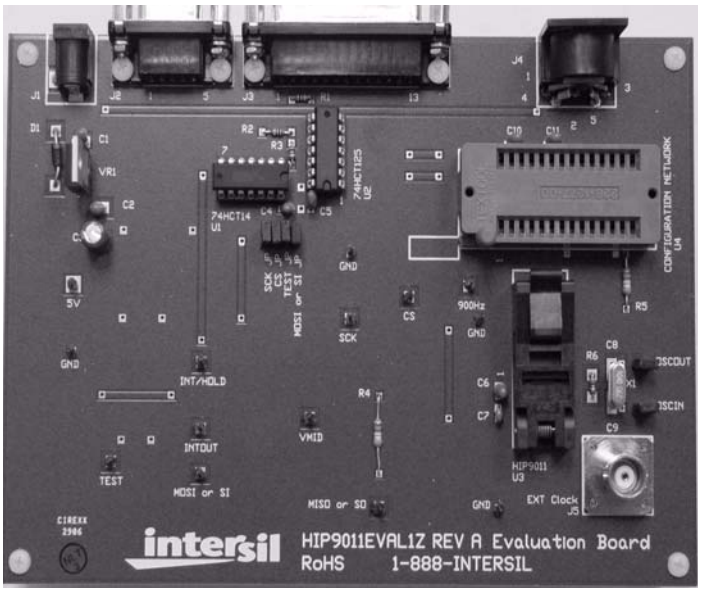
AN9770
Rev 1.00
Nov 6, 2006

Engine Knock Sensing Applications (HIP9011EVAL1Z)

HIP9011EVAL1Z Evaluation Board



There continues a driving effort by the Government and the automotive industry to make cars more efficient with lower emissions. Tighter and more extensive control of automobile engines by microcontrollers has resulted in significant strides towards these goals.

One of the factors contributing to these improvements is engine ignition control. The HIP9011 helps in the ongoing battle to enhance engine performance by providing more detailed information to the engine microcontroller.

An important point to remember - automotive engines operate most efficiently when the engine is placed in the ignition timing condition just prior to ping or pre-ignition. The closer an engine can operate to this condition, the higher the performance. This is analogous to an operational amplifier, where the higher the gain, the lower the distortion. In the case of the knock signal processing IC, it provides a means of detecting engine knock or ping at levels that were previously unrealizable by amplification and filter means. Figure 1 shows the HIP9011 in a typical engine application.

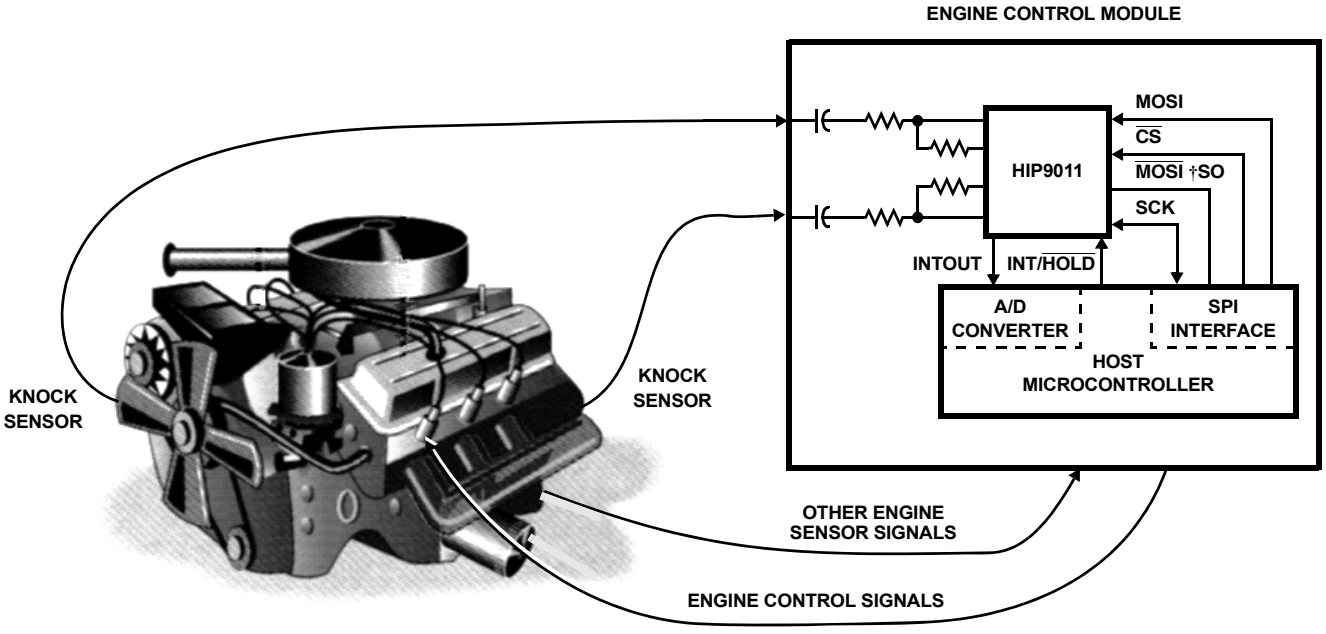


FIGURE 1. HIP9011 IN A TYPICAL ENGINE CONTROL APPLICATION

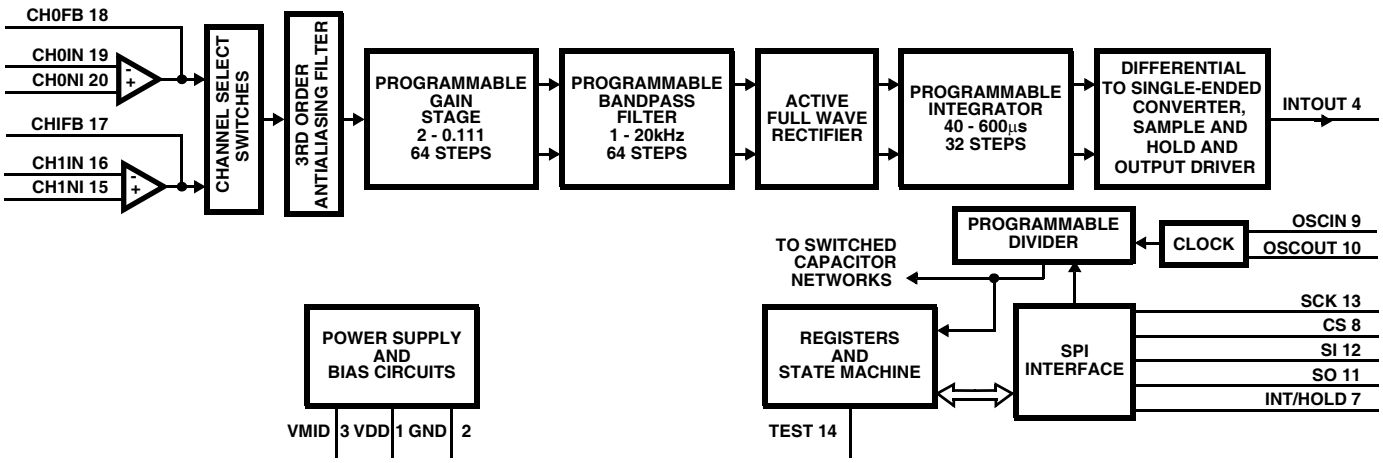


FIGURE 2. SIMPLIFIED BLOCK DIAGRAM OF THE HIP9011, SINGLE CHANNEL KNOCK SIGNAL PROCESSING IC

Operation of the Signal Processing IC

Inputs from one or two piezoelectric sensors mounted on the engine block are capacitively coupled to the inputs of the operational amplifiers within the HIP9011. Two sensors are shown in the examples in this application note, one for each side of a "V" type of engine configuration. Engines configured in-line may use sensors placed on either end of the engine block. Often only one sensor is used by strategically locating a point where optimum signal output is available. The ability of this IC to have programmable gain changes at each ignition pulse can help with these configurations. In some high end applications two HIP9011 are used.

The input coupling capacitor and series input resistors to the inverting input of the operational amplifiers within the HIP9011 serve as a high pass filter to reduce low frequency components from the transducer. AC coupling also has the advantage of reducing the possibility of driving the output of the input amplifier towards the positive supply with increased leakage resistance of the transducer or environment with time. Leakage resistance to ground will pull the inverting input of the operational amplifier to ground, thus forcing its output high. The non-inverting input of the HIP9011 is not committed, but in most applications, it is usually returned to the mid supply voltage, available as an output terminal of the device.

A signal from the engine's microcontroller determines which transducer input signal will be processed by the HIP9011 operational amplifier for each ignition pulse by toggling the transmission gate on the output of these amplifiers. From here the signal is applied to an anti aliasing filter within the HIP9011. This filter excludes input signals above 20kHz from passing on to the following switched capacitor filter and gain stages. Signals above 20kHz could cause problems with the 200kHz clocking frequency of the switched capacitor filters and amplifiers. A filter channel is provided in the HIP9011, with a tuning range from 1.22kHz to 19.98kHz, in 64 steps. Serial control signals are sent via the SPI bus to the HIP9011 by the microcontroller. These control signals set the filter frequencies within these ICs.

The output of the Filter Stage in the HIP9011 is applied to a full wave rectifier and then to an integrator. The integrator operation is initiated by the INT/$\overline{\text{HOLD}}$ signal from the microcontroller. It is only during the rising edge of the INT/$\overline{\text{HOLD}}$ signal that the integrator starts from its initial reset condition of 0.125V. Integration is towards the positive supply when a knock signal is present. Severity of the knock signal and the integrators programmable time constant determines the final level. The integrator time constant is programmable in 32 steps from 40µs to 600µs. This time constant can be viewed as an output signal attenuator. Again, the value of the time constant is set by the SPI control signals from the microcontroller.

Immediately after the INT/$\overline{\text{HOLD}}$ signal goes low, the integrators output signal, INTOUT is held in the HIP9011's output sample and hold circuit for the microcontroller's A/D converter to process. Figure 2 shows the block diagram of the HIP9011. Figure 3 shows the waveforms for the integrator, INTOUT on the top trace. The center trace shows the input signal from a simulated pressure transducer mounted on the cylinder. An expanded waveform of the simulated engine input signal during the integration period is shown in the circled display of Figure 3. The bottom trace shows the INT/$\overline{\text{HOLD}}$ signal.

From this discussion we see that we have an IC that can detect low levels of engine knock or ping by using bandpass filters, rectification and an integration process. The gated integrator allows the IC to only monitor engine noise during the time that engine knock is expected to occur, thus, vastly reducing the influence of background noise.

Integrator Operation

Observation of the integrator output signal, INTOUT, is important to the setup and understanding of the operation of this signal processing IC. This observation can be distorted by instrumentation used to view the INTOUT signal. In Figure 5, the upper waveform shows what looks like inaccuracies in the INTOUT signal. This is due to aliasing of the oscilloscope sampling system with only 500 samples. Not shown in this

display is the 200kHz clock signal that only appears during the integration portion of the sample cycle. This signal causes aliasing or a “low frequency beat” in the oscilloscope display between the 500 samples and the 200kHz pulses appearing on the ramp only during the integration interval. Once the signal is acquired, the INTOUT signal during the hold period remains constant and free of the 200kHz pulses until the next integration period. The sample and hold circuit within the HIP9011 is timed so that it only samples during a non pulse period, thus preventing it from acquiring either peaks or valleys.

The lower trace of Figure 5 more accurately depicts the INTOUT waveform. Note the 200kHz clock signal on the integrator ramp. One million samples were used for this display. Also note that INTOUT is constant between integration cycles and shows no 200kHz pulses.

For observation purposes only, or when working with a digital oscilloscope with limited samples, an external anti aliasing filter may be assembled with a series 51k resistor and a 510pF capacitor to ground. The filter attenuates the internal 200kHz clock signal during integration, For operation with a sampling A/D converter that is strobed and samples after the integration cycle, no filter is needed.

Laboratory Setup

It is desirable to get a “feeling” for the operation of the HIP9011 before proceeding to an evaluation with an engine, Figure 6 shows a bench test setup where this can be easily accomplished.

One generator is used to provide the INT/$\overline{\text{HOLD}}$ signal to the Evaluation Board. In the actual application this signal would be supplied by the engine controller. The width of this signal may vary from several hundred microseconds to several milliseconds depending upon the engine rpm and engine type. Generally, there is a large signal at high engine rpms and lower signals at low rpms. At the lower rpm, the integration period may be extended to gain more samples and effectively produce high sensitivity to obtain more output.

The second generator provides the signal that serves as a knock signal. It is interesting to note the variation of the integrator output, INTOUT, as the IC filter frequency or oscillator frequency is varied from 200Hz to 100kHz. Figure 4 shows the IC’s filter response as a sweep frequency signal is applied to only the filter circuit for five selected filter frequencies from 1.22kHz to 19.98kHz. These curves were taken only of the filters to show their response and comparatively constant output through out the entire filter frequency range.

Figure 7 shows the HIP9011 connected to an engine. The microcontroller with inputs from the engine, provides the INT/HOLD signal to initiate operation of the integrator within the knock signal processing IC.

Evaluation Board

Figure 8 shows the schematic diagram of the evaluation board. A 4MHz crystal is supplied with the board. 4MHz ceramic resonators such as the TDK FRC4.0MCS have been successfully used in the board. Three pins are provided on the board to accept resonators to replace the crystal.

A prewired input amplifier configuration board is provided as shown in Figure 9. This board is connected for single ended operation.

Figure 10 shows the schematic diagram for a differential input board that may be wired for the HIP9011. This may be fabricated with the one generic blank board supplied with the evaluation board.

Figure 11 is a top view of the evaluation board.

Software Displays

Figure 12 shows the display for the HIP9011 appearing on the computer when using the Evaluation Board in a Microsoft® Windows® setup. In some Windows setups the text displayed may override the boxes and be difficult to read due to computer settings. This can be corrected by changing the font size on the computer. This is described in the “Installing Knock Signal Processor Software” section of this application note.

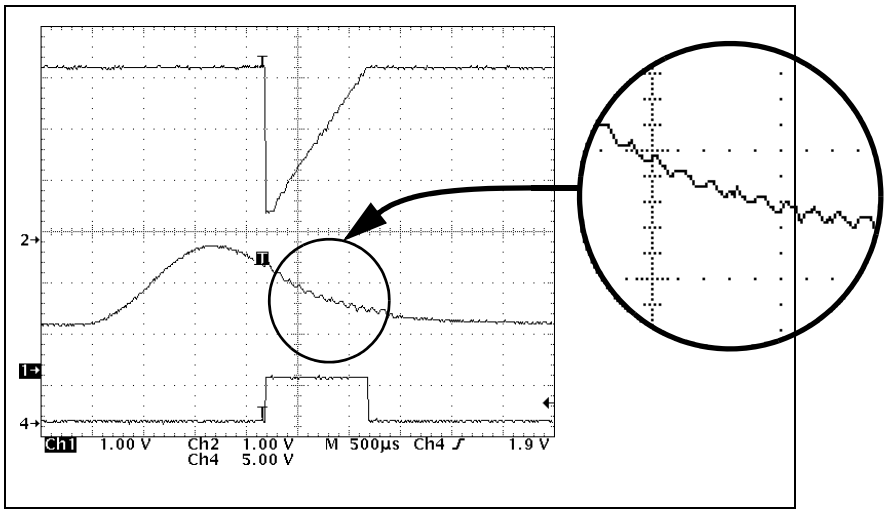


FIGURE 3. WAVEFORMS ASSOCIATED WITH THE HIP9011

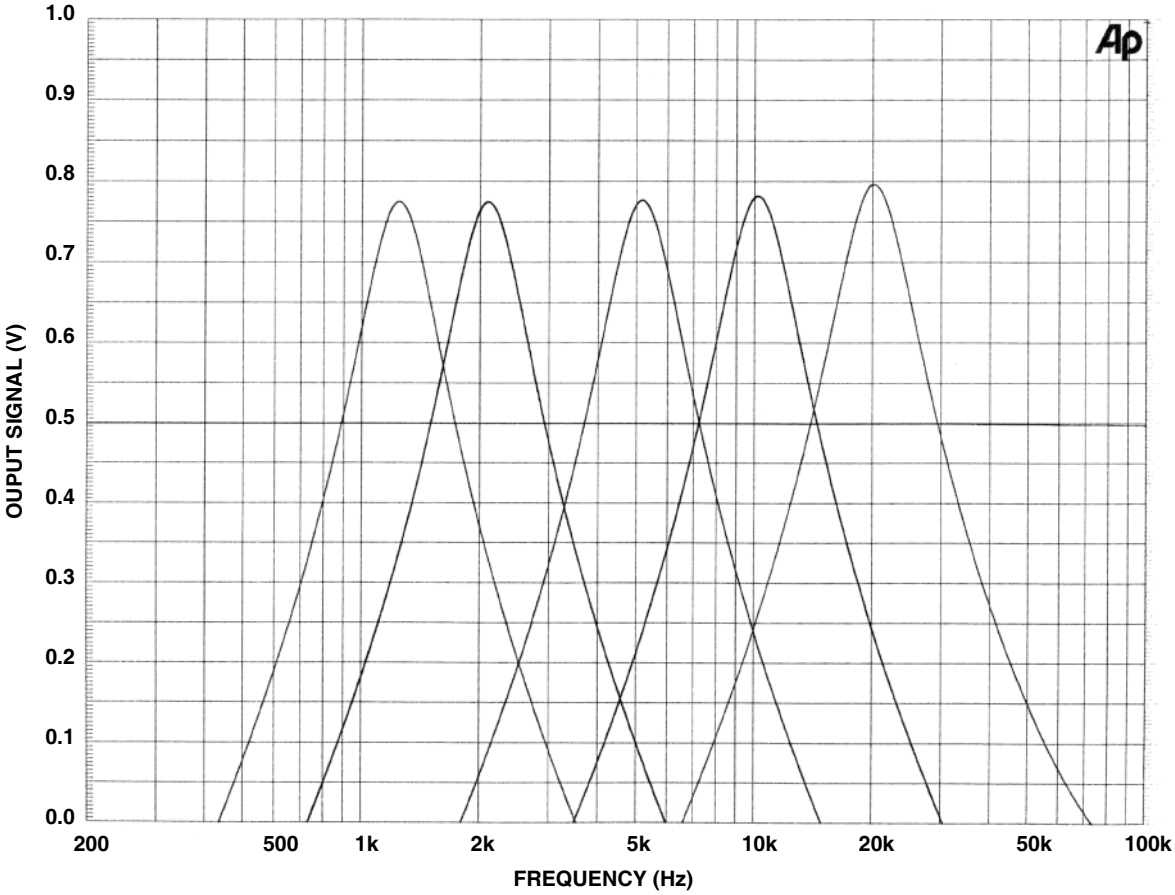


FIGURE 4. RESPONSE OF ONLY THE FILTERS WITHIN THE HIP9011

The codes written by the computer for each function are displayed on the lower right side of the display. Multiple settings may easily be obtained by opening more windows with different settings and clicking with the mouse on the desired window, to activate the desired setting.

Figure 13 through Figure 17 shows the writing sequence to the knock processing IC by the computer for various settings of the knock signal processing ICs.

Open Knock Sensor Detection

One means to detect an open sensor is to couple a low level, low frequency AC signal to the amplifier input. If the coupling capacitor value carrying this signal is small compared to the capacitance of the piezoelectric transducer, the coupled signal will be attenuated. To a first order, this would be the capacitance ratio Ccoupling/Csensor. Moreover, if the low level signal's frequency is below the normal spectrum of engine signals it will be further attenuated by the bandpass filters. To accomplish this function on the Evaluation Board, two terminals are provided. One is marked 900Hz, while the other is the ground return for that signal. When the piezoelectric transducer is removed from the input circuit, the previously attenuated 900Hz signal will become large and drive the IC's input operational amplifier to full output, which will produce higher frequency components that will look like a severe knock signal that can not be handled by the control system. Software would then retard the timing to a minimum that would allow the engine to function, but at a lower efficiency level. Service would be required to restore normal engine operation.

Another Open Knock Sensor Approach with a Software Algorithm

The main focus of this method to detect sensor disconnect is based on exploiting the re-programmability of the gain stage within the IC. If a user reprograms the gain stage, for example, at every 5th engine revolution for an open sensor condition, the response time and accuracy of the feedback knock sensor control should not impair the engine performance over most of the entire engine speed range.

The approach is to adjust the GAIN stage prior to supplying the knock signal to the Band Pass Filter stage. To determine the sensor disconnect threshold value for the knock sensor system, the gain would be reduced to the lowest programmable level. This would then provide a signal level/reference value closest to that produced by a sensor that was disconnected.

Then with the GAIN stage programmed to a more normal/frequent operating value, should a sensor become disconnected, the INTOUT signal level would drop to a level

near the level/value that was determined when the GAIN stage was set at the lowest value of gain. From this higher gain value/operating condition, the system could then determine that the sensor has been disconnected.

Another approach that has been suggested is to, at engine start up, advance the engine timing to the knock level and observe the INTOUT signal. If knock cannot be detected, the sensor is assumed open.

Application Tips

Here are several important points about the application of the HIP9011 that will enhance the performance of a system using this IC. First, as mentioned previously, it is suggested that a coupling capacitor be placed in series with the transducer. This minimizes the possibility of pulling the inverting input of the operational amplifiers within the IC to ground. Grounding the inverting input forces the amplifier output high, thus limiting the signal handling ability of the amplifiers.

Another important point is to insure that the input amplifier and following stages operate at near their maximum peak to peak signal level without overload under the maximum expected input. Doing this allows the integrator stage to be set to lower gain settings, larger time constants, and thus reduces sensitivity in the output stage. This is analogous to a public address amplifier where the master gain control, analogues to the integrator stage, is set to full gain and the input gain control set to minimum gain. Under these conditions the public system will be noisy.

As a goal keep the output of the input operational amplifiers within half of the maximum expected output swing. This will insure that the following analog initializing filter has sufficient dynamic range. The switched capacitor gain stage can be used to either attenuate or amplify the signal. By observing these conditions, the signal going into the integrator stage will usually require a large time constant to keep the integrator from saturating. Also, remember that the effective system gain can be increased by increasing the integration window when higher gain is needed, usually, at lower engine speeds.

Other Applications

Because of the extremely unique design of this signal processing IC with over 130,000 programming combinations, the user is afforded maximum flexibility of signal detection and processing. Other applications are possible such as security systems with acoustical spectrum analysis with the aid of the filter within this device. Room, area or system profiles can be stored and compared with current values.

Analysis of heavy transmissions or other machinery with sensors used to detect bearing wear and other acoustical qualities is possible. Here preventive maintenance would be one of the key qualities.

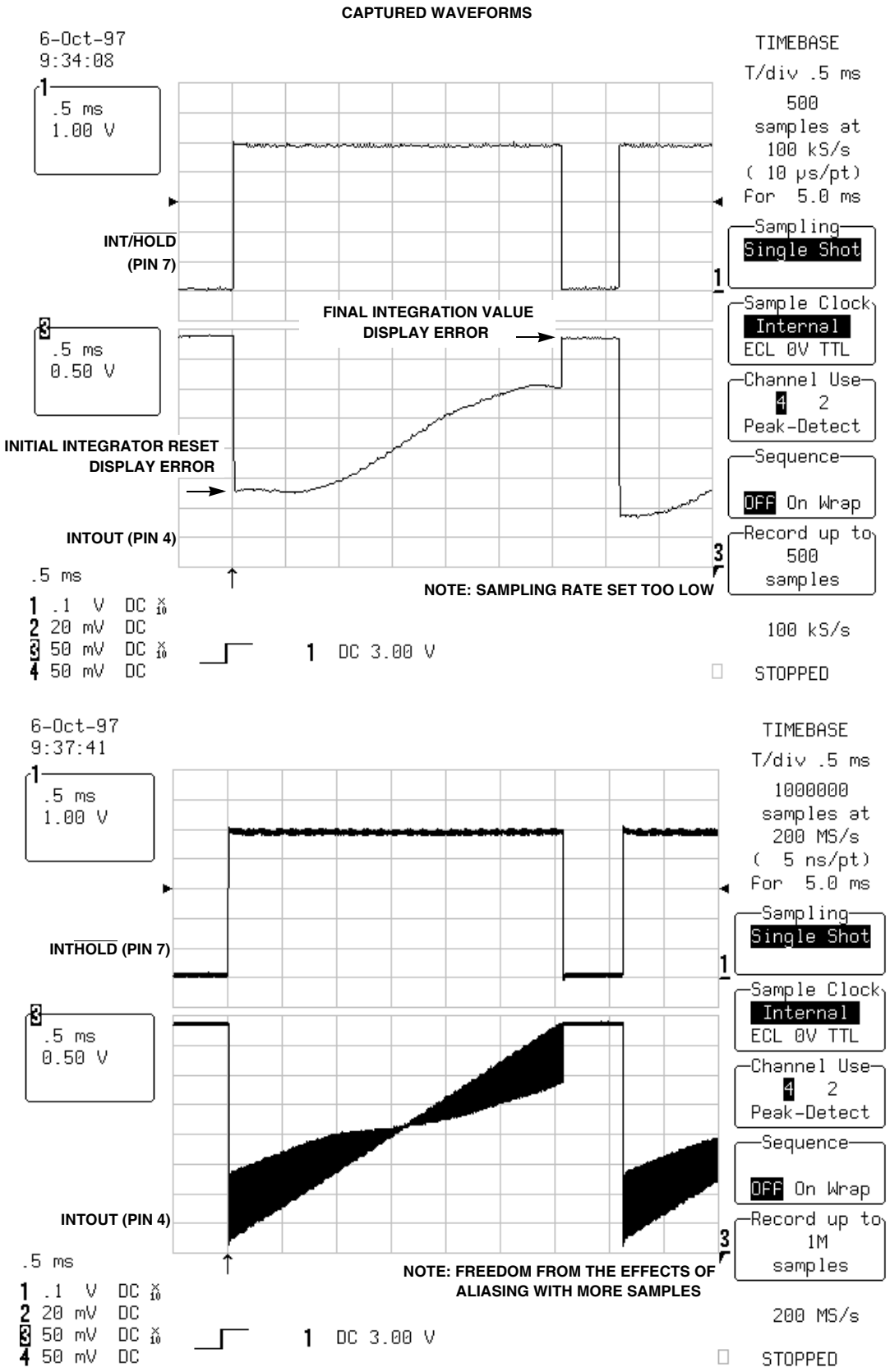


FIGURE 5. INTOUT (PIN 4) OUTPUT WAVEFORM DISPLAY INACCURACIES DUE TO DIGITAL SAMPLING SCOPE SETTINGS

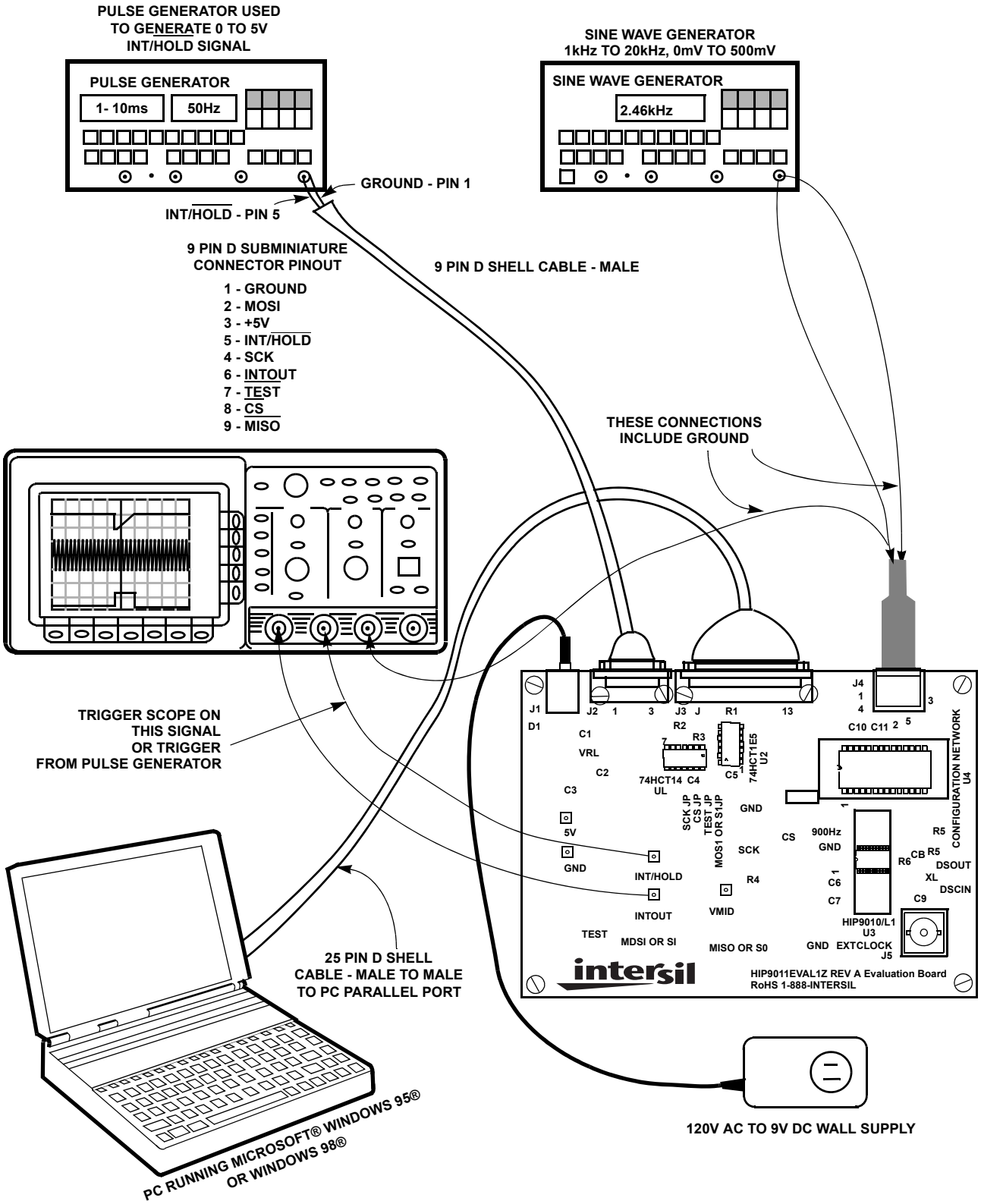


FIGURE 6. KNOCK SENSOR IC EVALUATION BOARD CONNECTIONS FOR BENCH TESTING

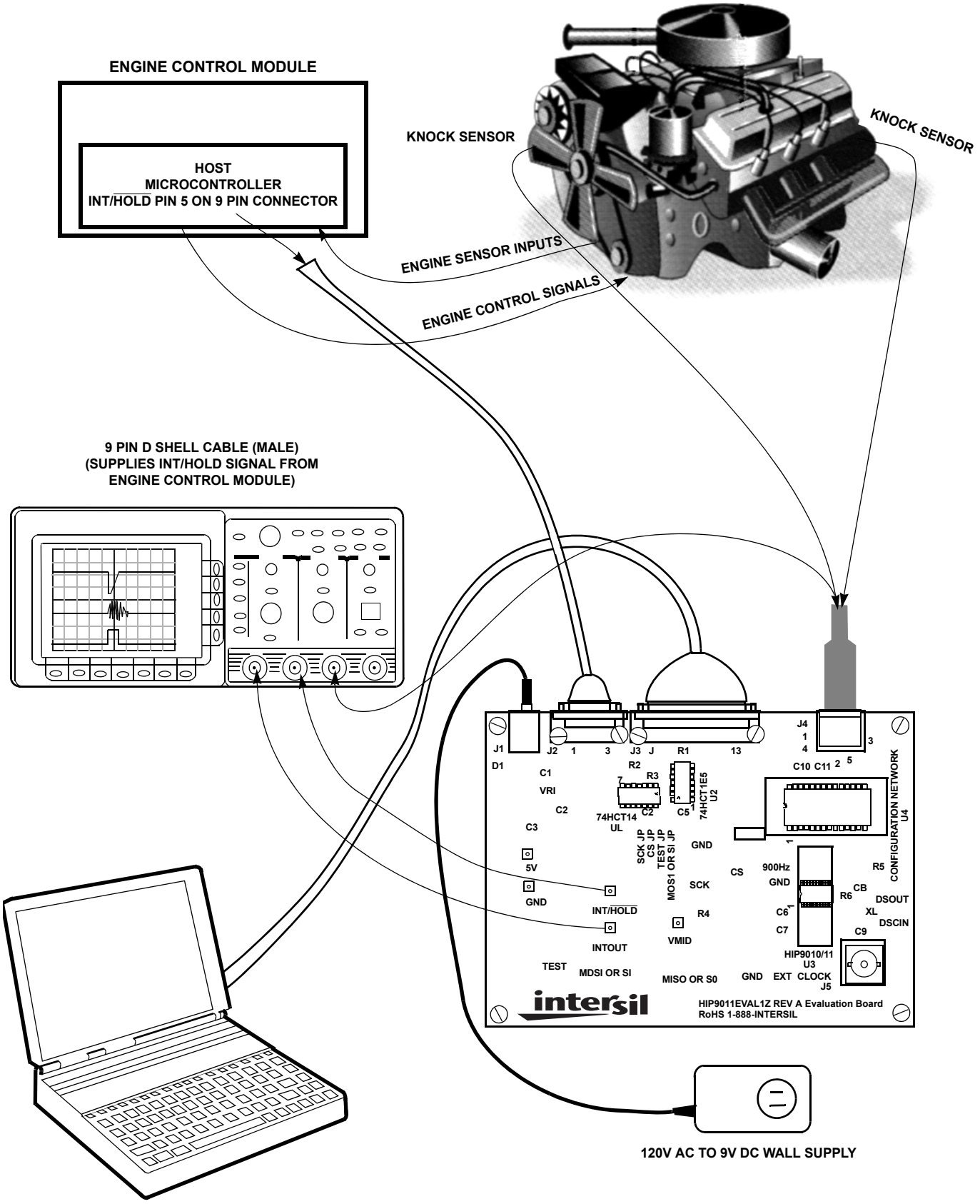


FIGURE 7. KNOCK SENSOR IC EVALUATION BOARD CONNECTIONS FOR TESTING WITH AN ENGINE

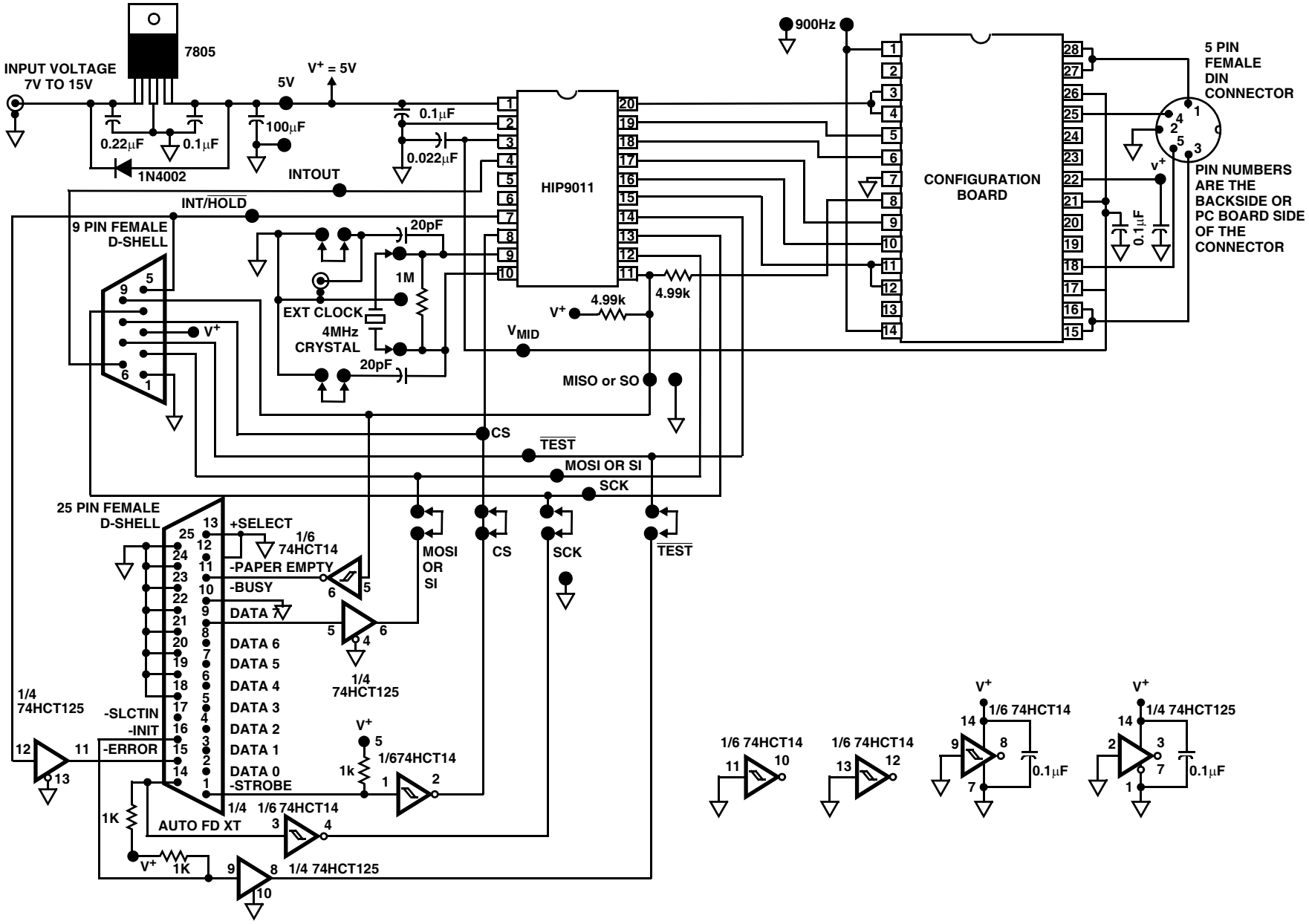


FIGURE 8. HIP9011 EVALUATION BOARD SCHEMATIC DIAGRAM

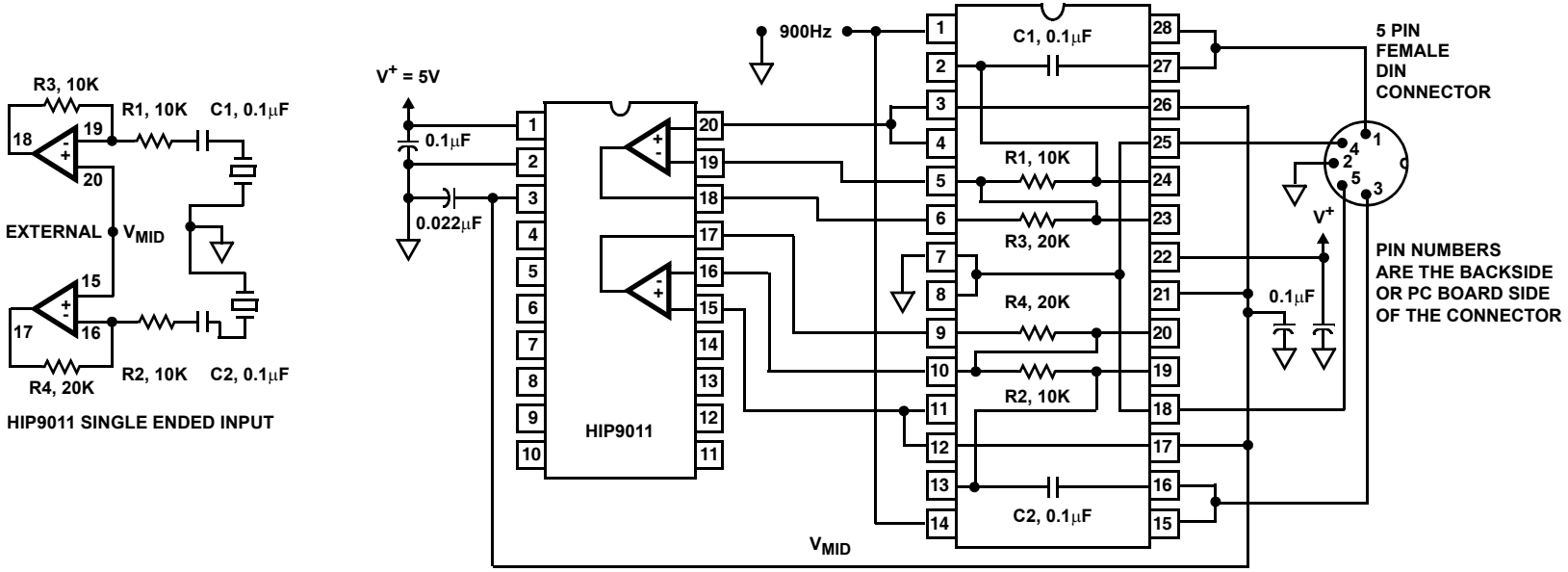
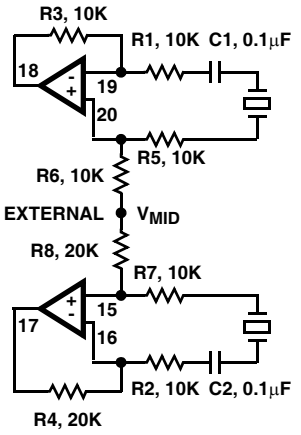
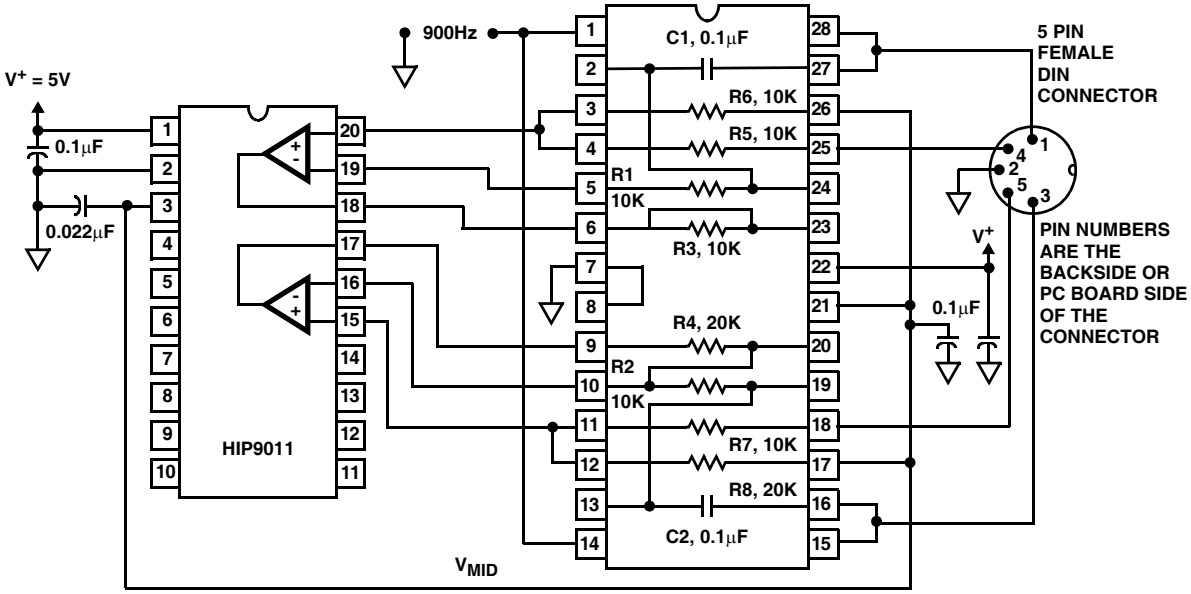


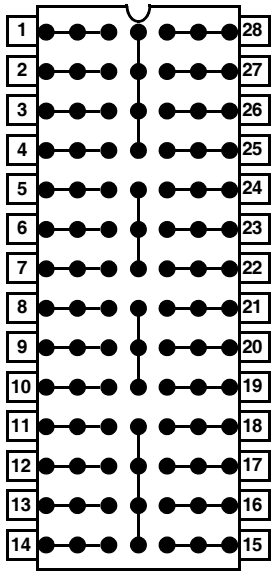
FIGURE 9. SCHEMATIC AND FUNCTIONAL DIAGRAMS OF THE HIP9011 SINGLE-ENDED CONFIGURATION BOARD (HIP9011CONFIG1Z)



HIP9011 DIFFERENTIAL INPUT

†HIP9011 DIFFERENTIAL BOARD NOT SUPPLIED





HIP9011 GENERIC CONFIGURATION BOARD (HIP9011_28DIP1Z)

NOTE: Generic configuration board for end-users custom differential input amplifier designs.

FIGURE 10. SCHEMATIC AND FUNCTIONAL DIAGRAMS OF THE HIP9011 GENERIC CONFIGURATION BOARD (HIP9011_28DIP1Z)

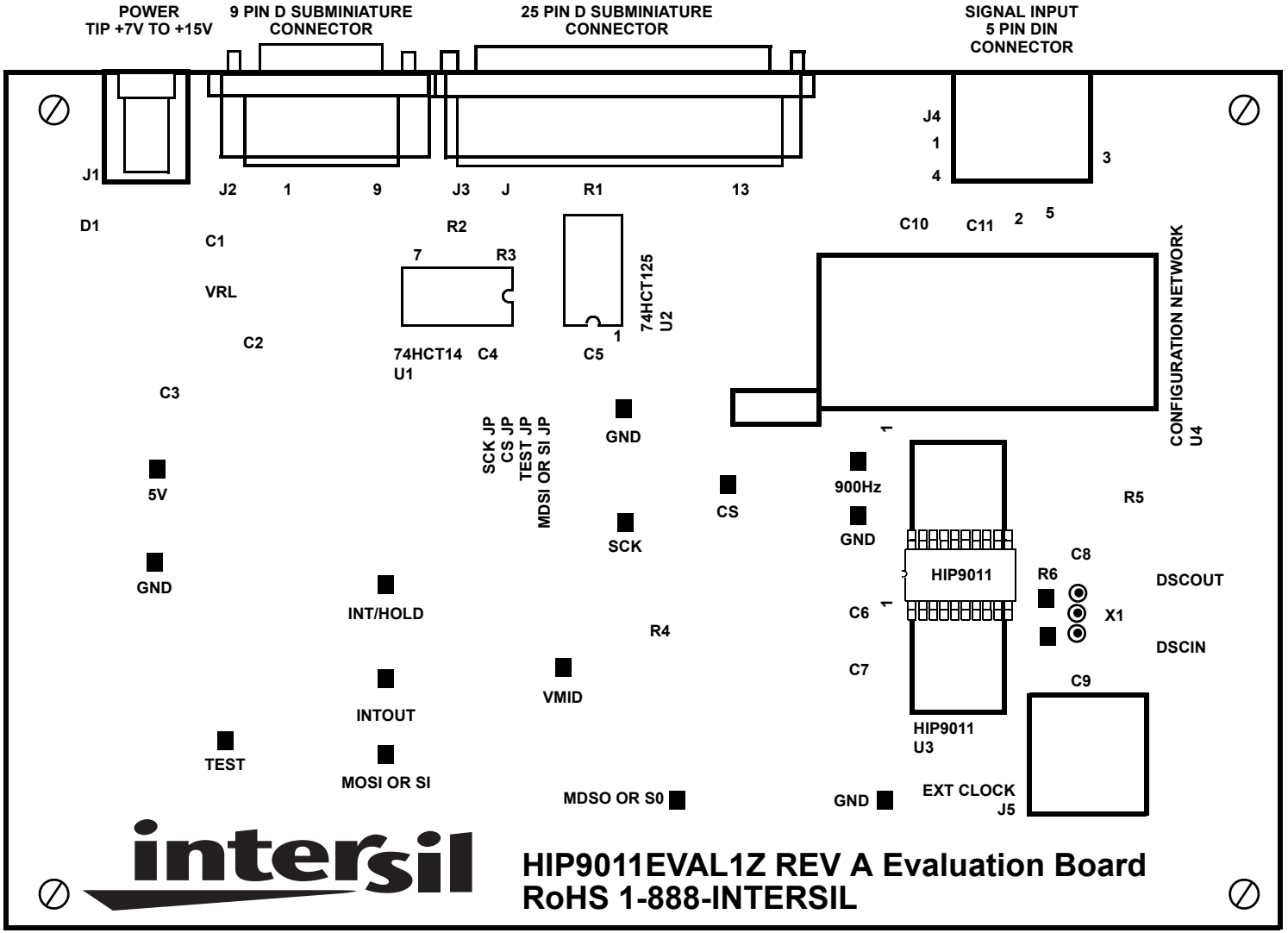


FIGURE 11. HIP9011 EVALUATION BOARD (HIP9011EVAL1Z)

Installing Knock Signal Processor Software in Microsoft® Windows 95® and Windows 98®

1. Download the HIP9011EVAL1Z evaluation board software (HIP9011.exe) from the Intersil website to your computer desktop.
2. To run the software, double-click the HIP9011.exe program icon. Multiple programs can be displayed with different conditions. Double-clicking on the desired program will activate those conditions.

WARNING: Set system font to small. Large fonts will cause the program to be unreadable.

If the INT/$\overline{\text{HOLD}}$ signal from either the pulse generator or the engine is not applied to the Parallel Port of the PC, the PC will lock up when you click on the blocks within the block diagram.

When the system is operating, the computer < > keys will step through each item in the selected window on the block diagram. The function is selected or activated by clicking the left mouse button when the spark plug pointer is on that desired function box. The End and Home keys will take the function to either extreme. Clicking with the pointer on the dots of the channel selection switch will activate that channel. Channel 0 is set to a gain of one and Channel 1 is set to a gain of two, so you can see the INTOUT signal increase when switching from Channel 0 to Channel 1.

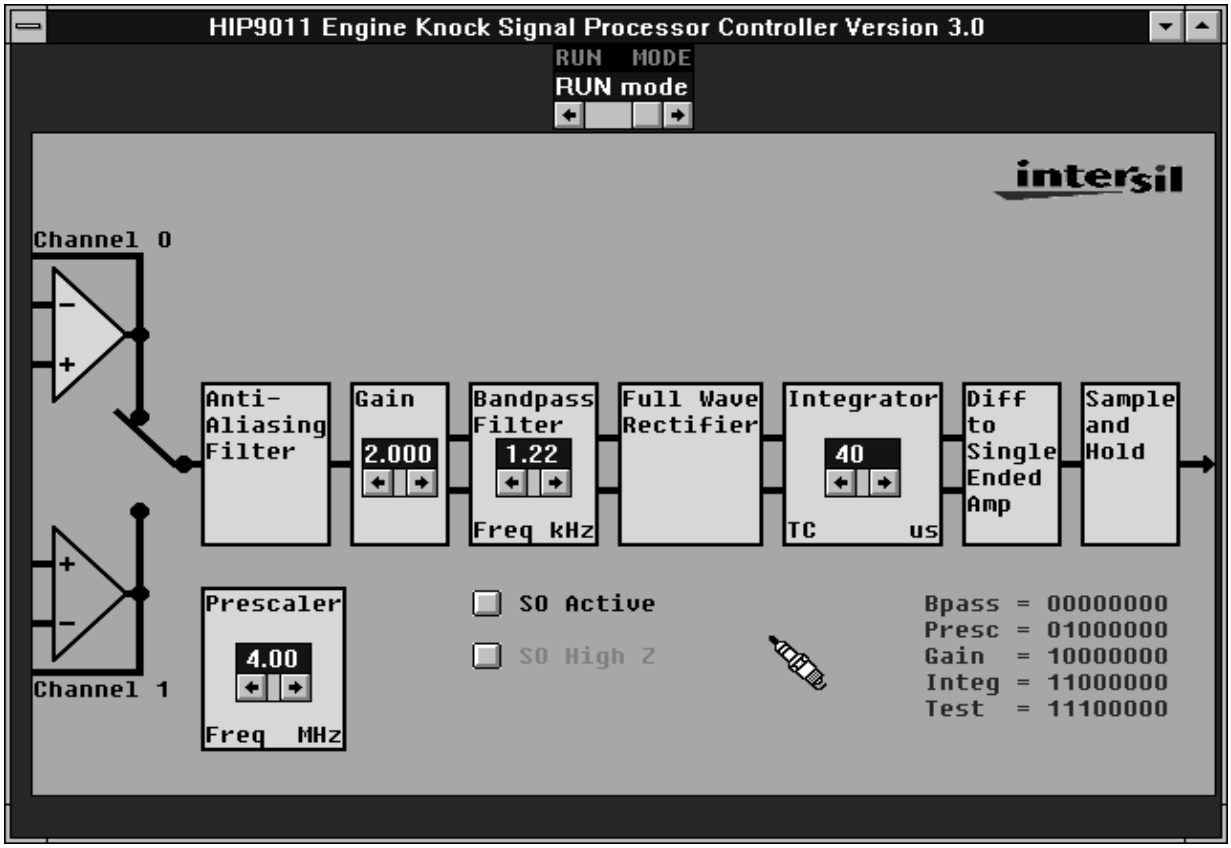
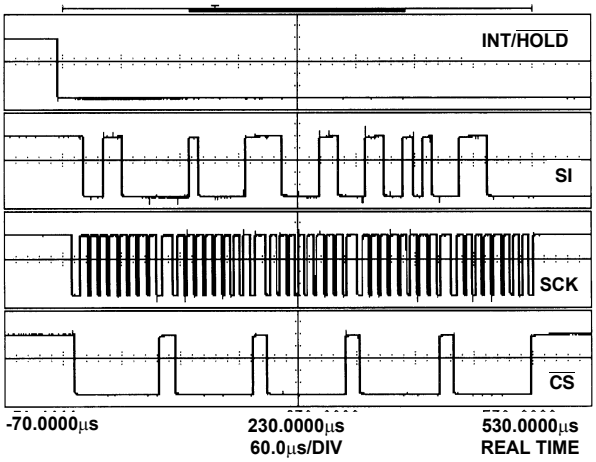


FIGURE 12. HIP9011 DISPLAY ON PC - DISPLAY IS IN COLOR



NOTE: Above display shows all five words written to the HIP9011 by the PC. The following displays show in more detail each of four words for Gain, Filter Frequency, Integrator TC and Prescaler.

FIGURE 13. DATA WRITING SEQUENCE TO THE HIP9011 VIA THE SPI BUS

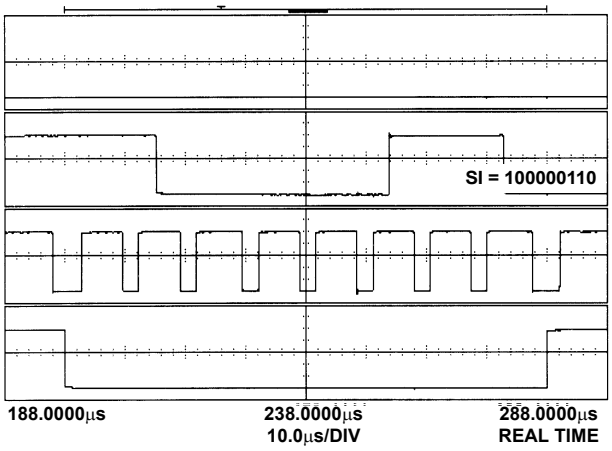


FIGURE 14. WRITING THE GAIN BYTE TO THE HIP9011

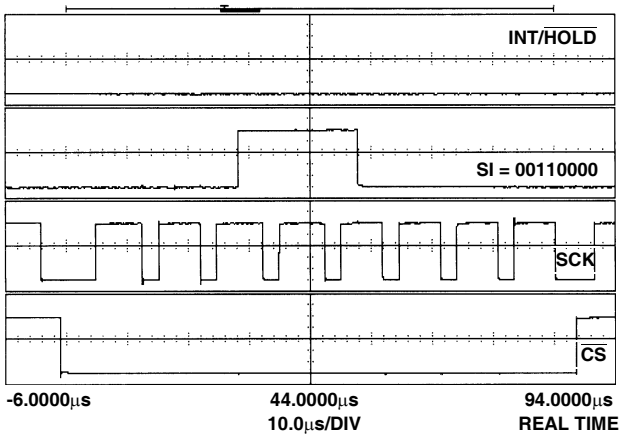


FIGURE 15. WRITING THE BANDPASS BYTE TO THE HIP9011

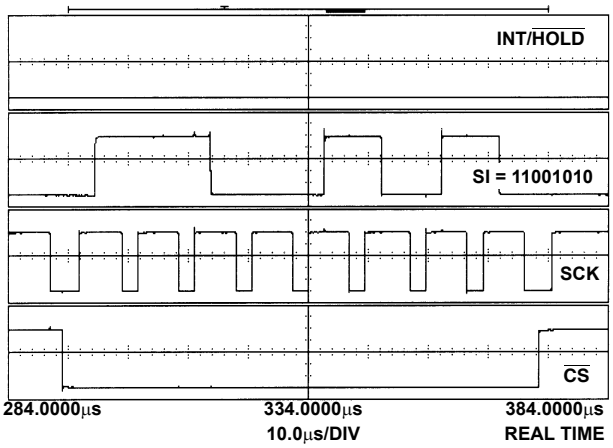


FIGURE 16. WRITING THE INTEGRATOR BYTE TO THE HIP9011

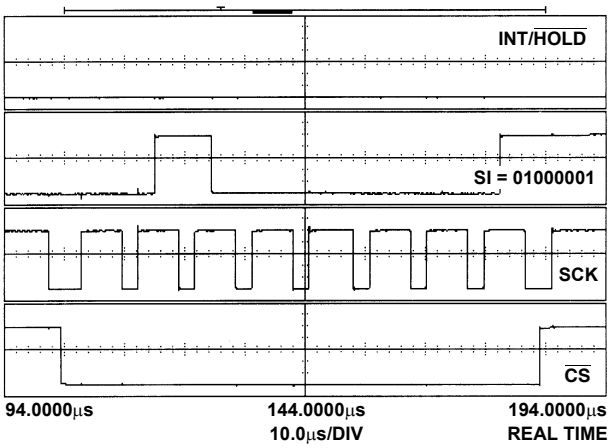


FIGURE 17. WRITING THE PRESCALER BYTE TO THE HIP9011

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
5. Renesas Electronics products are classified according to the following two quality grades: “Standard” and “High Quality”. The intended applications for each Renesas Electronics product depends on the product’s quality grade, as indicated below.

   "Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.

   "High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.

   Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user’s manual or other Renesas Electronics document.
6. When using Renesas Electronics products, refer to the latest product information (data sheets, user’s manuals, application notes, “General Notes for Handling and Using Semiconductor Devices” in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note 1) “Renesas Electronics” as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.

(Note 2) “Renesas Electronics product(s)” means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)

RENESAS

SALES OFFICES

Renesas Electronics Corporation

http://www.renesas.com

Refer to "http://www.renesas.com/" for the latest and detailed information.

Renesas Electronics America Inc.
1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.
Tel: +1-408-432-8888, Fax: +1-408-434-5351

Renesas Electronics Canada Limited
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-651-700, Fax: +44-1628-651-804

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
Room 1709 Quantum Plaza, No.27 ZhichunLu, Haidian District, Beijing, 100191 P. R. China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, 200333 P. R. China
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852 2886-9022

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics India Pvt. Ltd.
No.777C, 100 Feet Road, HAL 2nd Stage, Indiranagar, Bangalore 560 038, India
Tel: +91-80-67208700, Fax: +91-80-67208777

Renesas Electronics Korea Co., Ltd.
17F, KAMCO Yangjae Tower, 262, Gangnam-daero, Gangnam-gu, Seoul, 06265 Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5338

© 2018 Renesas Electronics Corporation. All rights reserved.

Colophon 7.0