

RAPCON

**REAL-TIME RAPID CONTROL PROTOTYPING PLATFORM
FOR
MATLAB/SIMULINK**

Quick Reference

release 1.7

May 1, 2016

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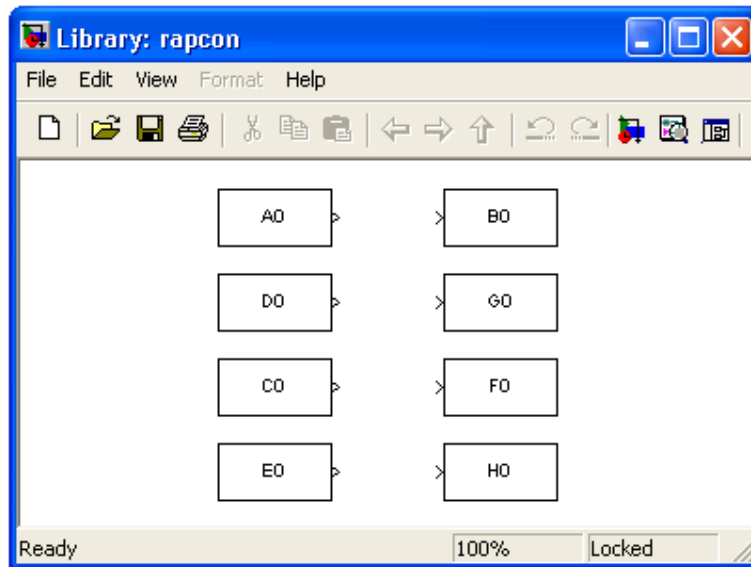
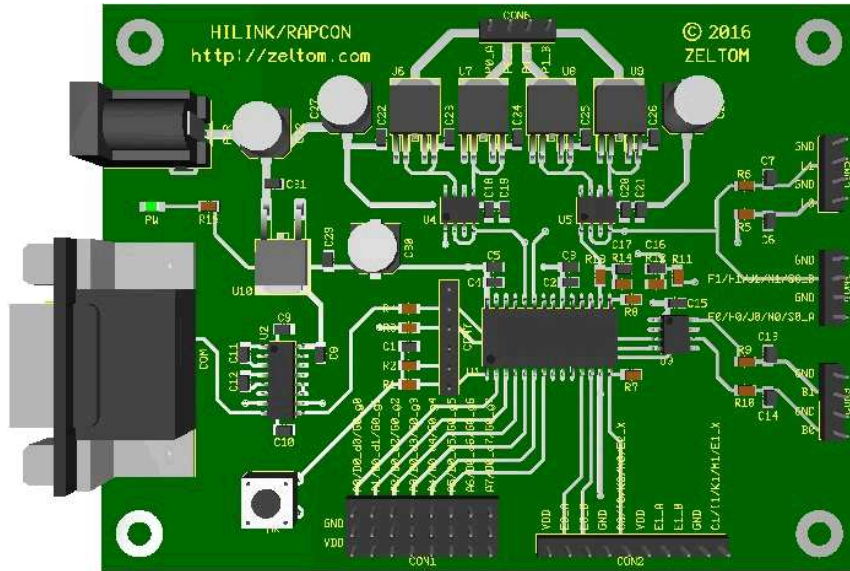
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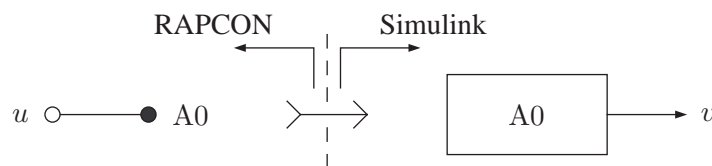
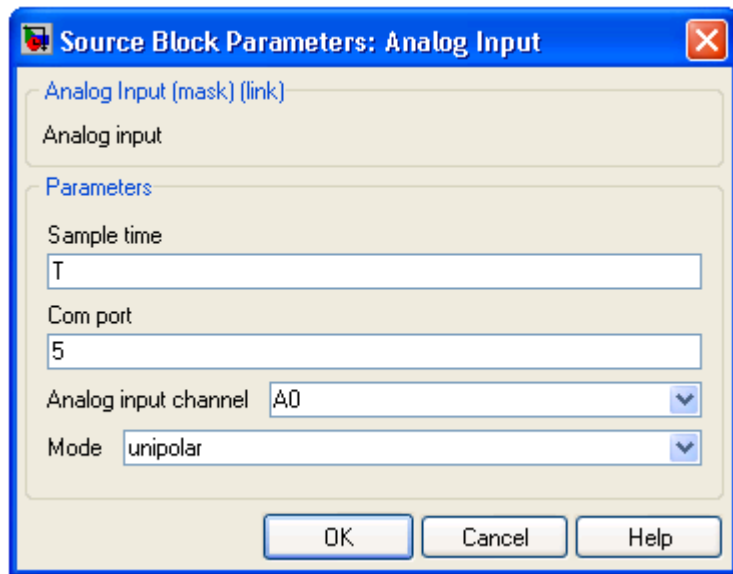
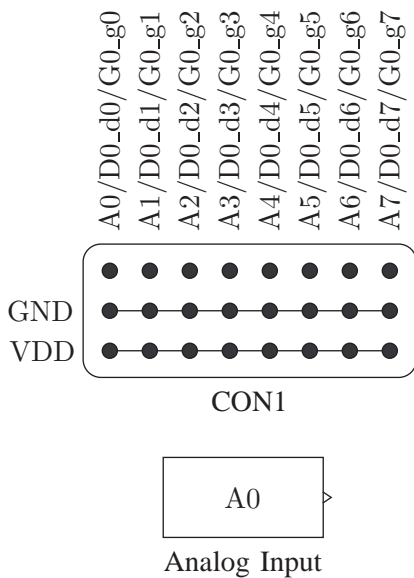
Belleville, MI 48111

USA



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

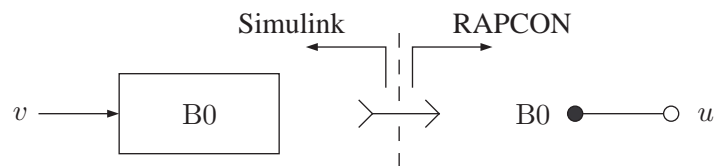
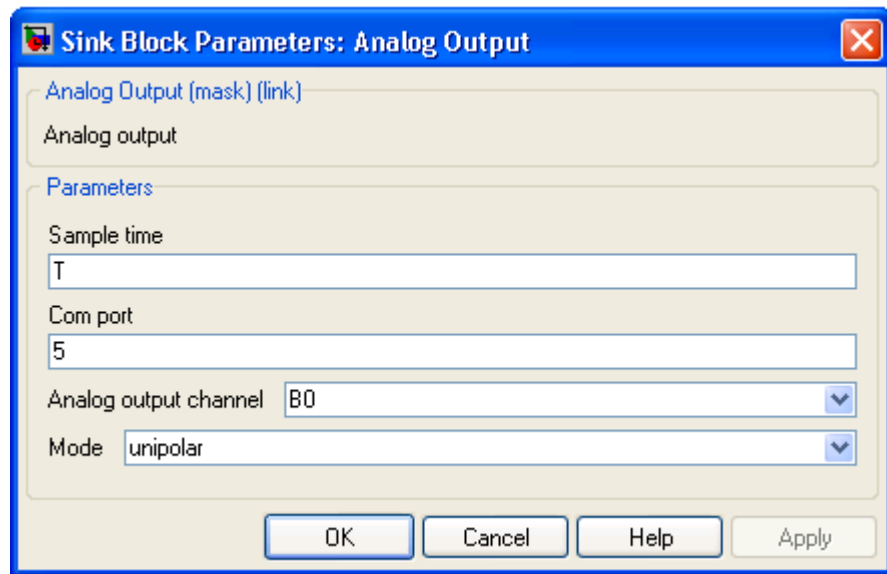
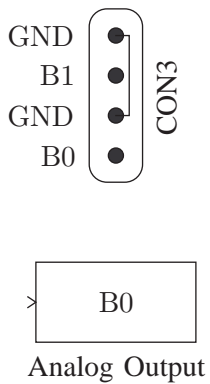


$$\text{unipolar mode} \Rightarrow v \approx \begin{cases} 5, & u \geq 5 \\ u, & 0 < u < 5 \\ 0, & u \leq 0 \end{cases}$$

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

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

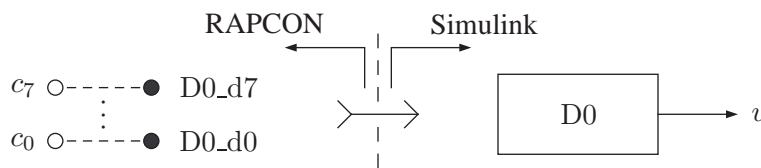
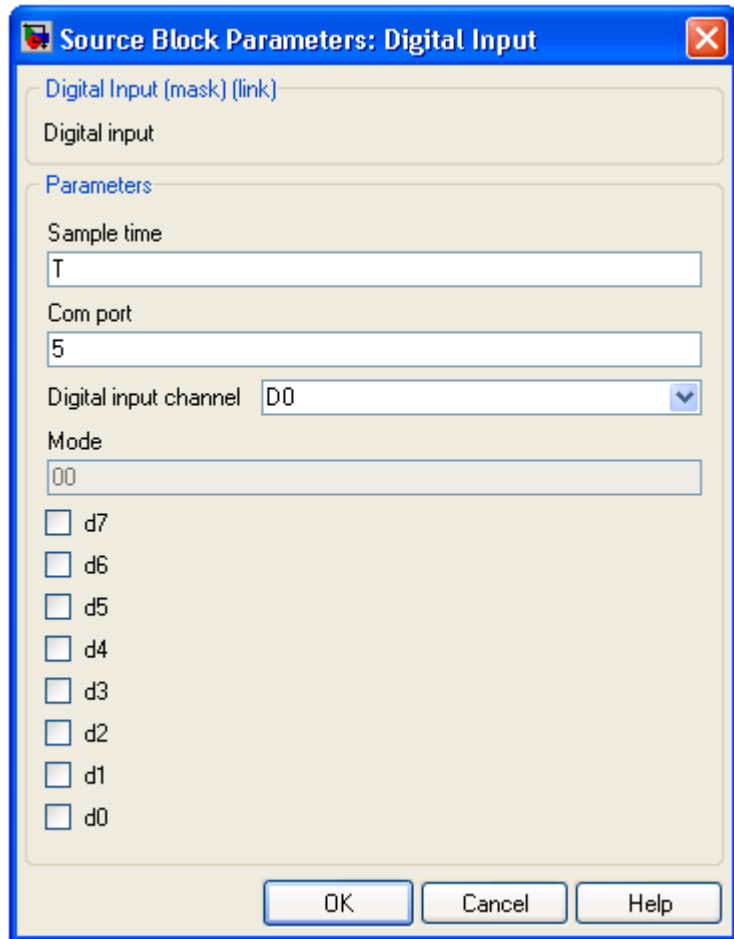
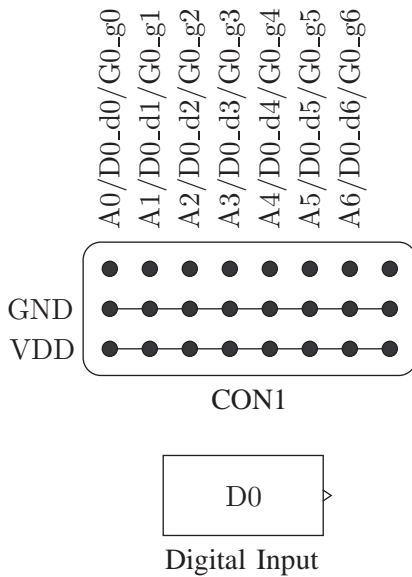


$$\text{unipolar mode} \Rightarrow u \approx \begin{cases} 4.096, & v \geq 4.096 \\ v, & 0 < v < 4.096 \\ 0, & v \leq 0 \end{cases}$$

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

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

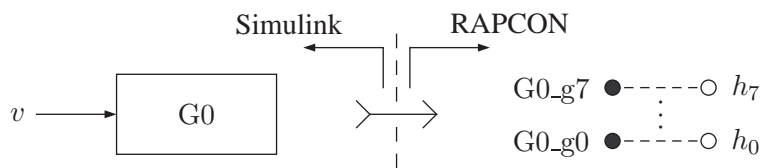
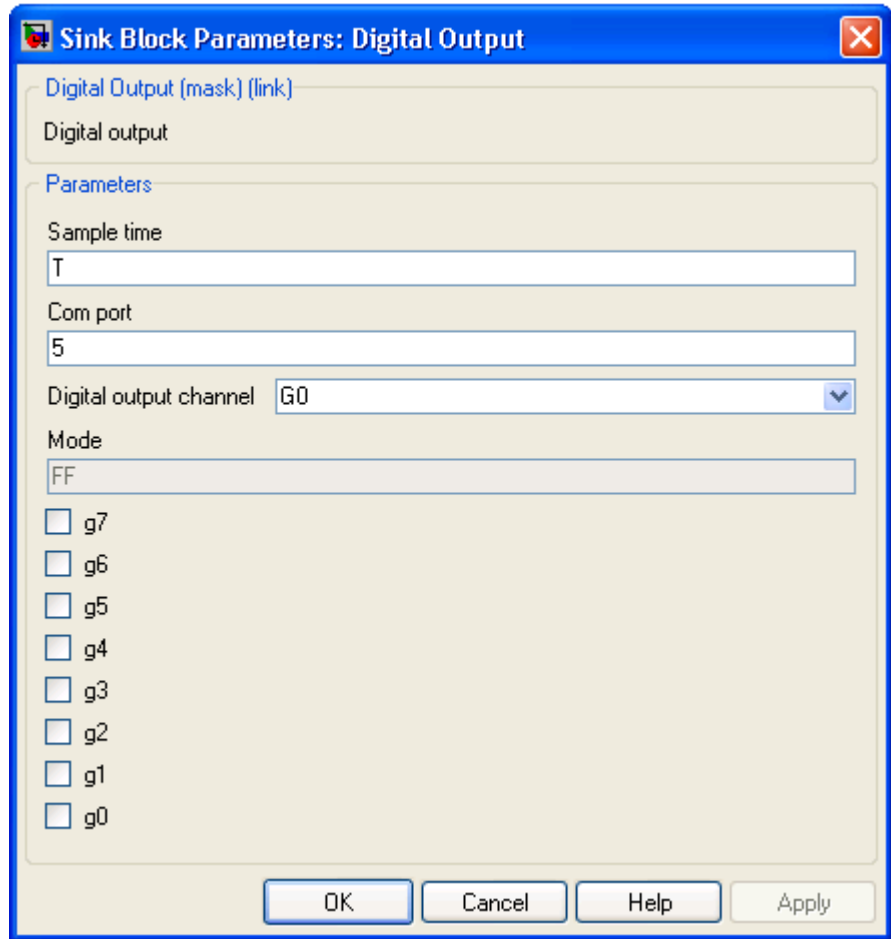
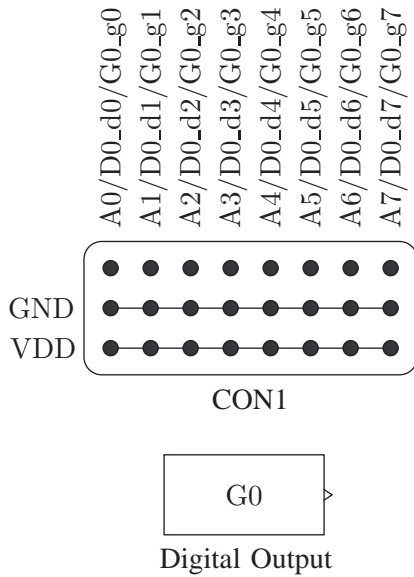


$$v = 128 d_7 + 64 d_6 + 32 d_5 + 16 d_4 + 8 d_3 + 4 d_2 + 2 d_1 + 1 d_0$$

$$d_i = \begin{cases} c_i \text{ (1 or 0),} & \text{Ai is not used and D0_di is used (di is checked)} \\ 0, & \text{Ai is used, or Ai, D0_di and G0_gi are not used} \\ h_i \text{ (1 or 0),} & \text{Ai and D0_di are not used, but G0_gi is used with output } h_i \end{cases}$$

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

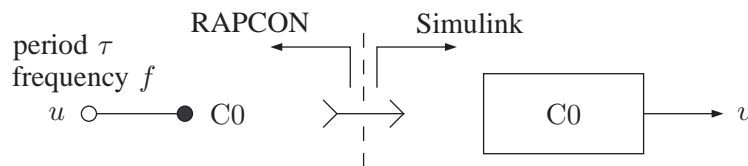
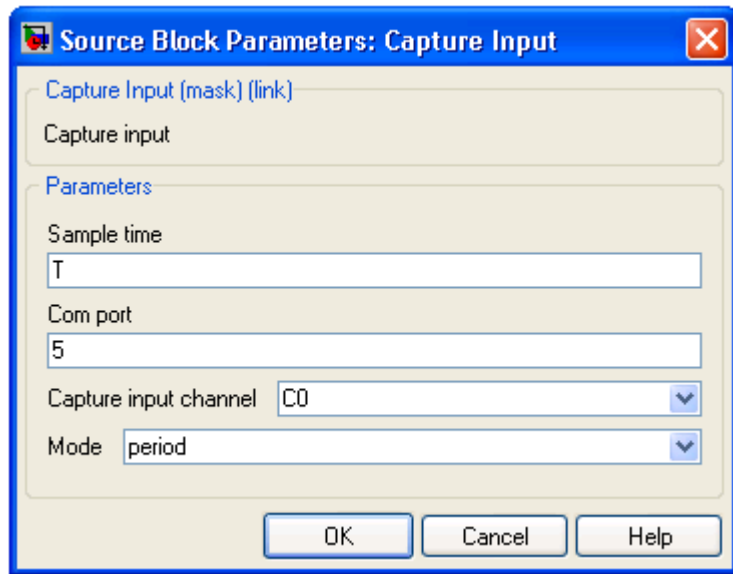
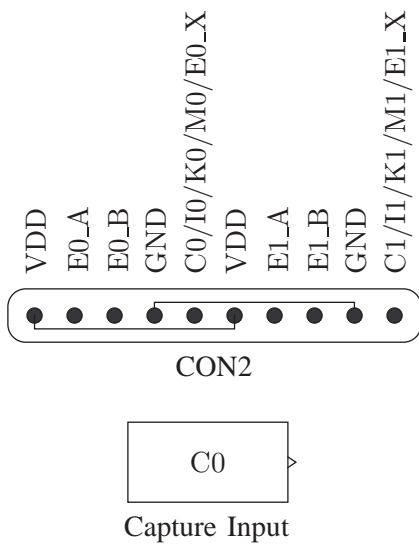


$$128 g_7 + 64 g_6 + 32 g_5 + 16 g_4 + 8 g_3 + 4 g_2 + 2 g_1 + 1 g_0 = v \& 0 \times 00FF$$

$$h_i = \begin{cases} g_i \text{ (1 or 0),} & \text{Ai and D0_di are not used, and G0_gi is used (gi is checked)} \\ \text{(analog input),} & \text{Ai is used, or Ai, D0_di and G0_gi are not used} \\ c_i \text{ (1 or 0),} & \text{Ai is not used and D0_di is used with input } c_i \end{cases}$$

5. Capture Input

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

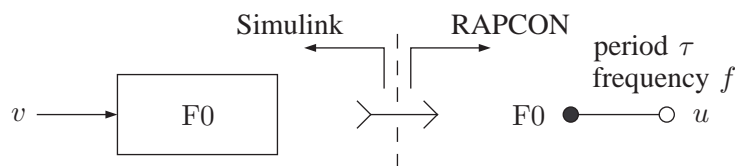
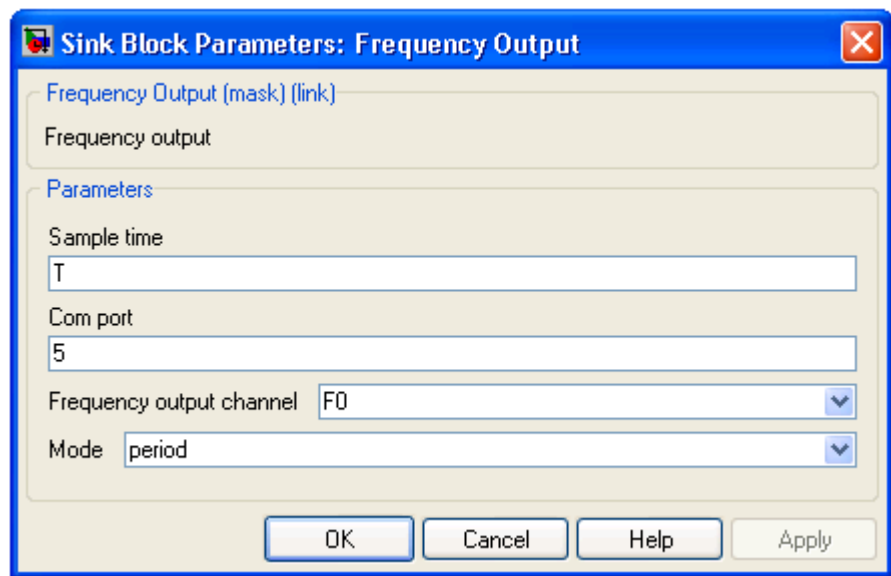
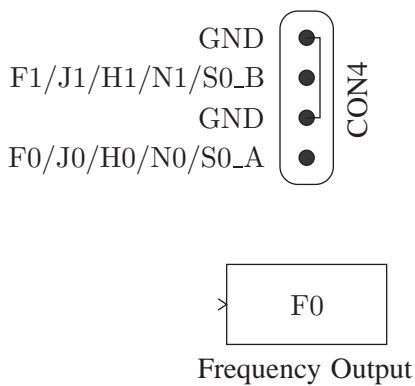


$$\text{period mode} \Rightarrow v \approx \begin{cases} 569.0963 \times 10^{-3}, & \tau \geq 569.0963 \times 10^{-3} \\ \tau, & 34.7354 \times 10^{-6} < \tau < 569.0963 \times 10^{-3} \\ 34.7354 \times 10^{-6}, & \tau \leq 34.7354 \times 10^{-6} \end{cases}$$

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

6. Frequency Output

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

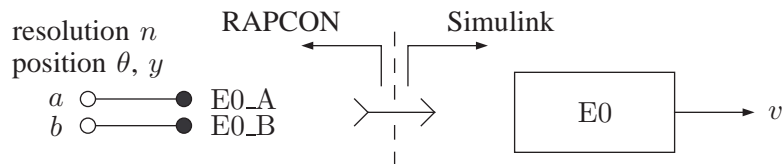
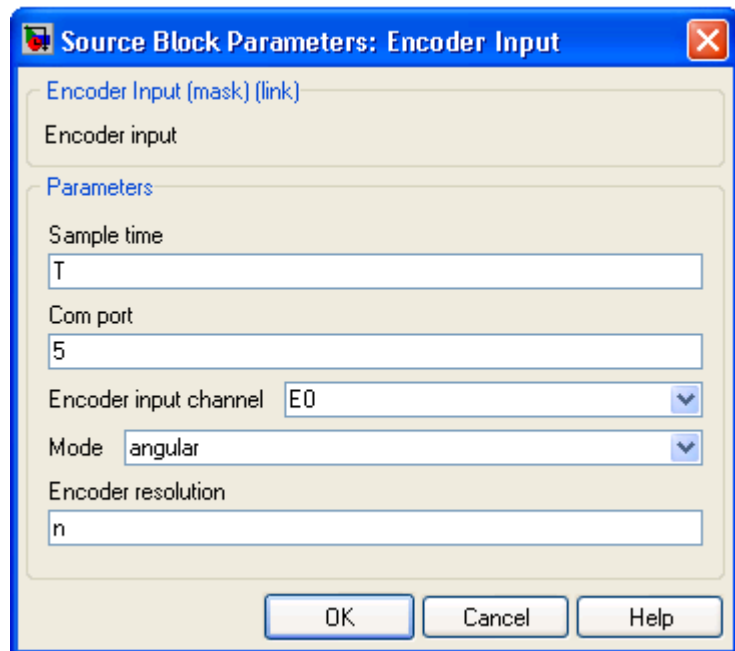
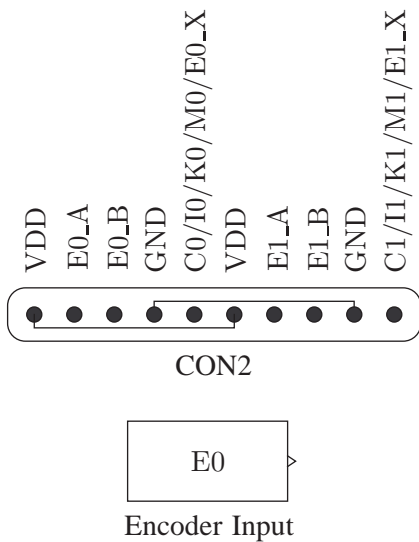


$$\text{period mode} \Rightarrow \tau \approx \begin{cases} 569.0963 \times 10^{-3}, & v \geq 569.0963 \times 10^{-3} \\ v, & 34.7354 \times 10^{-6} < v < 569.0963 \times 10^{-3} \\ 34.7354 \times 10^{-6}, & v \leq 34.7354 \times 10^{-6} \end{cases}$$

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

7. Encoder Input

- 2 encoder input channels E0 – 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)

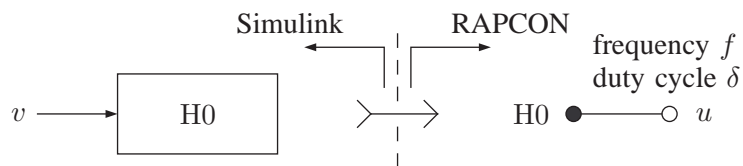
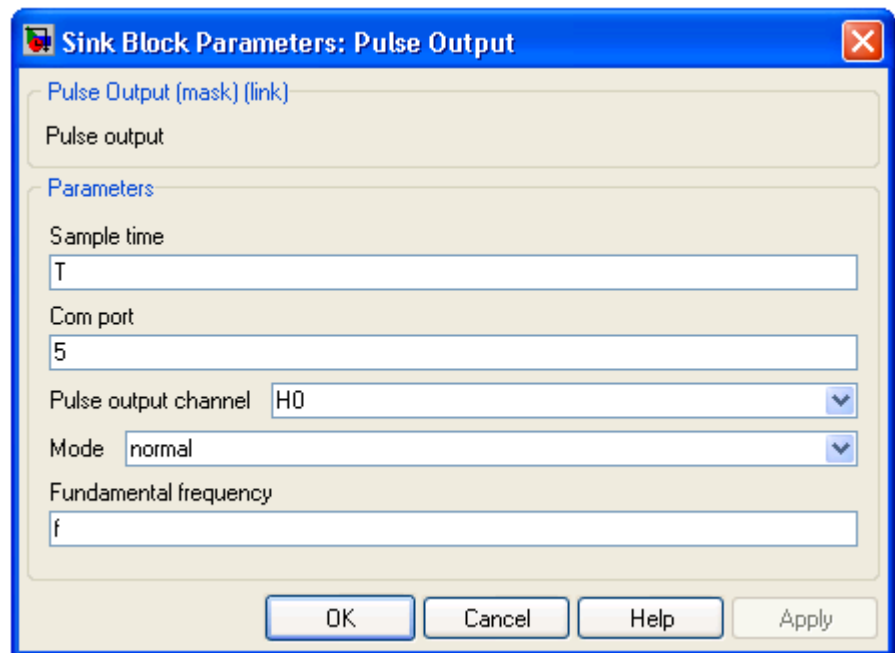
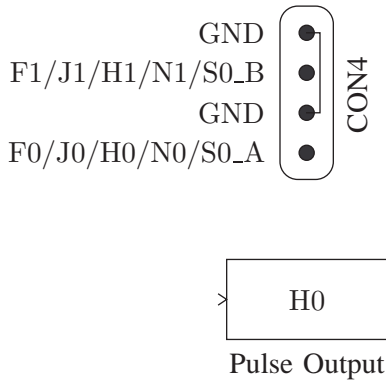


$$\text{angular mode} \Rightarrow v \approx \begin{cases} +32767\pi/2/n, & \theta \geq 32767\pi/2/n \\ \theta, & -32768\pi/2/n < \theta < +32767\pi/2/n \\ -32768\pi/2/n, & \theta \leq -32768\pi/2/n \end{cases}$$

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

8. Pulse Output

- 2 pulse output channels H0 – 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)

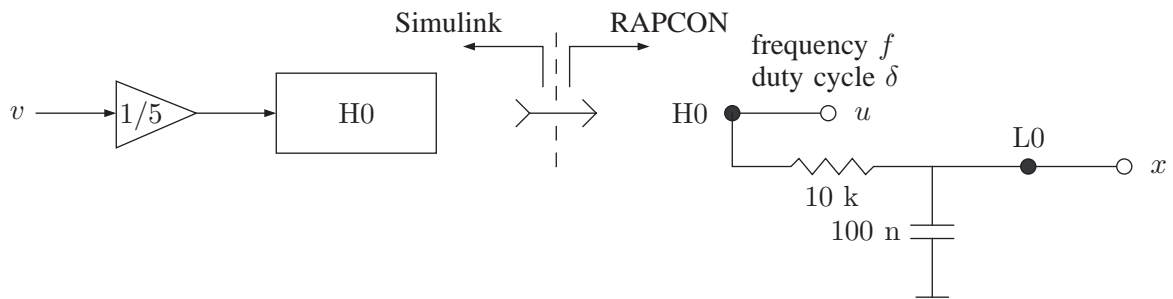


$$\text{normal mode} \Rightarrow \delta \approx \begin{cases} 1 (u \text{ is high}), & v \geq 1 \\ v, & 0 < v < 1 \\ 0 (u \text{ is low}), & v \leq 0 \end{cases}$$

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

9. Filtered Pulse Output

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

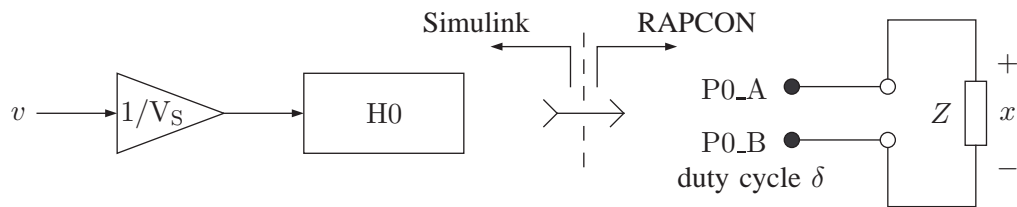


lowpass equivalent of $u \approx \delta v$

$$f \gg 159.1549\text{ Hz and } H_0 \text{ in normal mode} \Rightarrow x \approx \begin{cases} 5, & v \geq 5 \\ v, & 0 < v < 5 \\ 0, & v \leq 0 \end{cases}$$

10. H-bridge Power Output

- 2 H-bridge power output channels P0 – P1 with power outputs P0_A, P0_B – P1_A, 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 $x \approx (2\delta - 1)V_S$

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

11. Sampling Rate

$$\begin{array}{l} \text{number of input channels } n_i \leq 64 \\ \text{number of output channels } n_o \leq 64 \end{array} \Rightarrow \text{sampling rate } f = \frac{1}{T} \leq \frac{46080}{2 \max(n_i, n_o) + 1}$$

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 → Real-Time Workshop → 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 → Configuration Parameters...” for your model.
- Refer to the Matlab help files for setting up the configuration parameters under “Tools → 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 RAPCON installation directory and make sure that the “Current Directory” of Matlab is your RAPCON installation directory.
- Make sure that the com port number of each RAPCON block (default is 5) matches with the com port you are using.
- Rebuild your model whenever you make any changes in the parameters of the RAPCON 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 RAPCON 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: 460800 baud, 8 bit data, no parity, 1 stop bit
- Analog inputs: A0 – A7, 0 – 5 V analog, 12 bit resolution
- Analog outputs: B0 – B1, 0 – 5 V analog, 12 bit resolution
- Digital inputs: D0_d0 – D0_d7, 0 – 5 V digital, 8 lines
- Digital outputs: G0_g0 – G0_g7, 0 – 5 V digital, 8 lines
- Capture inputs: C0 – C1, 0 – 5 V digital, 16 bit resolution
- Frequency outputs: F0 – F1, 0 – 5 V digital, 16 bit resolution
- Encoder inputs: E0_A, E0_B, E0_X – E1_A, E1_B, E1_X, 0 – 5 V digital, 16 bit resolution
- Pulse outputs: H0 – H1, 0 – 5 V digital, 16 bit resolution
- Filtered pulse outputs: L0 – L1, 0 – 5 V analog
- H-bridge power outputs: P0_A, P0_B – P1_A, 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 15.2 kHz
- Size: 10.16 cm × 7.62 cm
- Weight: 43.9 g

16. Requirements

- PC with Windows XP or later and 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)
- RAPCON hardware (real-time control board) 1.5 or later
- RAPCON 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