analog, digital, frequency and pulse output: minimum -25 mA, maximum $+25$ mA
- Each filtered pulse output: minimum -25 mA, maximum $+25$ mA
- Each H-bridge power output: minimum -5 A, maximum $+5$ A
- Voltage regulator output: maximum 0.5 A (total)
- Total current from/into all inputs and outputs (except power supply, voltage regulator and H-bridges): minimum -200 mA, maximum $+200$ mA
- Operating ambient temperature: minimum 10 °C, maximum 50 °C