Intersil HIP9010/11 Engine Knock Sensing Applications (HIP9010/11EVAL)

Application Note | *November 1999* | AN9770

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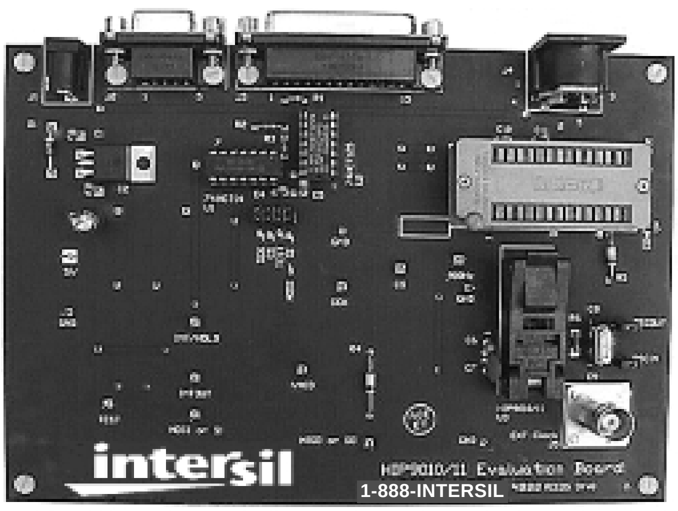
HIP9010/11 Evaluation Board



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 HIP9010 and 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 HIP9010 or HIP9011 in a typical engine application.

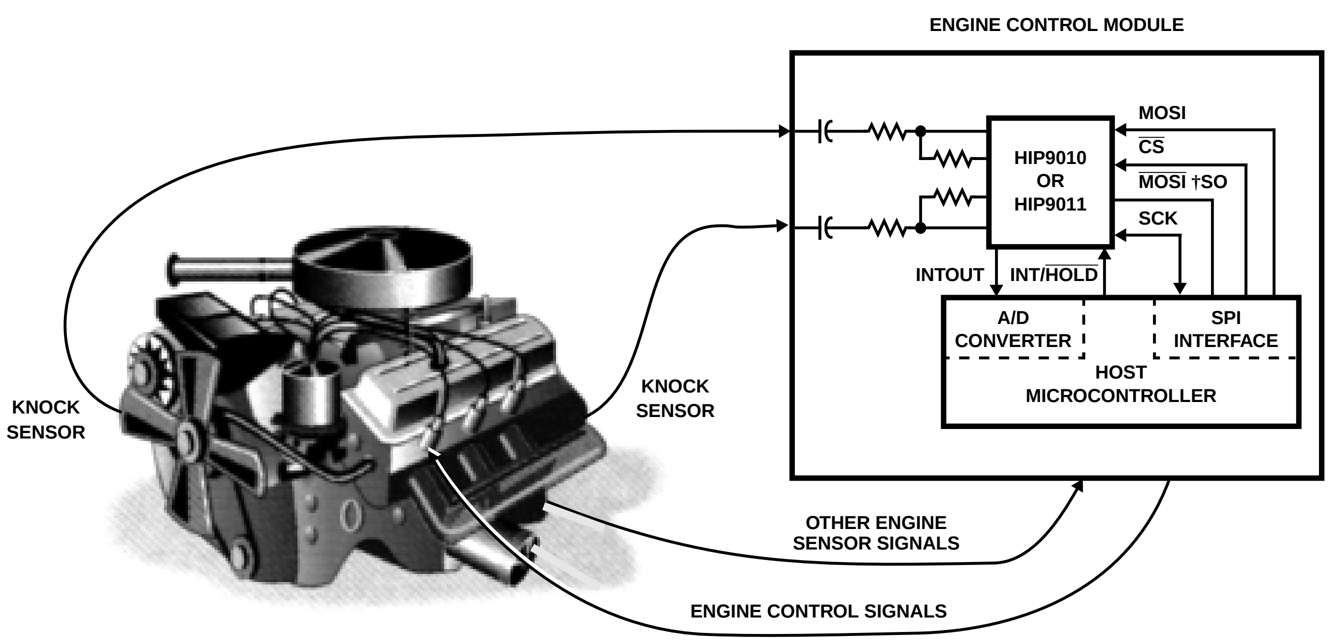


FIGURE 1. HIP9010 OR HIP9011 IN A TYPICAL ENGINE CONTROL APPLICATION

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 HIP9010/11. 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 these ICs to have programmable gain changes at each ignition pulse can help with these configurations. In some high end applications two HIP9010/11 are used.

The input coupling capacitor and series input resistors to the inverting input of the operational amplifiers within the HIP9010 and 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. On the HIP9010, the non-inverting inputs are returned to a mid supply voltage. 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 both devices.

A signal from the engine's microcontroller determines which transducer input signal will be processed by the HIP9010/11 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 HIP9010/11. 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. Two filter channels are provided in the HIP9010, each with a tuning range from 1.22kHz to 19.98kHz, in 64 steps. Serial control signals are sent via the SPI bus to the HIP9010 or HIP9011 by the microcontroller. These control signals set the filter frequencies within these ICs.

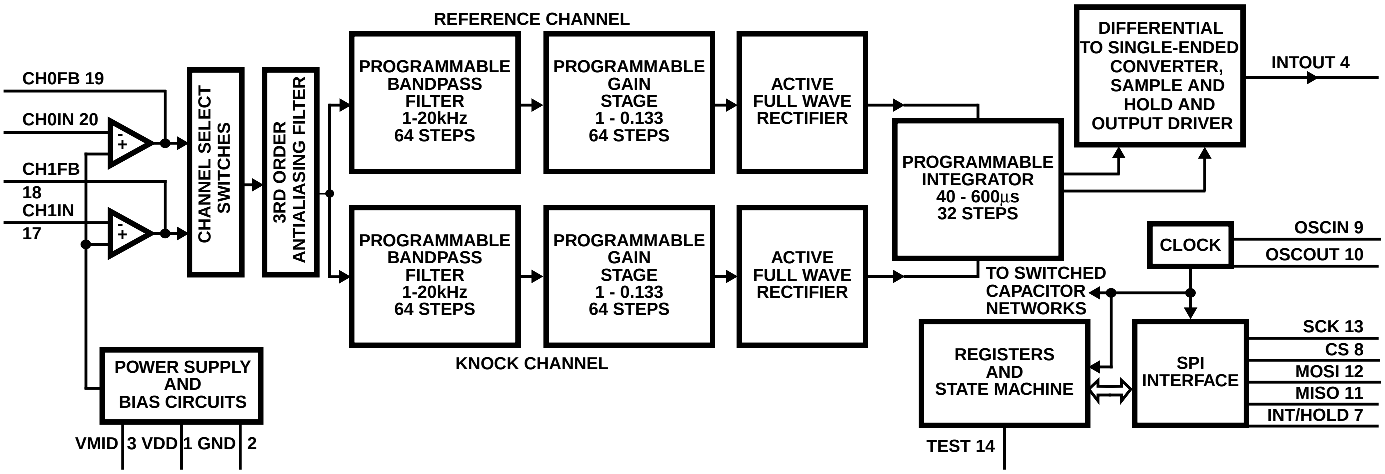


FIGURE 2. SIMPLIFIED BLOCK DIAGRAM OF THE HIP9010, DUAL CHANNEL KNOCK SIGNAL PROCESSING IC

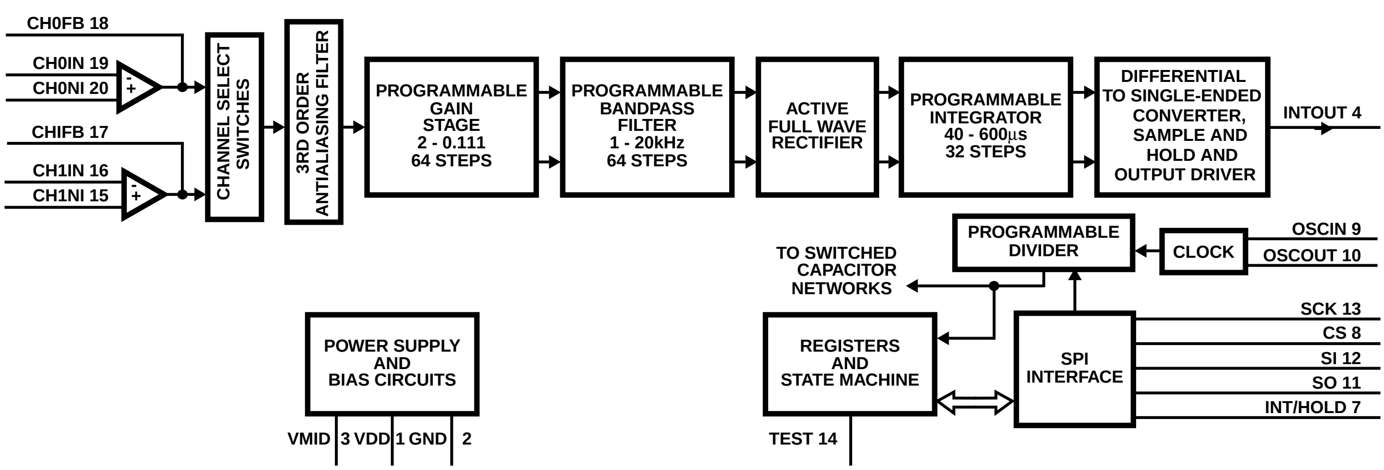


FIGURE 3. SIMPLIFIED BLOCK DIAGRAM OF THE HIP9011, SINGLE CHANNEL KNOCK SIGNAL PROCESSING IC

In both the HIP9010 and HIP9011, outputs from the Filter Stage in the HIP9011 and the Gain Stage in the HIP9010, are 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 0.5V in the HIP9010 and 0.125V in the HIP9011. 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 HIP9010/11's output sample and hold circuit for the microcontroller's A/D converter to process. Figure 2 shows a block diagram of the HIP9010 and Figure 3 shows the block diagram of the HIP9011. Figure 4 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 4. The bottom trace shows the INT/$\overline{\text{HOLD}}$ signal.

HIP9010 Reference Channel

During this discussion, we did not mention the Reference Channel's role in the HIP9010 signal processing. The engines background signal as detected by the knock sensor contains a variety of signals that can add to the output of the integrator. To reduce the effects of these undesirable signals the rectified output of the Reference Channel is used. Signals from this channel result in integration in the negative direction. By setting the filter frequency of the Reference Channel to the undesired signal frequency and setting that channel's gain to a level sufficient to just cancel its contribution to the positive output of the Knock Channel, the effects of the undesired signal can be minimized.

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. Moreover, the HIP9010, has a second channel to further reduce the effects of the undesired engine background noise during the integration interval.

Integrator Operation

Observation of the integrator output signal, INTOUT, is important to the setup and understanding of the operation of these signal processing ICs, This observation can be distorted by instrumentation used to view the INTOUT signal. In Figure 6, 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 signals that only appears during the integration portion of the sample cycle. These signals cause 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 HIP9010/11 is timed so that it only samples during a non pulse period, thus preventing it from acquiring either peaks or valleys.

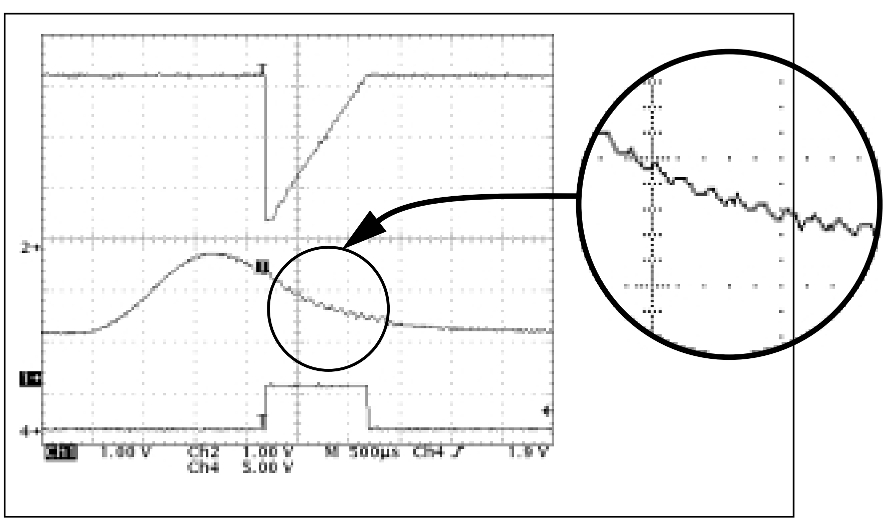


FIGURE 4. WAVEFORMS ASSOCIATED WITH THE HIP9010 AND HIP9011

The lower trace of Figure 6 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 HIP9010/11 before proceeding to an evaluation with an engine, Figure 7 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 that variation of the integrator output, INTOUT, as the IC filter frequency or oscillator frequency is varied from 200Hz to 100kHz. Figure 5 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 8 shows the HIP9010/11 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 9 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 sucessfully used in the board. Three pins are provided on the board to accept resonators to replace the crystal.

Two prewired input amplifier configuration boards are provided with the Evaluation Boards as shown in Figure 10. One board is for the single ended input amplifier of the HIP9010 and the other board is for the differential input HIP9011. Both boards are connected for single ended operation.

Figure 11 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 12 is a top view of the evaluation board.

Software Displays

Figure 13 shows the display for both the HIP9010 and 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.

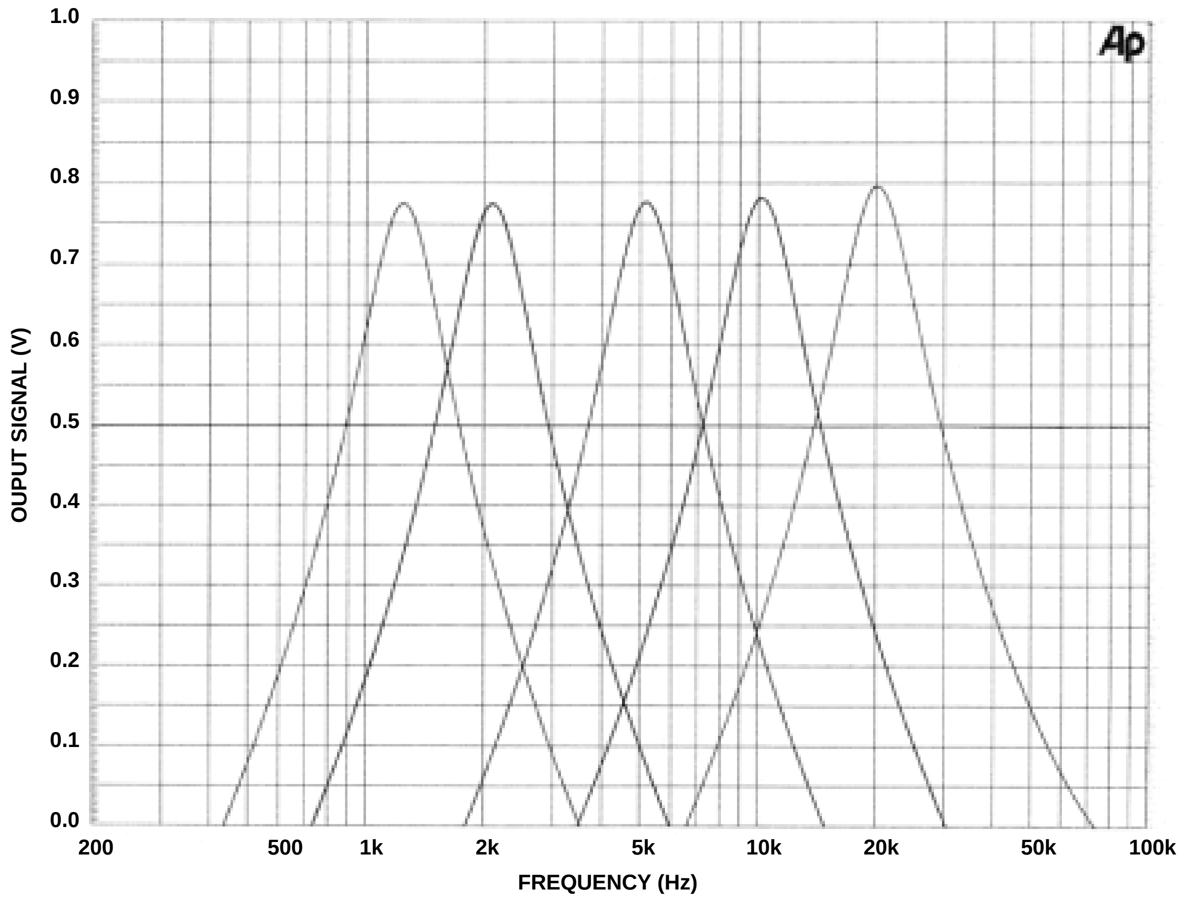


FIGURE 5. RESPONSE OF ONLY THE FILTERS WITHIN THE HIP9010 AND HIP9011

The codes written by the computer for each function is 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 14 through Figure 24 shows the writing sequence to the knock processing IC by the computer for various settings of the knock signal processing ICs.

Open Knock Signal 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 these ICs. 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 either the HIP9010 or the HIP9011 that will enhance the performance of a system using these ICs. First, as mentioned previously, it is suggested that a coupling capacitor be placed inseries with the transducer. This minimizes the possibility of pulling the inverting input of the operational amplifiers within these ICs 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 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 antialiasing filter has sufficient dynamic range. In the HIP9010, the following switched capacitor filter stage reduces the signal amplitude by the filtering process and keeps the signal from saturating the filters, even though these switched capacitor filter stages have a gain of two. In the HIP9011, 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 these two signal processing ICs 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 filters within these devices. 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.

CAPTURED WAVEFORMS

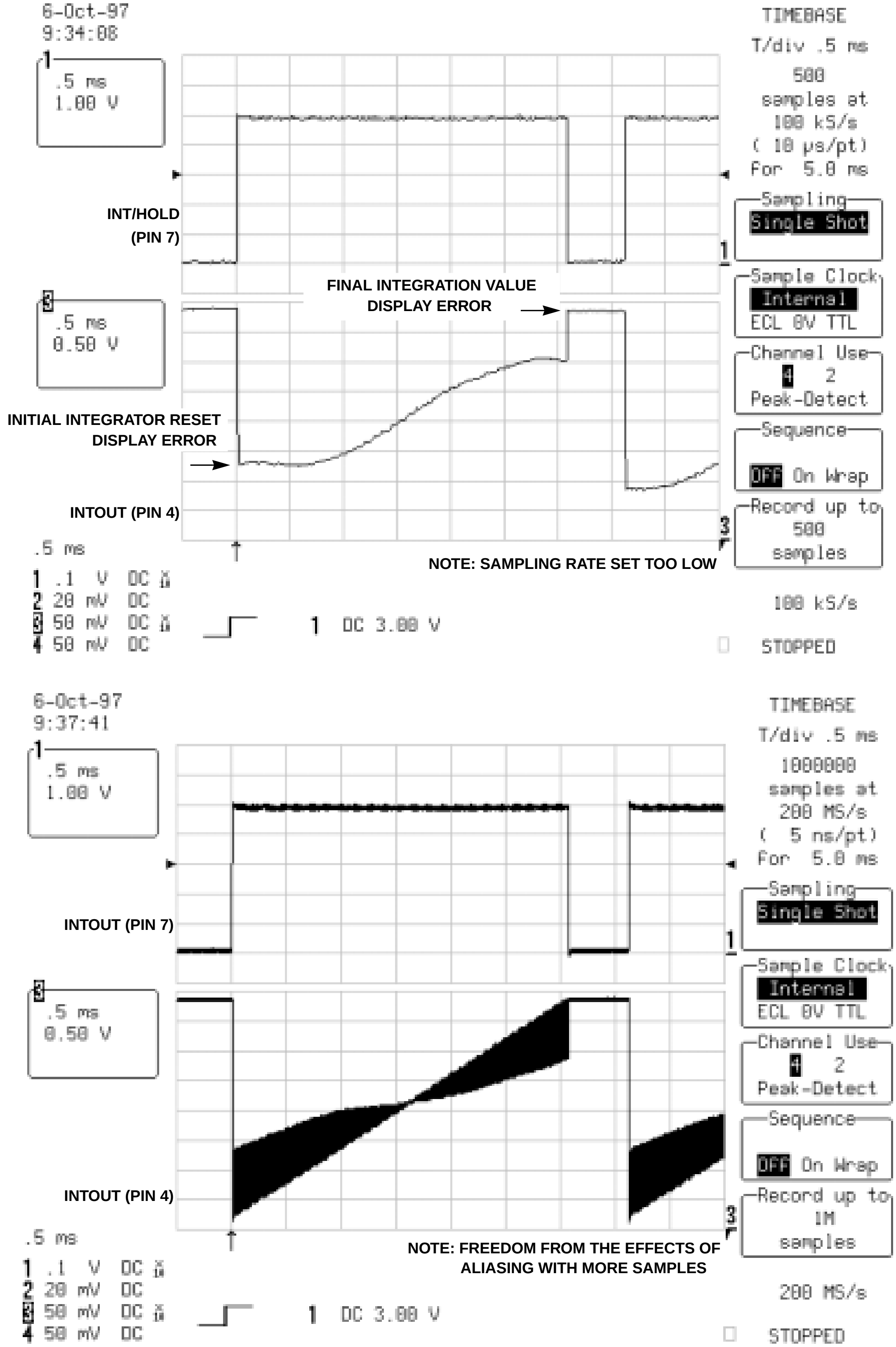


FIGURE 6. INTOUT (PIN 4) OUTPUT WAVEFORM DISPLAY INACCURACIES DUE TO DIGITAL SAMPLING SCOPE SETTINGS

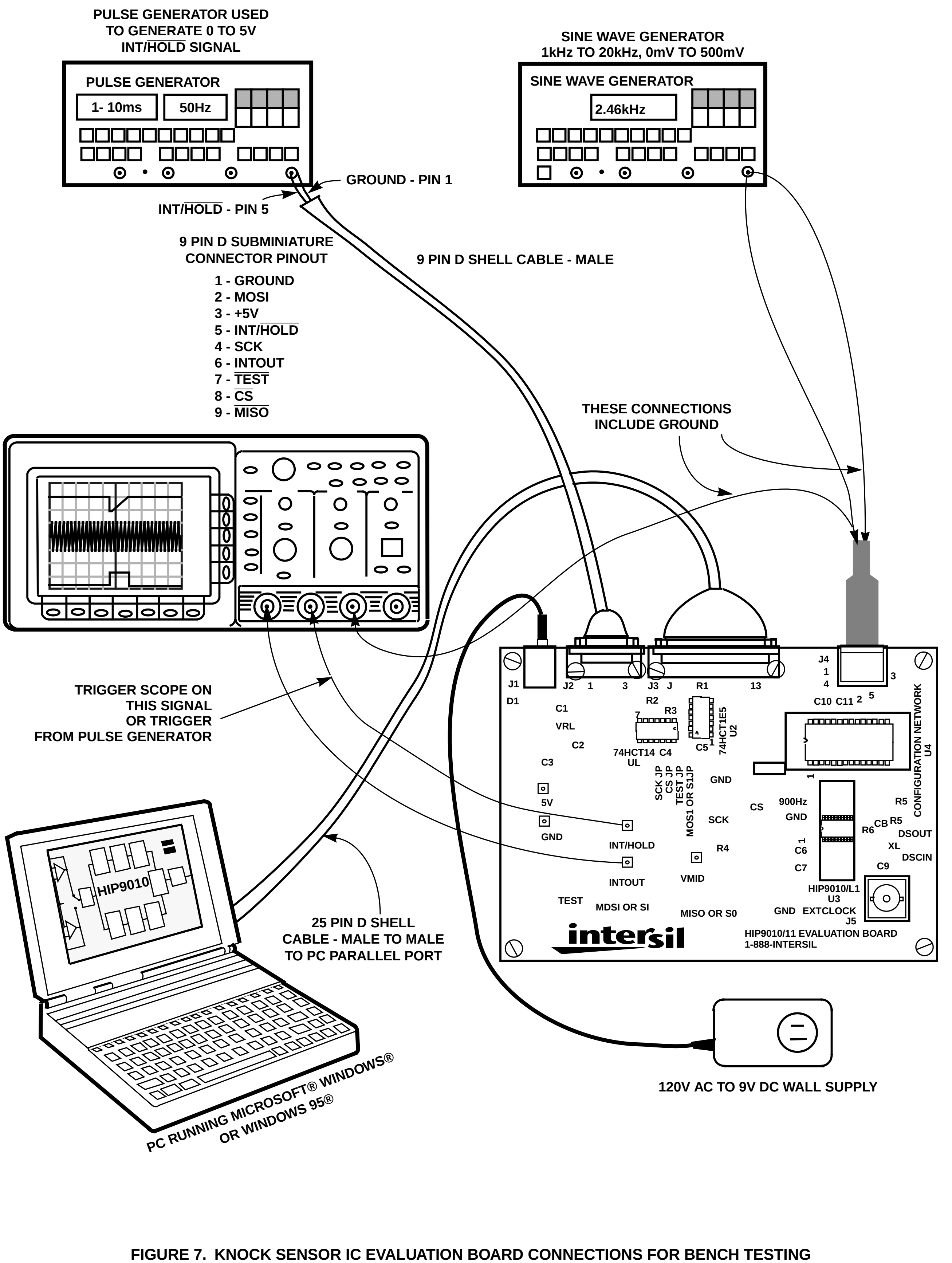


FIGURE 7. KNOCK SENSOR IC EVALUATION BOARD CONNECTIONS FOR BENCH TESTING

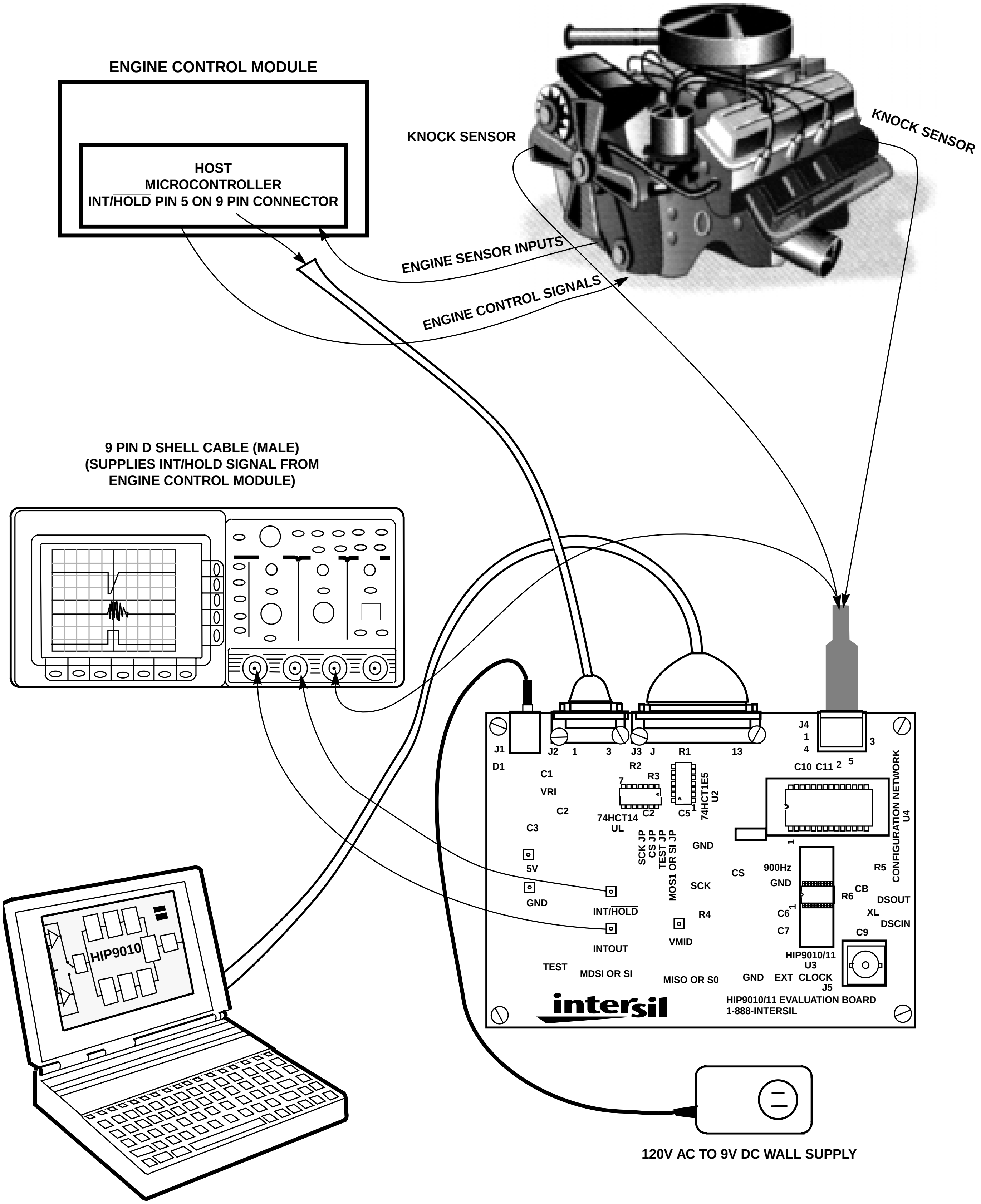


FIGURE 8. KNOCK SENSOR IC EVALUATION BOARD CONNECTIONS FOR TESTING WITH AN ENGINE

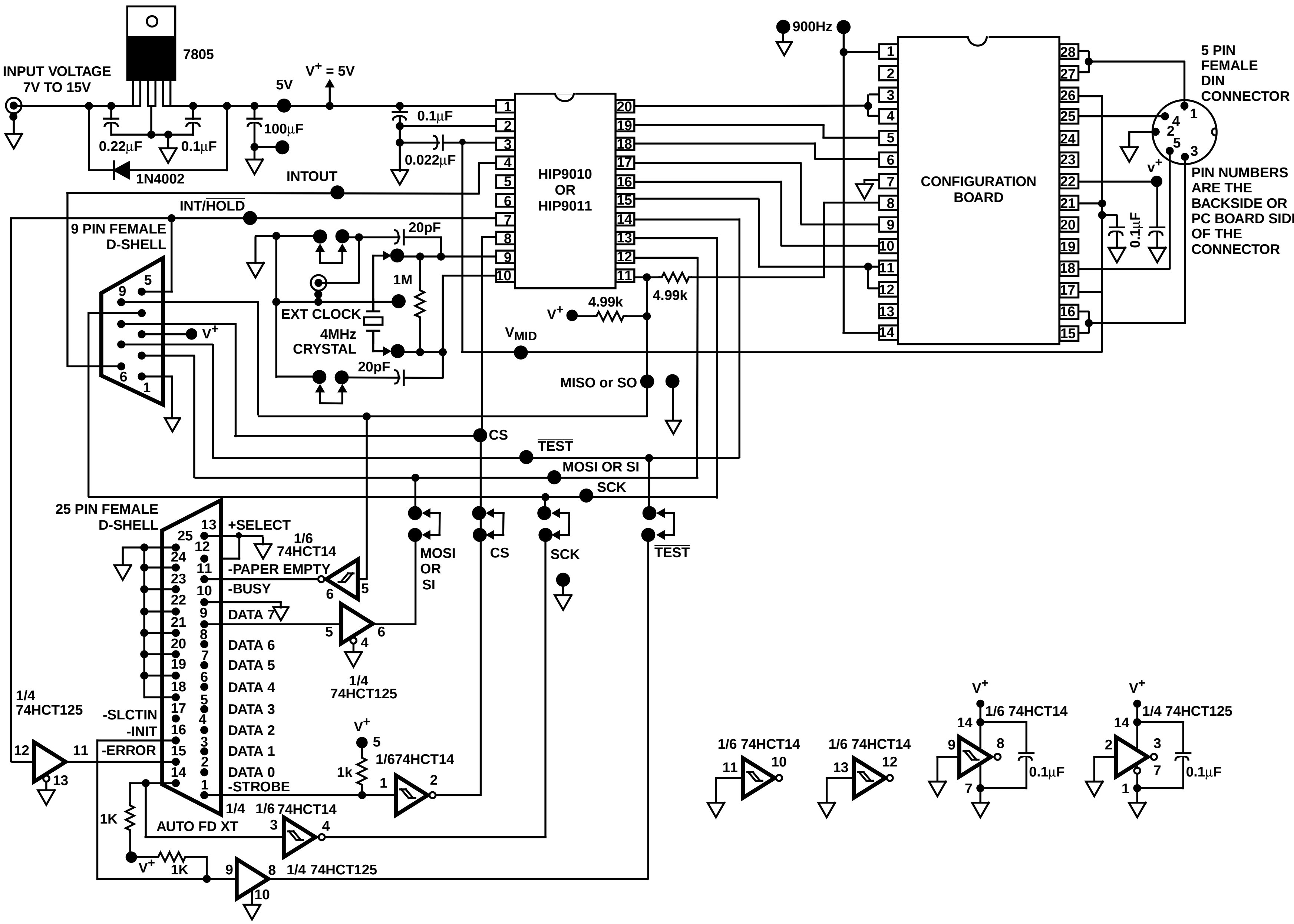


FIGURE 9. HIP9010/HIP9011 EVALUATION BOARD SCHEMATIC DIAGRAM

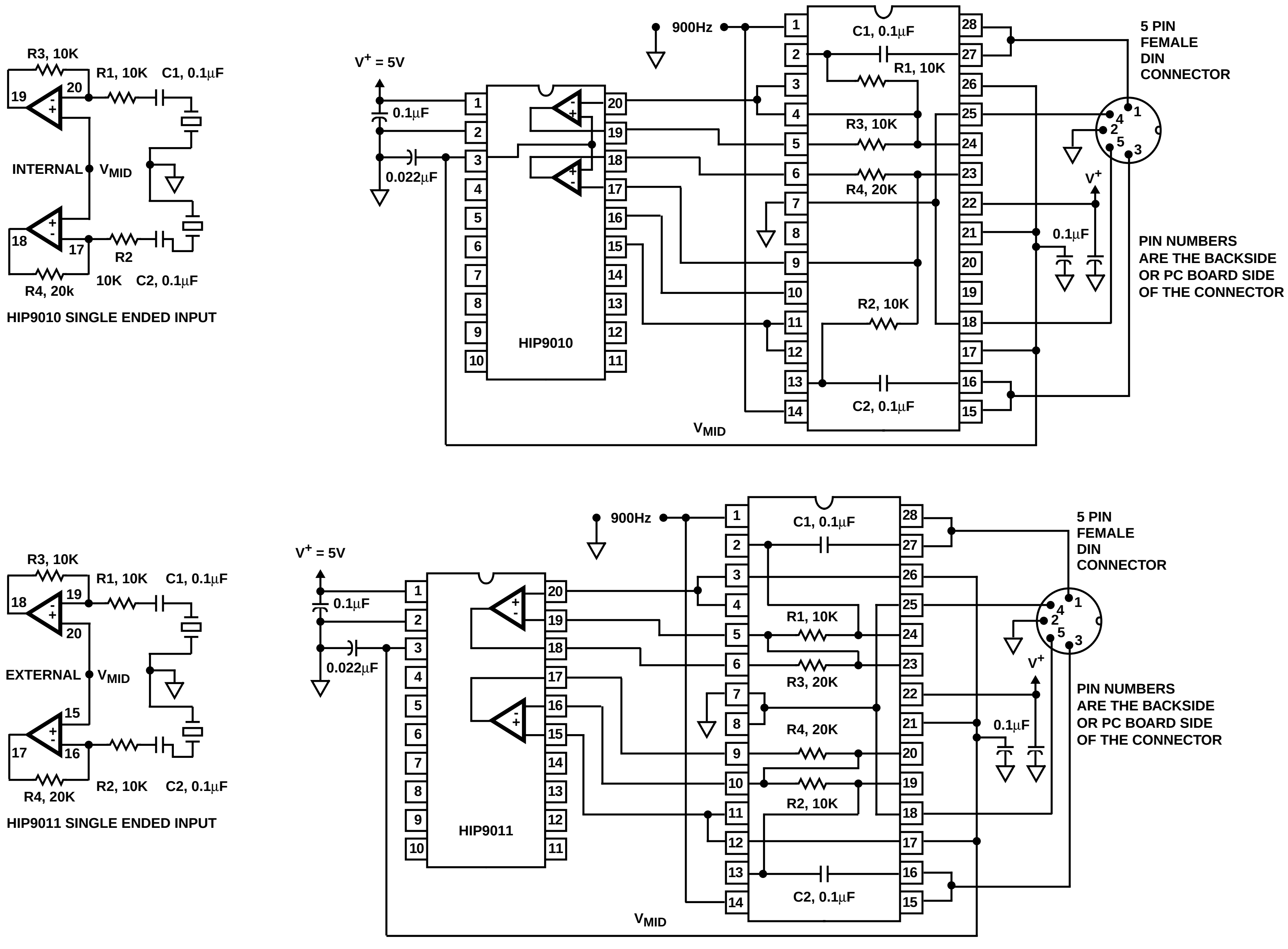
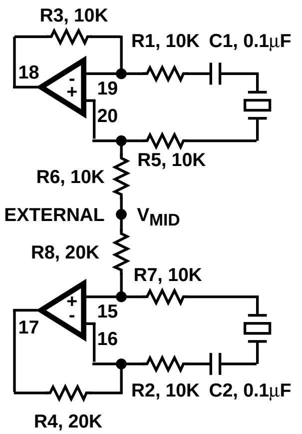
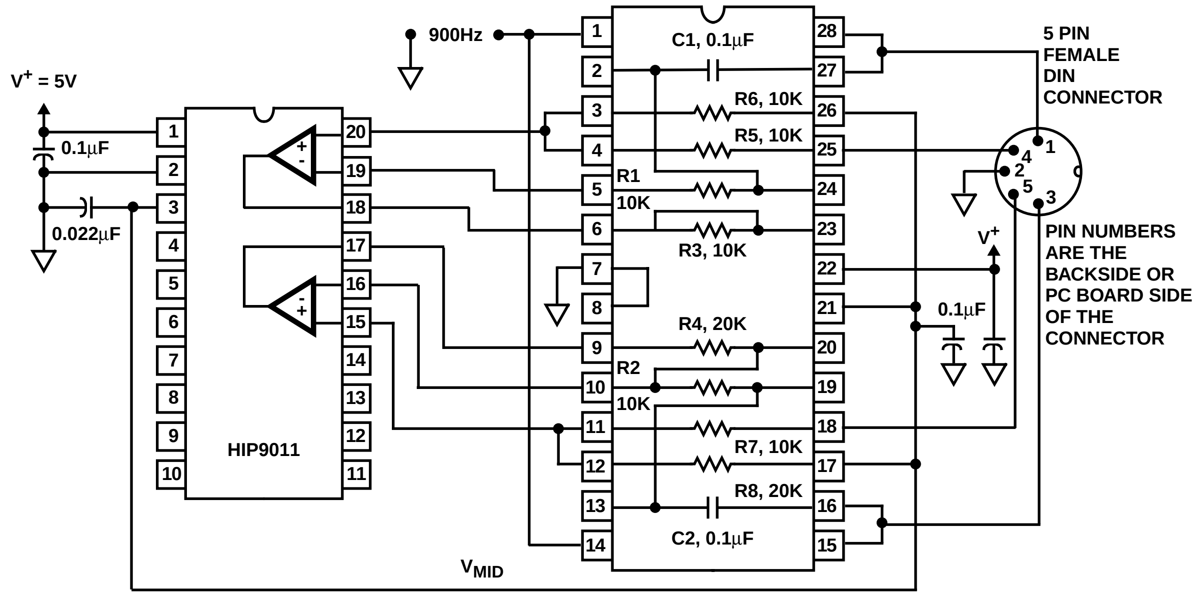


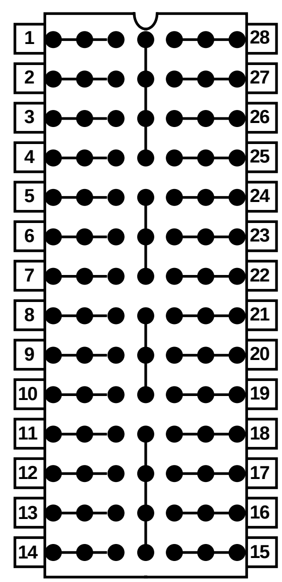
FIGURE 10. SCHEMATIC AND FUNCTIONAL DIAGRAMS OF THE CONFIGURATION BOARDS FOR BOTH THE HIP9010 AND THE HIP9011



HIP9011 DIFFERENTIAL INPUT

†HIP9011 DIFFERENTIAL BOARD NOT SUPPLIED





GENERIC CONFIGURATION BOARD

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

FIGURE 11. SCHEMATIC AND FUNCTIONAL DIAGRAMS OF THE CONFIGURATION BOARDS FOR BOTH THE HIP9010 AND THE HIP9011

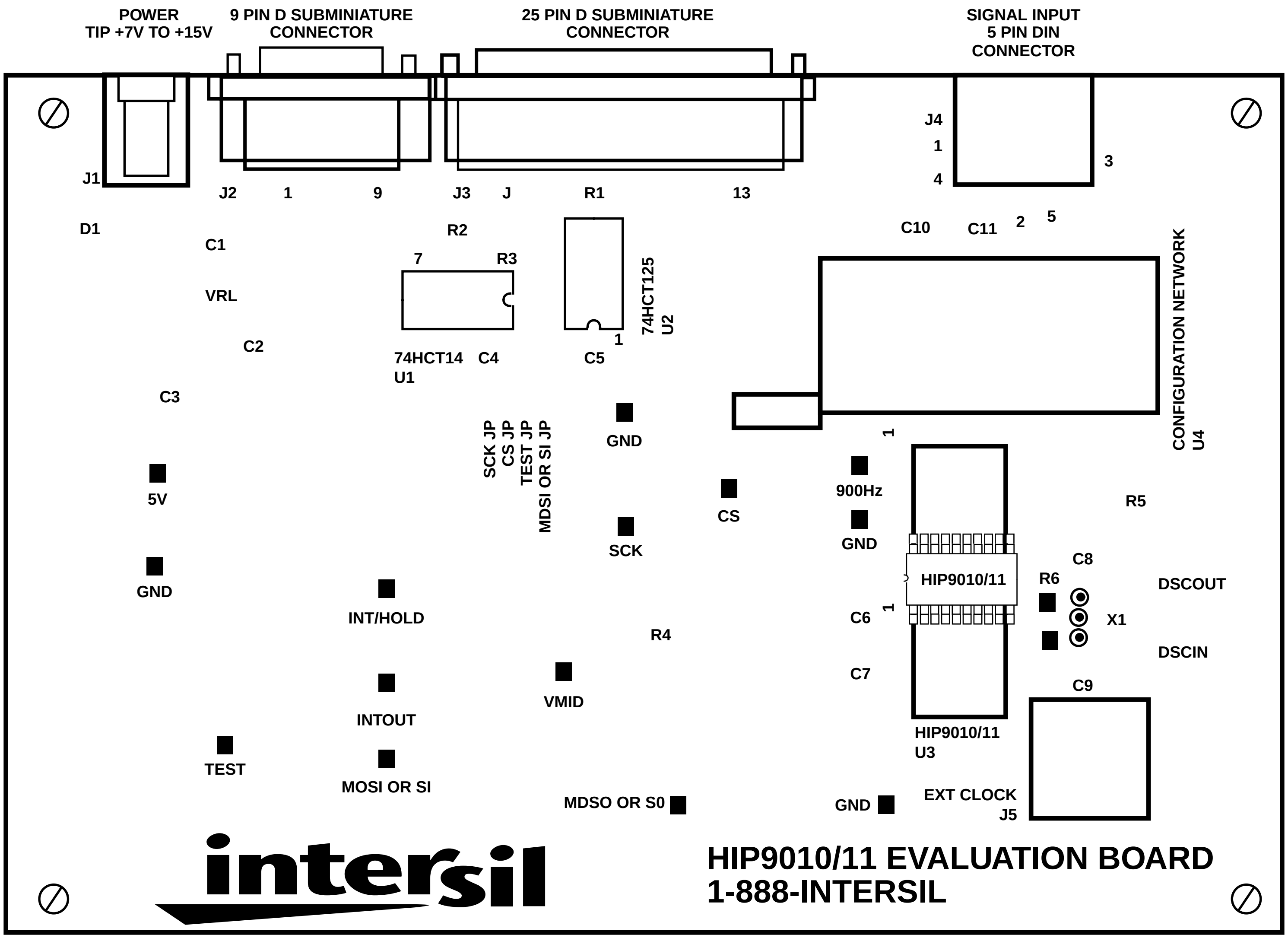


FIGURE 12. HIP9010/11 EVALUATION BOARD

Installing Knock Signal Processor Software

Installing Knock Signal Processing Software in Microsoft® Windows 3.0® or Microsoft® Windows 3.1®

1. Make one directory on the hard-drive named Knock. Copy the contents of floppy disk into the directory you made on the hard-drive.
2. Open Microsoft® Windows 3.0® or Microsoft® Windows 3.1®
3. In the Program Manager:
   Pull down the File menu
   Choose New
4. New Program Object window will appear
   (Note) Choose Program Group
   Click OK
5. Program Group Properties window will appear
   Description: (type) Knock Processors
   Group File: (leave blank)
   Click OK
   A Window will open called Knock Processor
6. In the Program Manager:
   Pull down the File menu
   Choose New
7. New Program Object window will appear
   (Note) choose Program Item
   Click OK
8. Program Item Properties window will appear
   Description: (type) 9010 Knock Processor
   Command Line: (type) c:\knock\9010.exe
   Working Directory: (leave blank)
   Shortcut Key: (leave blank)
   Click OK
9. In the Program Manager:
   Pull down the File menu
   Choose New
10. New Program Object window will appear
    (Note) choose Program Item
    Click OK
11. Program Item Properties window will appear
    Description: (type) 9011 Knock Processor
    Command Line: (type) c:\knock\9011.exe
    Working Directory: (leave blank)
    Shortcut Key: (leave blank)
    Click OK

Car icons should appear in the Knock Processors Group Box/window. Clicking on these icons should bring up the block diagram of the HIP9010 or HIP9011. Reference Figure 8.

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.

This should get you started.

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

1. Insert the HIP9010/11 EVALUATION BOARD SOFTWARE 3.5 inch.floppy disk into your computer.
2. Double-click the My Computer icon that is on your computer desktop.
3. A window appears with disk drive icons. Double-click on the disk drive that has the HIP9010/11 software.
4. Another window appears with two programs listed. Copy the two programs by dragging their icons from the window over to the desktop.
5. The two programs are now on your desktop ready to use. Close the windows opened for transferring the programs and remove the floppy disk from the floppy disk drive.
6. To run the programs, double-click on either of the two program icons. 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.

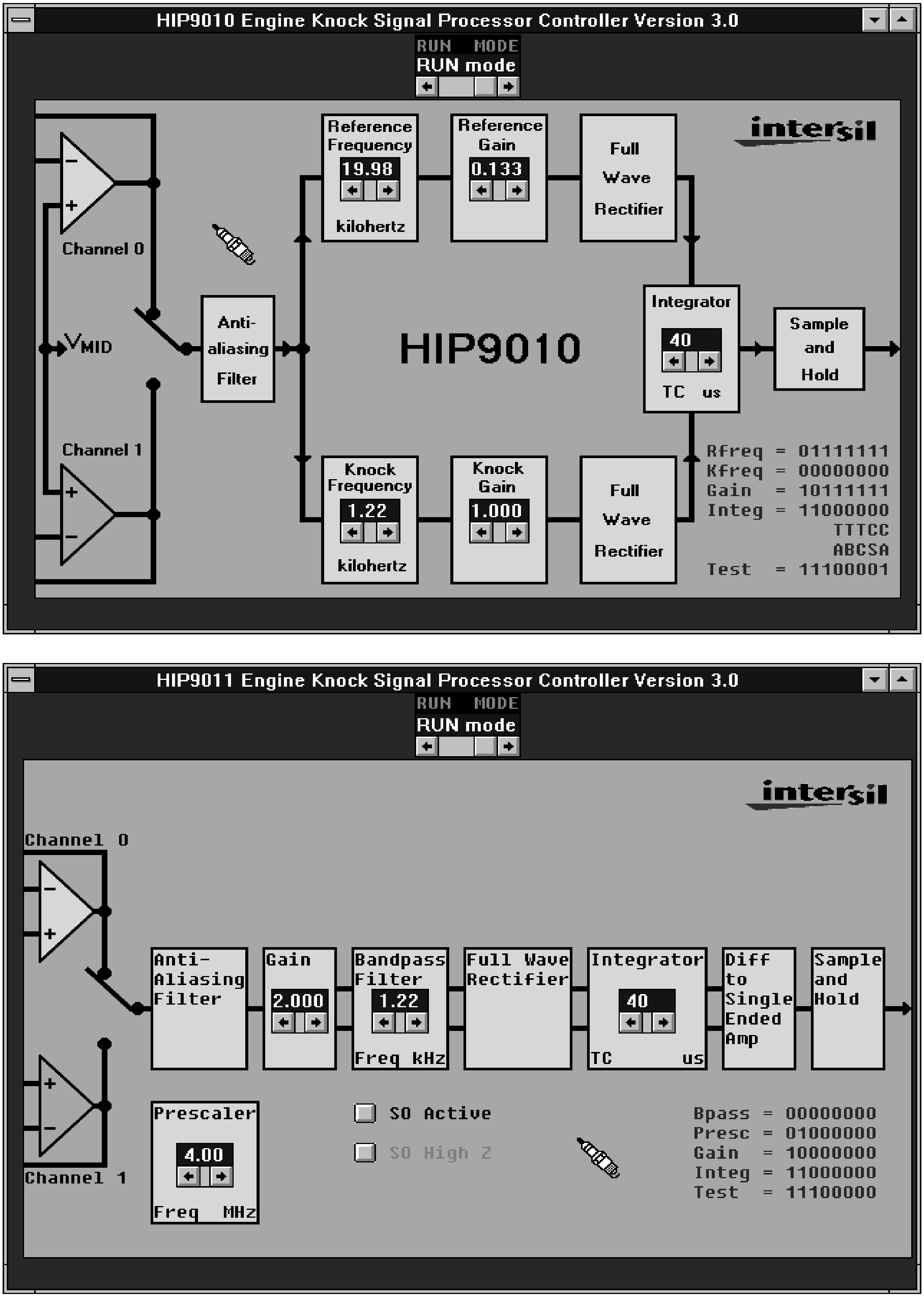
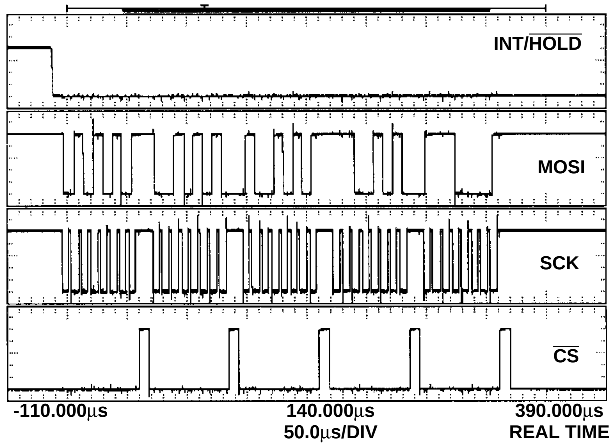


FIGURE 13. HIP9010 AND HIP9011 DISPLAYS ON PC - DISPLAYS ARE IN COLOR



NOTE: Run mode is as follows: Input Channel = 0, Reference Frequency = 2.92kHz, Knock Frequency = 7.27kHz, Reference Gain = 0.497, Integrator T_C = 100µs.

FIGURE 14. DATA WRITING SEQUENCE TO THE HIP9010 VIA THE SPI BUS

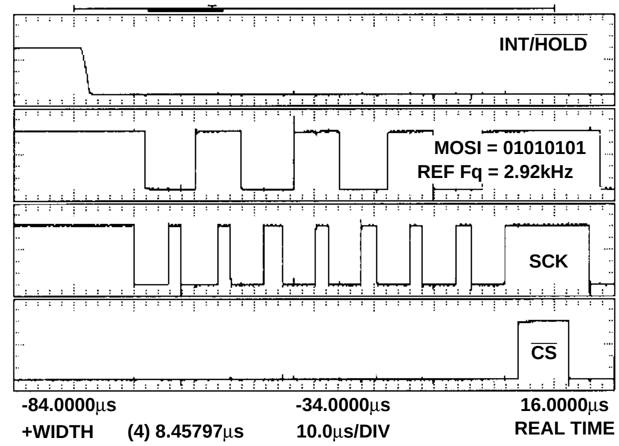


FIGURE 15. WRITING THE REFERENCE FREQUENCY BYTE TO THE HIP9010

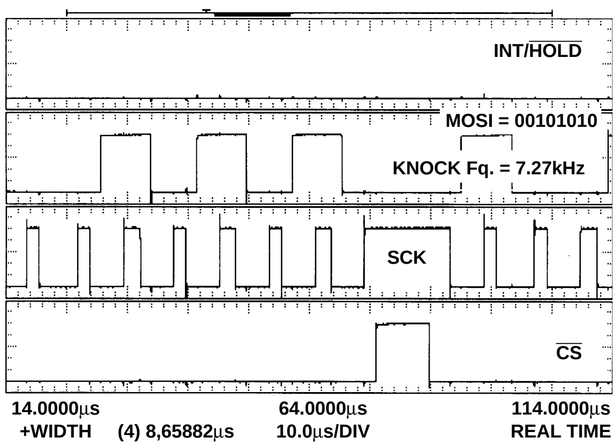


FIGURE 16. WRITING THE KNOCK FREQUENCY BYTE TO THE HIP9010

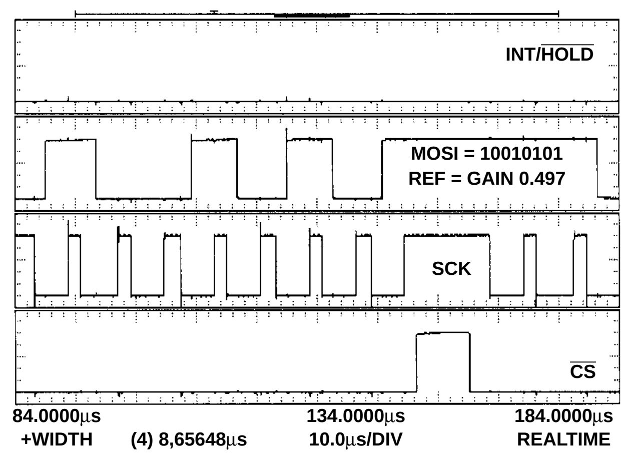


FIGURE 17. WRITING THE REFERENCE GAIN BYTE TO THE HIP9010

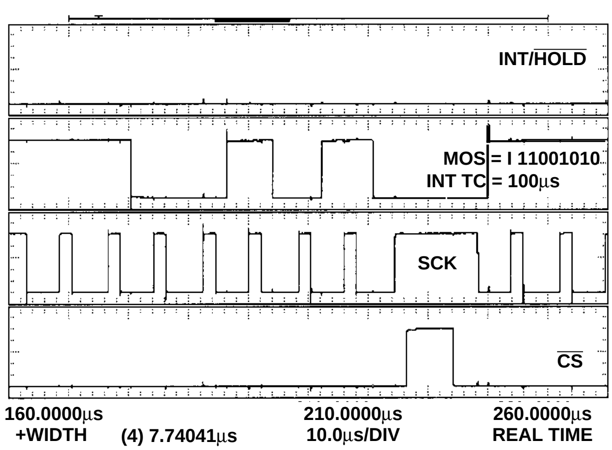


FIGURE 18. WRITING THE INTEGRATOR TC BYTE TO THE HIP9010

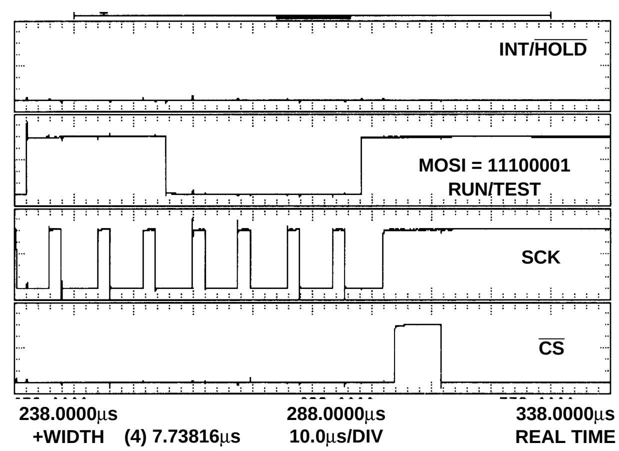
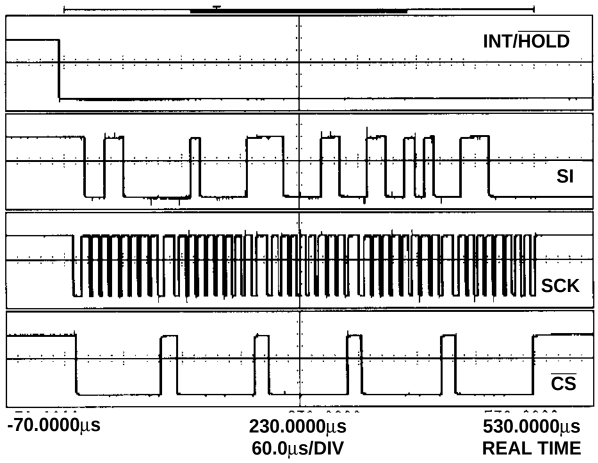


FIGURE 19. WRITING THE RUN/TEST BYTE TO THE HIP9010



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 20. DATA WRITING SEQUENCE TO THE HIP9011 VIA THE SPI BUS

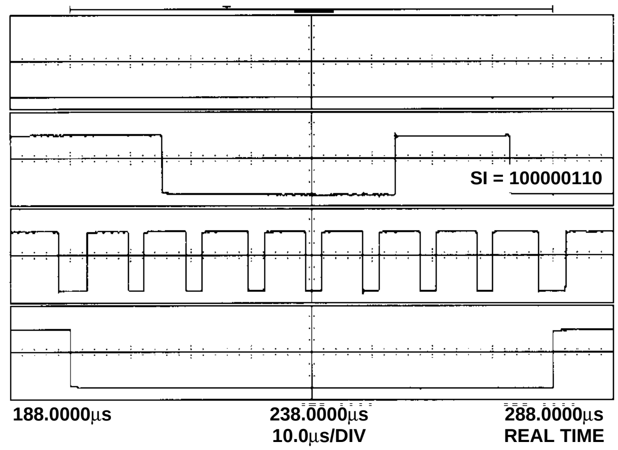


FIGURE 21. WRITING THE GAIN BYTE TO THE HIP9011

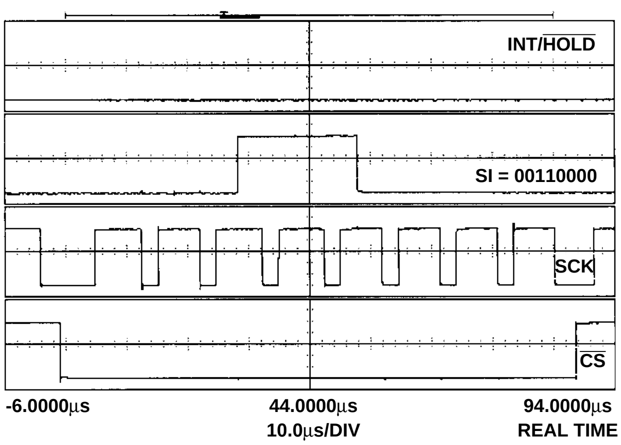


FIGURE 22. WRITING THE BANDPASS BYTE TO THE HIP9011

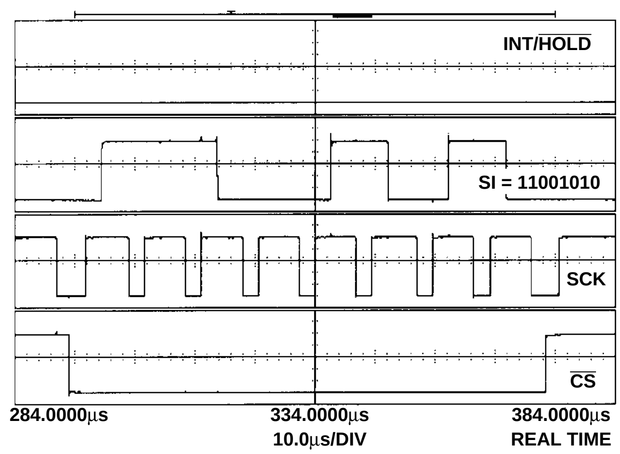


FIGURE 23. WRITING THE INTEGRATOR BYTE TO THE HIP9011

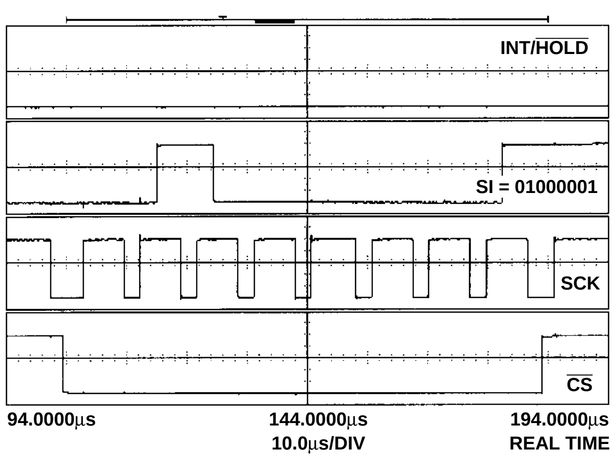


FIGURE 24. WRITING THE PRESCALER BYTE TO THE HIP9011

Sales Office Headquarters

NORTH AMERICA
Intersil Corporation
P. O. Box 883, Mail Stop 53-204
Melbourne, FL 32902
TEL: (321) 724-7000
FAX: (321) 724-7240

EUROPE
Intersil SA
Mercure Center
100, Rue de la Fusee
1130 Brussels, Belgium
TEL: (32) 2.724.2111
FAX: (32) 2.724.22.05

ASIA
Intersil (Taiwan) Ltd.
7F-6, No. 101 Fu Hsing North Road
Taipei, Taiwan
Republic of China
TEL: (886) 2 2716 9310
FAX: (886) 2 2715 3029