Evaluation Board Documentation
ADE7758 Energy metering IC

Preliminary Technical Data — EVAL-ADE7758EB

FEATURES

Evaluation Board is designed to be used together with accompanying software to implement a fully functional Three-Phase Energy Meter (Watt-Hour Meter).

Easy connection of various external transducers via screw terminals.

Easy modification of signal conditioning components using PCB sockets.

LED indicators on logic outputs CF, VARCF, and IRQ.

Optically isolated data output connection to PC parallel port.

Optically isolated frequency output (CF) to BNC.

External Reference option available for on-chip reference evaluation.

GENERAL DESCRIPTION

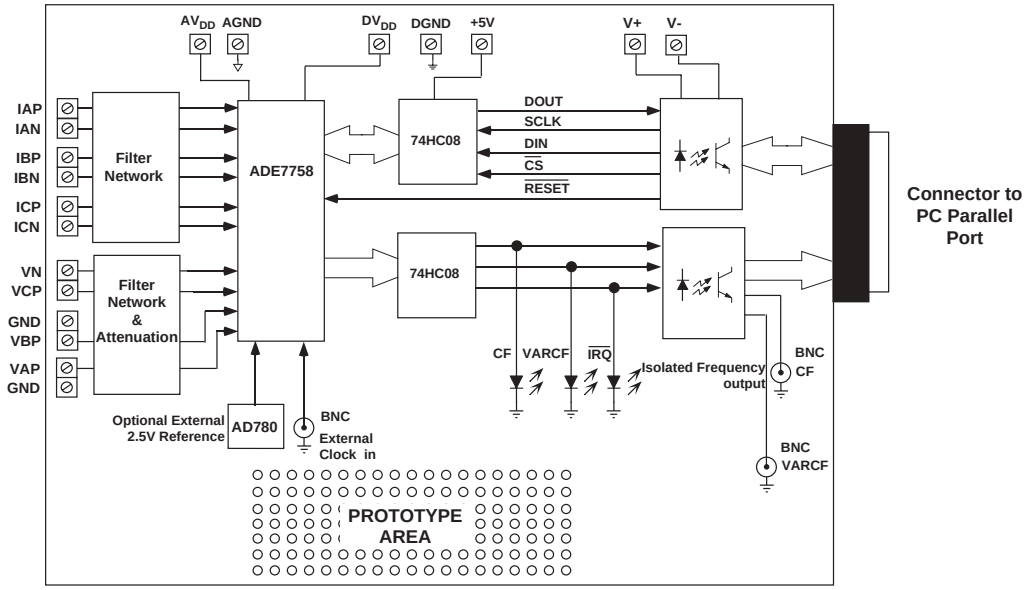
The ADE7758 is high accuracy electrical active power measurement ICs for three-phase applications with a pulse output. This output is intended to be used for calibration purposes. The ADE7758 incorporate ADCs, reference circuitry, and all the signal processing required to perform energy measurement.

The ADE7758 provides per phase Active, Reactive, and Apparent Energy information, RMS values, and temperature measurement via a serial interface. This documentation describes the ADE7758 evaluation kit Hardware and Software functionality. The evaluation board (watt-hour meter) is configured via the parallel port of a PC. The data interface between the evaluation board and the PC is fully isolated. Windows™ based software is provided with the evaluation board which allows it to be quickly configured as an energy meter.

The ADE7758 evaluation board and this documentation, together with the ADE7758 data sheet provide a complete evaluation platform for the ADE7758.

The evaluation board has been designed so that the ADE7758 can be evaluated in the end application, i.e., Watt-Hour Meter. Using the appropriate transducers on the current channel (e.g., CT) the evaluation board can be connected to a test bench or high voltage (240V rms) test circuit. On-board resistor dividers networks provide the attenuation for the line voltages. This application note also describes how the current transducers should be connected for the best performance. The evaluation board requires two external 5V power supplies (one is required for isolation purposes) and the appropriate current transducers.

FUNCTIONAL BLOCK DIAGRAM



REV. PrB 08/03

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ANALOG INPUTS (P4, P5, P6, P7, P8 AND P11)

Voltage and current signals are connected at the screw terminals P4-P6 and P7-P8 and P11 respectively. All analog input signals are filtered using the on-board anti-alias filters before being presented to the analog inputs of the ADE7758. The default component values which are shipped with the evaluation board are the recommended values to be used with the ADE7758. The user can easily change these components, however this is not recommended unless the user is familiar with sigma-delta converters and also the criteria used for selecting the component values for the analog input filters - *See ADE7758 datasheet.*

Current sense inputs (P4, P5 and P6)

P4, P5 and P6 are two-way connection blocks which allow ADE7758's current inputs of phase A, B and C respectively to be connected to current transducers. Figure 1 shows the connector P4 and the filtering network which is provided on the evaluation board.

The resistors SH1A, SH2A, SH1B, SH2B, SH1C and SH2C are by default not populated. They are intended to be used as burden resistors when CTs are used as the current transducers—*see using a CT as a the current transducer*.

The RC networks R9/C5, R7/C8, R15/C9, R13/C12, R21/C13, R19/C16 are used to provide phase compensation when a Current Transformer is being used as the current transducer with the ADE7758—see using a Current Transformer as the current transducer. These RC networks are easily disabled by placing JP4, JP1, JP10, JP7, JP16 & JP13 and removing C5, C8, C9, C12, C13 and C16 (socketed).

The RC networks R10/C6, R8/C7, R16/C10, R14/C11, R22/C14 and R20/C15 are the anti-alias filters which are required by the on-chip ADCs. The default corner frequency for these LPFs (Low Pass Filters) is selected as 4.8kHz (1kΩ & 33nF). These filters can easily be adjusted by replacing the components on the evaluation board. However before adjusting the component values the user should first review the ADE7758 datasheet.

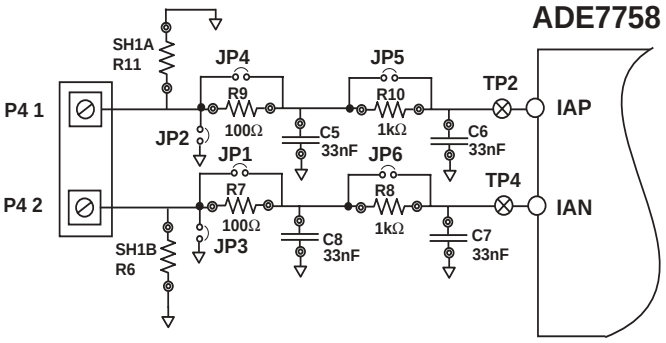


Figure 1 — Current Channel on the ADE7758 evaluation board

Using a CT as the current transducer

Figure 2 shows how a CT can be used as a current transducer in one phase of a 3-phase 4-wire distribution system (Phase A). In a three phase distribution system Phase A, Phase B and Phase C are nominally 120° phase difference to each other. Each phase usually requires a connection of this type for current sensing.

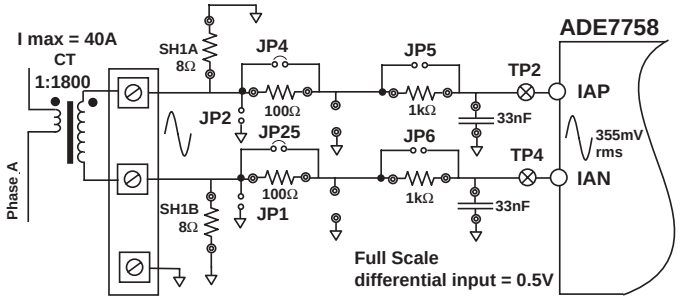


Figure 2 — CT connection to Current Channel

The CT secondary current is converted to a voltage by using a burden resistance across the secondary winding outputs. Care should be taken when using a CT as the current transducer. If the secondary is left open, i.e., no burden is connected, a large voltage could be present at the secondary outputs. This can cause an electrical shock hazard and potentially damage electronic components.

Warning!

Using a CT without a burden resistor can lead to electrical shock.

The anti-alias filters should be enabled by opening jumpers JP5, JP6, JP11, JP12, JP17 and JP18—see Figure 2.

Most CTs will have an associated phase shift of between 0.1° and 1° at 50Hz/60Hz. This phase shift or phase error can lead to significant energy measurement errors, especially at low power factors. However this phase error can be corrected by writing to the Phase Calibration registers (APHCAL, BPHCAL and CPHCAL) in the ADE7758. The software supplied with the ADE7758 evaluation board allows user adjustment of the Phase Calibration register. See the *Evaluation Software Description* for more information.

For this example, notice that the maximum analog input range on the Current channel is set to 0.5V.

When using the ADE7758, the Gain for Current channel has been set to 1. The maximum analog input range and gain are set via the Gain register (GAIN)—*see the ADE7758 data sheet*. The evaluation software allows the user to configure the current channel gain. This means that the maximum peak differential signal on the current channel is 0.5V.

Voltage sense inputs (P7, P8 and P11)

The voltage inputs connections on the ADE7758 evaluation board can be directly connected to the line voltage sources. The line voltages are attenuated using a simple resistor divider network before it is presented to the ADE7758. The attenuation network on the voltage channels is designed such that the corner frequency (3dB frequency) of the network matches that of the RC (anti-aliasing) filters on the current channels inputs. This is important, because if they do not match there will be large errors at low power factors.

The Serial interface along with the digital parameters of the ADE7758 enable a fully software calibration procedure. In this case, the voltage attenuation networks are made up of R48, R49 and R47 for Phase A, R45, R46 and R44 for Phase B and R41, R42 and R43 for Phase C. Figure 3 shows a typical connection for the line voltage when using fixed resistors.

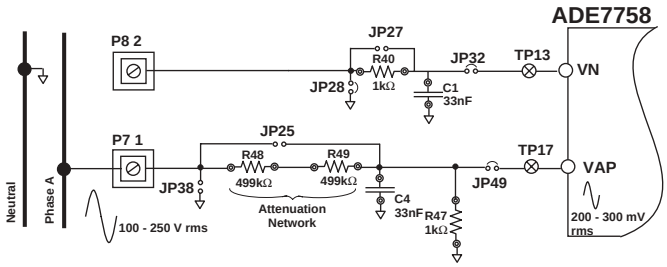


Figure 3 — Phase A Voltage Channel attenuation network using Fixed resistors

The attenuation networks can be easily modified by the user to accommodate any input signal level. However the value of R43, R44 and R47 (1kΩ) should not be altered as the phase response of Voltage channels should match that of the current channels.

The maximum signal level permissible at VAP, VBP and VCP is 0.5V peak for the ADE7758. Although the ADE7758 analog inputs can withstand ±6V without risk of permanent damage, the signal range should not exceed ±0.5V with respect to AGND for the ADE7758 for specified operation. Note that the analog input VN is connected to AGND via the anti-alias filter R40/C1 using JP28. Jumper JP27 should be left open.

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TABLE II : JUMPER SETTINGS

JUMPER	OPTION	DESCRIPTION
JP1-JP7-JP13	Closed	This will short out R7, R13 and R19 respectively. The effect is to disable the phase compensation filter on the analog inputs IAN, IBN and ICN respectively. Default Closed.
JP2-JP8-JP14	Closed	This will connect the analog input IAP, IBP and ICP respectively to ground. Default Open.
JP3-JP9-JP15	Closed	This will connect the analog input IAN, IBN and ICN respectively to ground. Default Open.
JP4-JP10-JP16	Closed	This will short out R9, R15 and R21 respectively. The effect is to disable the phase compensation filter (for Current transformers) on the analog inputs IAN, IBN and ICN respectively. Default Closed.
JP5-JP11-JP17	Closed	This will short out R10, R16 and R22 respectively. The effect is to disable the anti-alias filter on the analog inputs IAP, IBP and ICP respectively. Default Open.
	Open	Enable the anti-alias filter on IAP, IBP and ICP respectively.
JP6-JP12-JP18	Closed	This will short out R8, R14 and R20 respectively. The effect is to disable the anti-alias filter on the analog inputs IAN, IBN and ICN respectively. Default Open.
	Open	Enable the anti-alias filter on IAN, IBN and ICN respectively.
JP19	Closed	This will connect the Analog and Digital ground planes of the PCB. Default Closed.
JP20	Closed	This will connect an external reference 2.5V (AD780) to the ADE7754/8
	Open	This will enable the ADE7758 on-chip reference.
JP21	Closed	This connects the DVDD and +5V (buffers) supply for the evaluation board together. Default Closed.
JP22	Closed	This connects the AVDD and DVDD supply for the evaluation board together. Default Closed.
JP23-JP24-JP25	Closed	This will short the attenuation network on the voltage channels. Default Open
JP26	Closed	This will connect the optical isolator ground to the evaluation board ground (DGND). If full isolation between the evaluation board and PC is required, this jumper should be left open
JP27	Closed	This will short out R40. The effect is to disable the anti-alias filter on the analog input VN. Default Open
JP28	Closed	This will connect the analog input VN to ground. Default Closed.
JP29-JP35-JP38	Closed	This will connect the analog inputs VCP, VBP and VAP to ground respectively. Default Open-
JP47-JP48-JP49	Closed	This will short out disconnect Analog input VCP, VBP and VAP respectively from the ADE7758. Default Closed
JP30	Closed	This connects the buffered logic output VARCF to the LED CR1. Default Open.
JP31	Closed	This connects the buffered logic output VARCF to BNC J1 connector via an optical isolator. Default Open.
JP32	Closed	This will short out disconnect Analog input VN from the ADE7758. Default Closed
JP43	A	This connects the buffered logic output CF to BNC J3 connector via an optical isolator.
	B	This connects the buffered logic output CF to the LED CR2.
JP44	A	This connects the buffered logic output IRQ to the parallel port.
	B	This connects the uffered logic output IRQ the LED CR3.
JP46	N/A	This jumper is not used for the ADE7758, the setting does not matter.

SETTING UP THE EVALUATION BOARD AS AN ENERGY METER

Figure 4 shows a typical set up for the ADE7758 evaluation board. In this example a kWh meter for a 4 wire, three phase distribution system is shown. Current Transformers are used to sense phases' current and are connected as shown in Figure 4. For a more detailed description on how to use a CT as a current transducer see the *Current Sense Inputs* section of this documentation. The line voltage is connected directly to the evaluation board as shown. Note JP23, JP24 and JP25 should be left open to ensure that the attenuation networks are not bypassed. Also note the use of two power supplies.

The second power supply is used to power the optical isolation. With JP26 left open, this will ensure that there is no electrical connection between the high voltage test circuit and the frequencies outputs. The power supplies should have floating voltage outputs.

Setting up the evaluation board for the ADE7758

The configuration of the jumpers on the ADE7758 evaluation board for operation with the ADE7758 is detailed in Figure 4.

The evaluation board is connected to the PC parallel port using the cable supplied. The cable length should not exceed 6 feets (2 meters) or the serial communication between the PC and the evaluation board may become unpredictable and error prone.

When the evaluation board has been powered up and is connected to the PC, the supplied software can be launched. The software will automatically start in default mode. The next section describes the ADE7758 evaluation software in detail and how it can be installed and uninstalled.

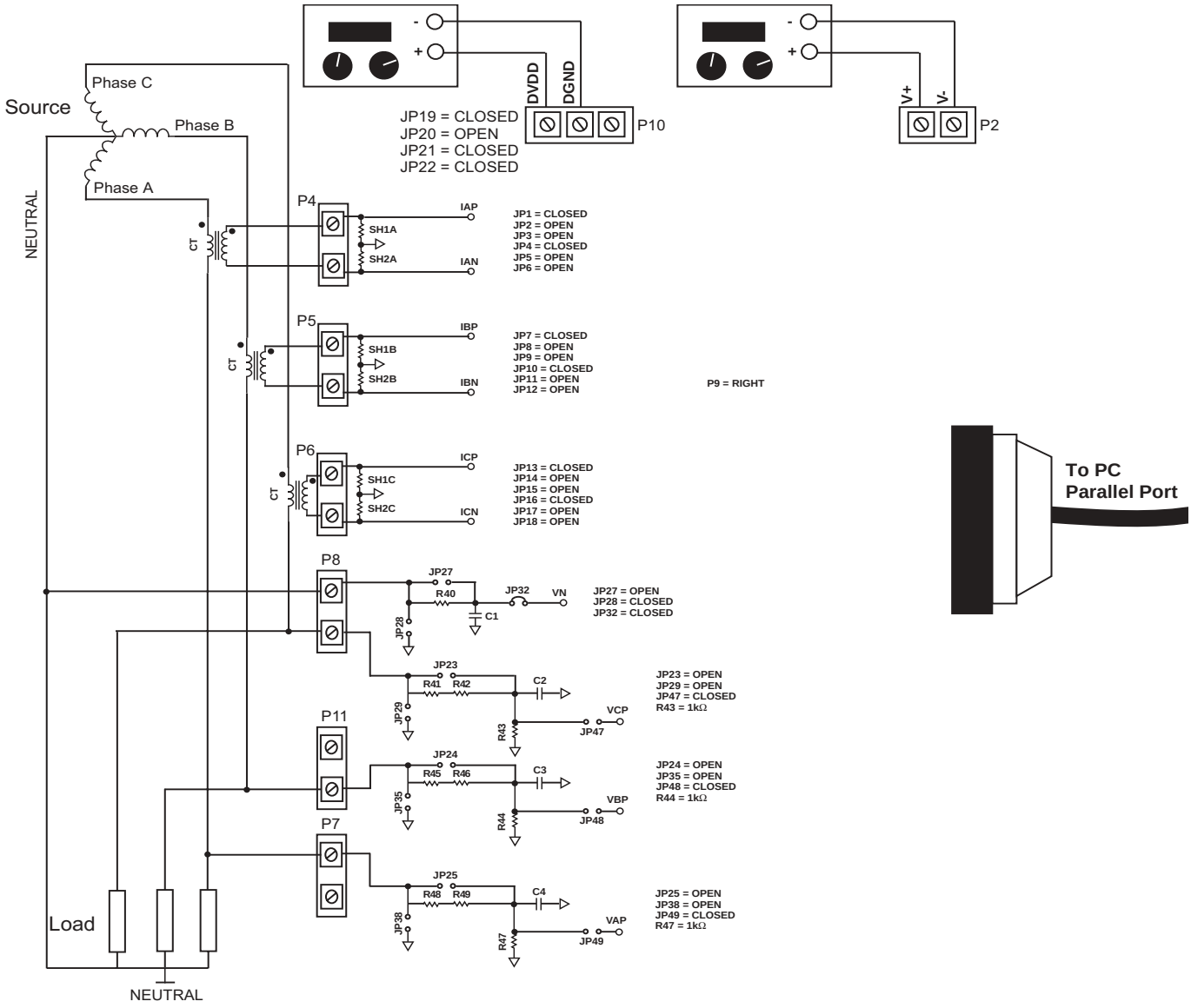


Figure 4 - Typical set up for the ADE7754-ADE7758 evaluation board

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ADE7758 EVALUATION SOFTWARE

The ADE7758 evaluation board is supported by Windows based software which will allows the user to access all the functionality of the ADE7758. The software is designed to communicate with the ADE7758 evaluation board via the parallel port of the PC.

Installing the ADE7758 Software

The ADE7758 Software is supplied on one CD-ROM. The minimum requirements for the PC are Pentium II 233MHz, 32 MB RAM, 10MB free HD space and at least one PS/2 or ECP parallel port . To install the software place the CD-ROM in the CDROM reader and double click "setup.exe". This will launch the set up program which will automatically install all the software components including the uninstall program and create the required directories. When the set up program has finished installing the "EvalADE7758" program the user will be prompted to install the National Instruments run-time engine. This software was developed using National Instruments LabView software and the run-time engine is required in order to run the "ADE7758Eval" program. Follow the on-screen instructions to complete the installation. You will need to reboot your computer to complete the installation.

To launch the software simply go to the Start—>Programs—>EvalADE7758 menu and click on "EvalADE7758".

Uninstalling the ADE7758 Evaluation Software

Both the "EvalADE7758" program and the NI run-time engine are easily uninstalled by using the Add/Remove Programs facility in the control panel. Simply select the program to uninstall and click the Add/Remove button.

When installing a new version of the ADE7758 evaluation software, the previous version should be uninstalled.

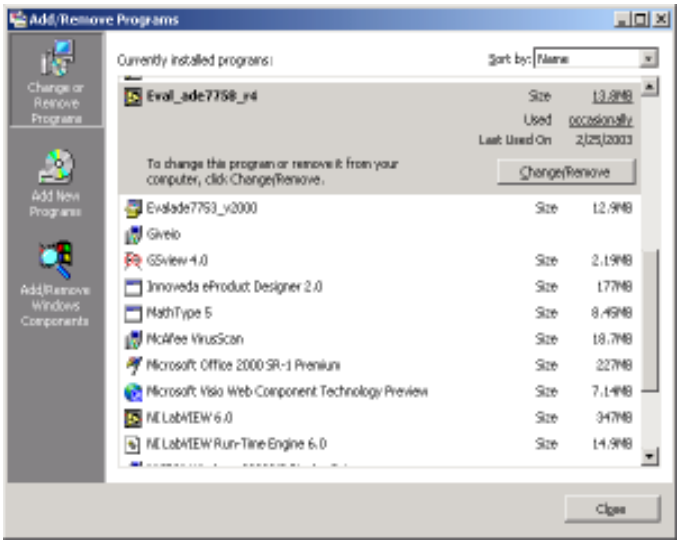


Figure 5 — Uninstalling the ADE7758 Eval Software

Default Mode

When the software is launched, the default screen shows the window, or mode, options. The user has the choice in different modes of operation: Active Energy, Reactive Energy, Apparent Energy Measurements, Voltage channels, Current Channels, Power Quality, Temperature and Interrupt. Each mode gives a view of the functionality of the ADE7758 and access to the relevent registers in the datapath. This software should be used in conjunction with the ADE7758 datasheet.

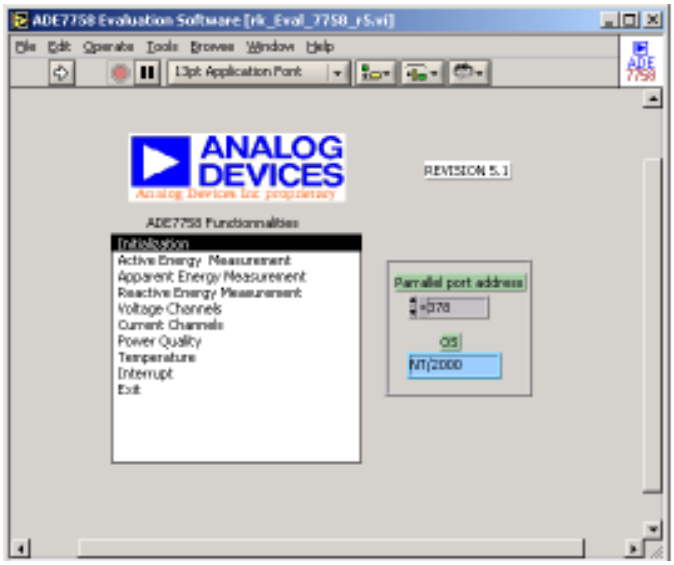


Figure 6 — Default ADE7758 Mode Selection Window

Active Energy Measurement

In this mode, all the parameters needed for the measurement of the Active Energy are shown in one window - *see Figure 7*.

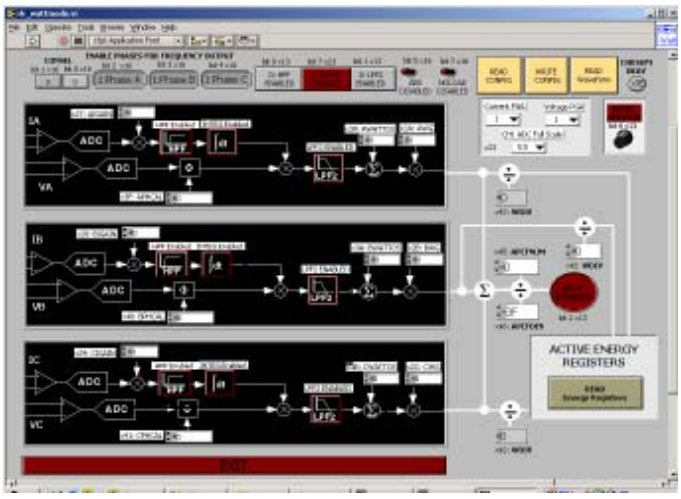


Figure 7 - Active Energy Measurement Window

The different modes, configuration and register values for the Active Energy Measurement can be selected in this window. All configuration registers are written or read to the ADE7758 when pushing the Write Configuration or Read Configuration buttons. The Active Energy and Line Active Energy registers are available by pressing the Read Energy Registers button. The Read Waveform button will launch where the current, voltage and multiplier waveforms are viewable by phase.

The ADE7758 can be reset to its default configuration by pushing the reset button.

Apparent Energy Measurement

In this mode, all the parameters needed for the measurement of the Apparent Energy are presented in one window - *see Figure 8*.

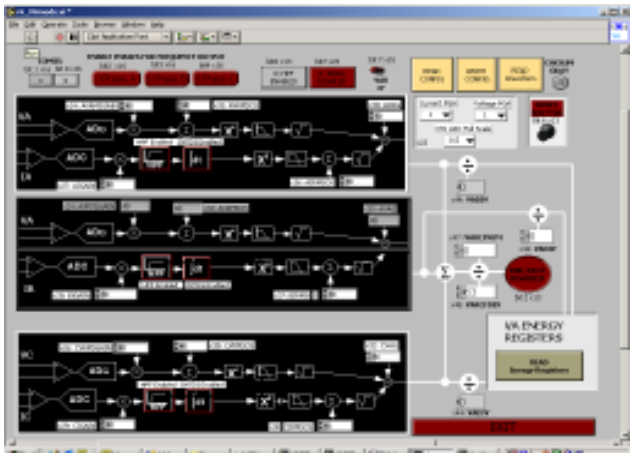


Figure 8 - Apparent Energy Measurement Window

The different modes, configuration and registers values for the Apparent Energy Measurement can be selected in this window. All configuration registers are written or read to the ADE7758 when pushing the Write Configuration or Read Configuration buttons. The Apparent Energy and Line Apparent Energy registers are available by pushing the Read Energy Registers button. The Read Waveform button will launch where the current, voltage and multiplier waveforms are viewable by phase.

The ADE7758 can be reset to its default configuration by pushing the reset button.

Reactive Energy Measurement

In this mode, all the parameters needed for the measurement of the Apparent Energy are presented in one window - *see Figure 9*.

The different modes, configuration and register values for the Reactive Energy Measurement can be selected in this window. All configuration registers are written or read to the ADE7758 when pushing the Write Configuration or Read Configuration buttons. The Active Energy and Line Active Energy registers are available by pressing the Read Energy Registers button. The Read Waveform button will launch where the current, voltage and multiplier waveforms are viewable by phase.

The ADE7758 can be reset to its default configuration by pushing the reset button.

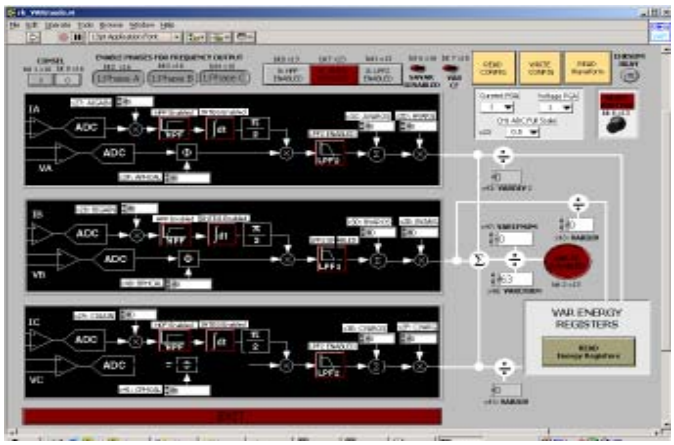


Figure 9 - Reactive Energy Measurement Window

Read Energy Registers

This window shows all of the energy registers in the ADE7758. There are several options for viewing the contents of the registers. The per phase energies are shown in the top three rows of energy displays. The sum of the three phases for active, apparent and reactive are shown in the bottom row of displays - *see Figure 10*.

The Active, Apparent and Reactive Energy registers can be read separately by pressing the small read buttons. The toggle switch sets the program to read the line accumulation registers or the regular accumulation registers for Active, Apparent or Reactive energy. Additionally, all of the registers can be read simultaneously by using the larger read buttons at the top. The configuration registers are written or read to the ADE7758 by pushing the Write Configuration or Read Configuration buttons.

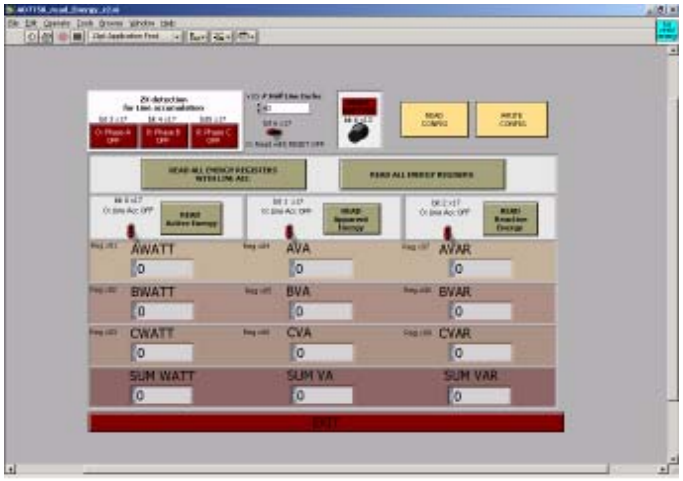


Figure 10- Read Energy Registeres Window

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Voltage Channels

In this mode, all the parameters needed for the measurement of the Voltage channels are presented in one window - *see Figure 11*.

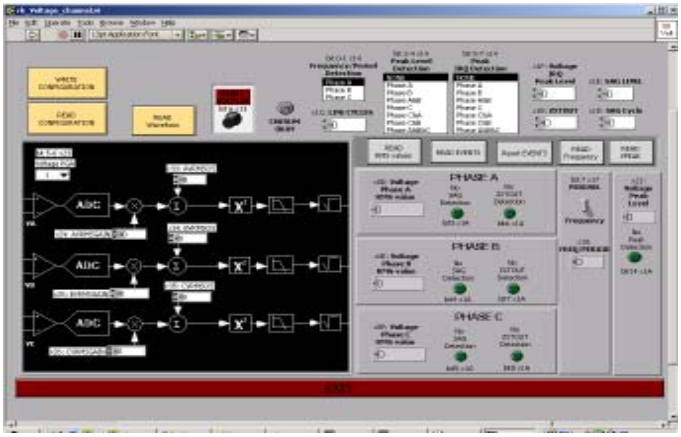


Figure 11 — Voltage Channels Window

The register values and information available for the Voltage Channels can be viewed in this window. All configuration registers are written or read to the ADE7758 by pushing the Write Configuration or Read Configuration buttons. To get the Voltage RMS, the "Read RMS value" should be depressed. Pressing the "Read Frequency" button displays the line period or the line frequency for the selected phase depending on the toggle switch setting. SAG, Peak and Zero-crossing Time-out interrupts information is available by pushing the "Read Events" button.

The Voltage Channel window gives also access to the waveform sampling data by pressing the Read Waveform button.

The ADE7758 can be reset to its default configuration by pushing the reset button.

Current Channels

In this mode, all the parameters needed for the measurement of the Current channels are presented in one window - *see Figure 12*.

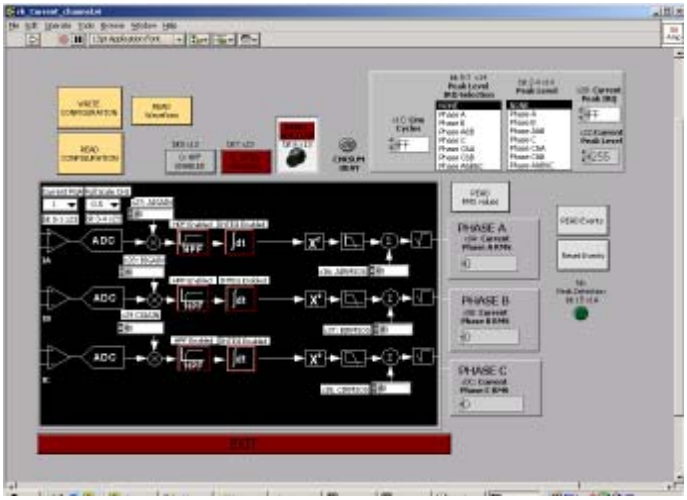


Figure 12 - Current Channels Window

The register values and information available for the Current Channels can be viewed in this window. All configuration registers are written or read by pushing the Write Configuration or Read Configuration buttons. The Current RMS and Peak interrupts information are available by pushing the appropriate buttons.

The Current Channel window gives also access to the waveform sampling data by pressing the Read Wavform button.

The ADE7758 can be reset to its default configuration by pushing the reset button.

Waveform Samples Window

The Waveform sample window is available from the energy measurement, voltage or current channel windows. This screen allows the user to read the waveform samples register. The available waveforms in the ADE7758 include: voltage, current, active power, reactive power, and apparent power. Pressing the Exit button will return the user to the previous window.

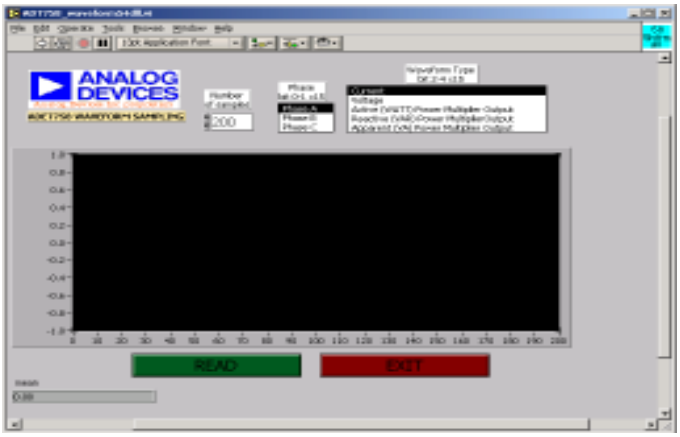


Figure 11 — Voltage Channels Window

Interrupts

This window gives access to the Interrupt Mask and STATUS registers of the ADE7758 - *see Figure 14*. For details on how to use the Interrupt and Mask registers, refer to the ADE7758 datasheet.

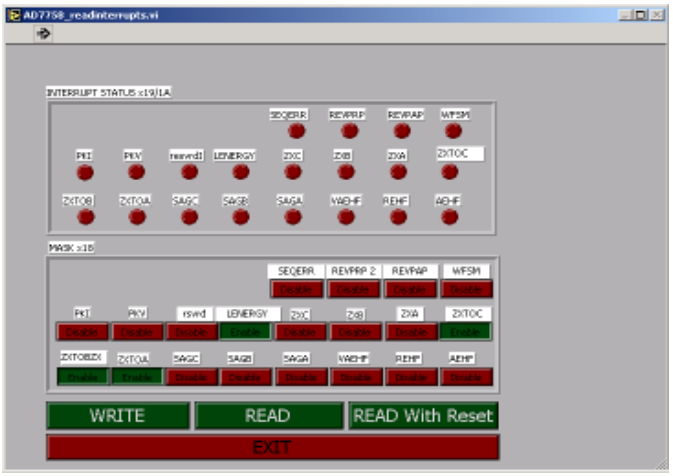


Figure 14 - Interrupts Window

Measuring CT Phase Errors using the ADE7758

The ADE7758 itself can be used to measure a CT (and external components) phase error during calibration. The assumption is that the ADE7758 has no internal phase error (APHCAL = BPHCAL = CPHCAL = 00 hex) and the error due to external components is small (<0.5°). The procedure is based on a two point measurement, at PF=1 and PF = 0.5 (lag). The PF is set up using the test bench source and this source must be very accurate. The ADE7758 should be configured for Active Energy measurement mode. An Active Energy measurement is first made with PF=1 (measurement A). A second Active Energy measurement should be made at PF=0.5 (measurement B). The frequency output CF can be used for this measurement. Using the formula shown below the phase error is easily calculated:

$$Phase\ Error\ (^\circ) = Tan^{-1}\left(\frac{B - A/2}{A/2 \cdot \sqrt{3}}\right)$$

For example, using the frequency output CF to measure power, a frequency of 3.66621Hz is recorded for a PF=1. The PF is then set to 0.5 lag and a measurement of 1.83817Hz is obtained. Using the formula above the phase error on Channel 1 is calculated as:

$$Phase\ Error\ (^\circ) = Tan^{-1}\left(\frac{1.83817 - 3.66621/2}{3.66621/2 \cdot \sqrt{3}}\right) = +0.091^\circ$$

The formula will also give the correct sign for the phase error. In this example the phase error is calculated as +0.091° at the input to the Current channel of ADE7758. This means that the CT has introduced a phase lead of 0.091°. Therefore the phase difference at the input to the Current channel is now 59.89° lag instead of 60° lag. Determining whether the error is a lead or lag can also be figured intuitively from the frequency output. Figure 14 shows how the output frequency varies with phase (cos{ϕ}). Since the output frequency B (1.83817Hz) at the PF=0.5 lag setting in the example is actually greater than A/2 (1.833105Hz), this means the phase error between the current channel and the voltage channel was actually less than 60°. This means there was additional lead in the current channel due to the CT.

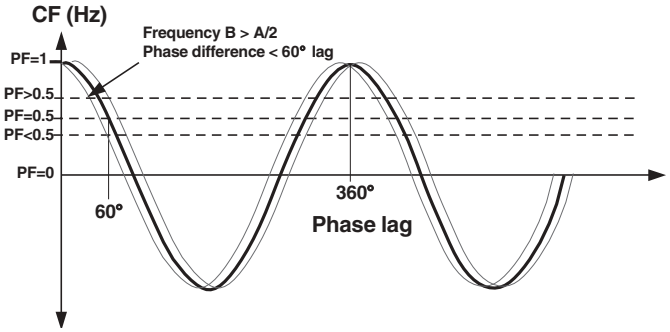


Figure 14—CF Frequency Vs Phase(PF)

Using the Phase Calibration to correct small (<0.5°) external phase errors

From the previous example it is seen that the CT introduced a phase lead in the current channel of 0.091° . Therefore instead of 60° phase difference between the current channel and the voltage channel, it is actually 59.89°. In order to bring the phase difference back to 60°, the phase compensation circuit in the voltage channel is used to introduce an extra lead of 0.091°. This is achieved by reducing the amount of time delay in the voltage channel.

The maximum time delay adjustment in the voltage channel is ±75.6µs with a CLKIN of 10MHz. The PHCAL registers are signed 2's complement 7 bit registers. Each LSB is equivalent to 1.2µs. In this example the line frequency is 50Hz. This means each LSB is equivalent to (360° x 1.2µs x 50) = 0.022°. To introduce a lead of 0.091° the delay in the voltage channel must be reduced. This is achieved by writing -4 (1Ch) or +0.088° to the PHCAL register.

Correcting large external phase errors

In this example the phase correction range at 50Hz is only approximately ±1.3°. However it is best to only use the PHCAL register for small phase corrections, i.e., <0.5°. If larger corrections are required the larger part of the correction can be made using external passive component. For example the resistors in the anti-alias filter can be modified to shift the corner frequency of the filter so as to introduce more or less lag. The lag through the anti-alias filters with 1kΩ and 33nF is 0.56° at 50Hz. Fine adjustments can be made with the PHCAL register. Note that typically CT phase shift will not vary significantly from part to part. If a CT phase shift is 1°, then the part to part variation should only be about ±0.1°. Therefore the bulk of the phase shift (1°) can be canceled with fixed component values at design. The remaining small adjustments can be made in production using the PHCAL registers.

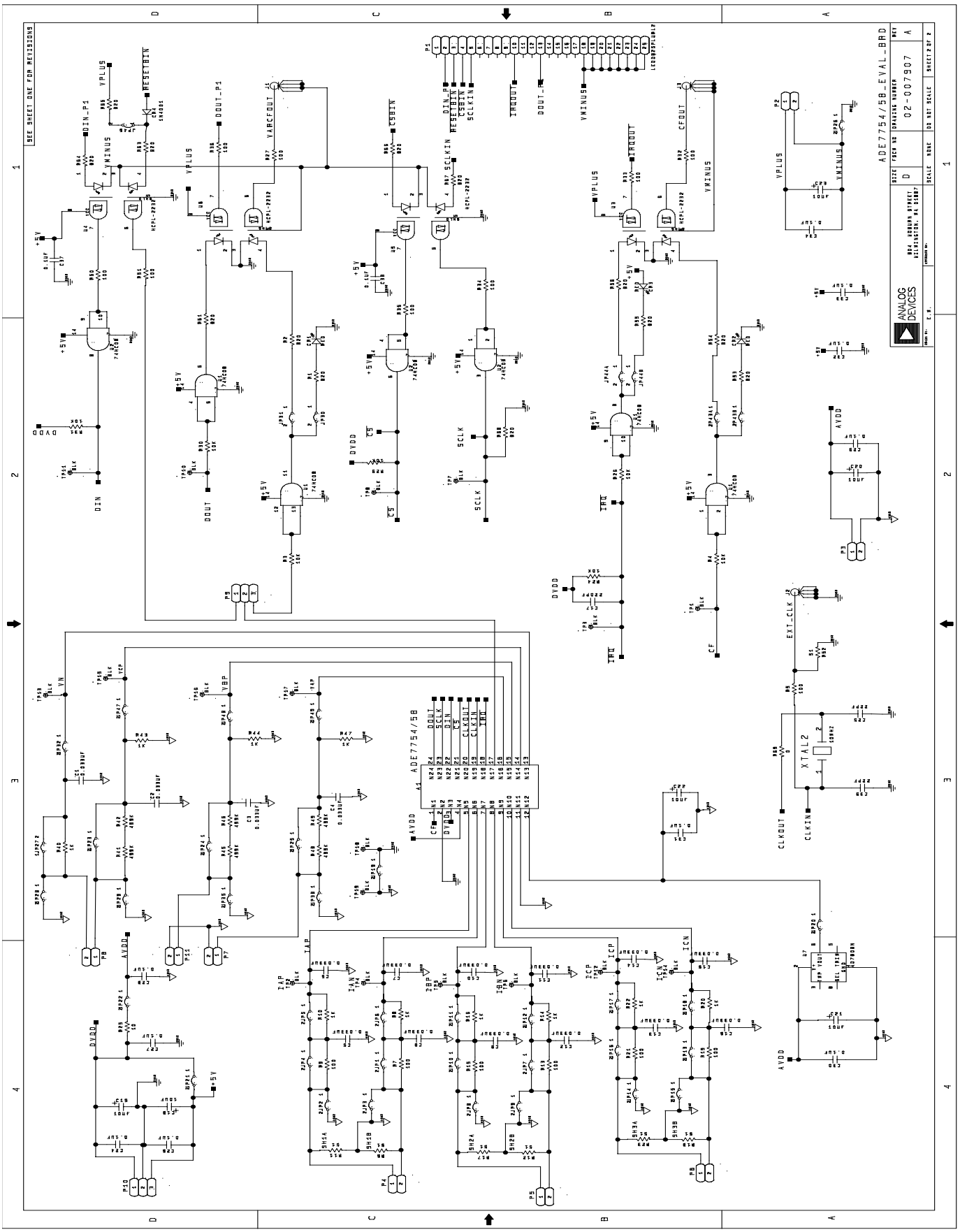
EVAL-ADE7758EB

Evaluation board BOM

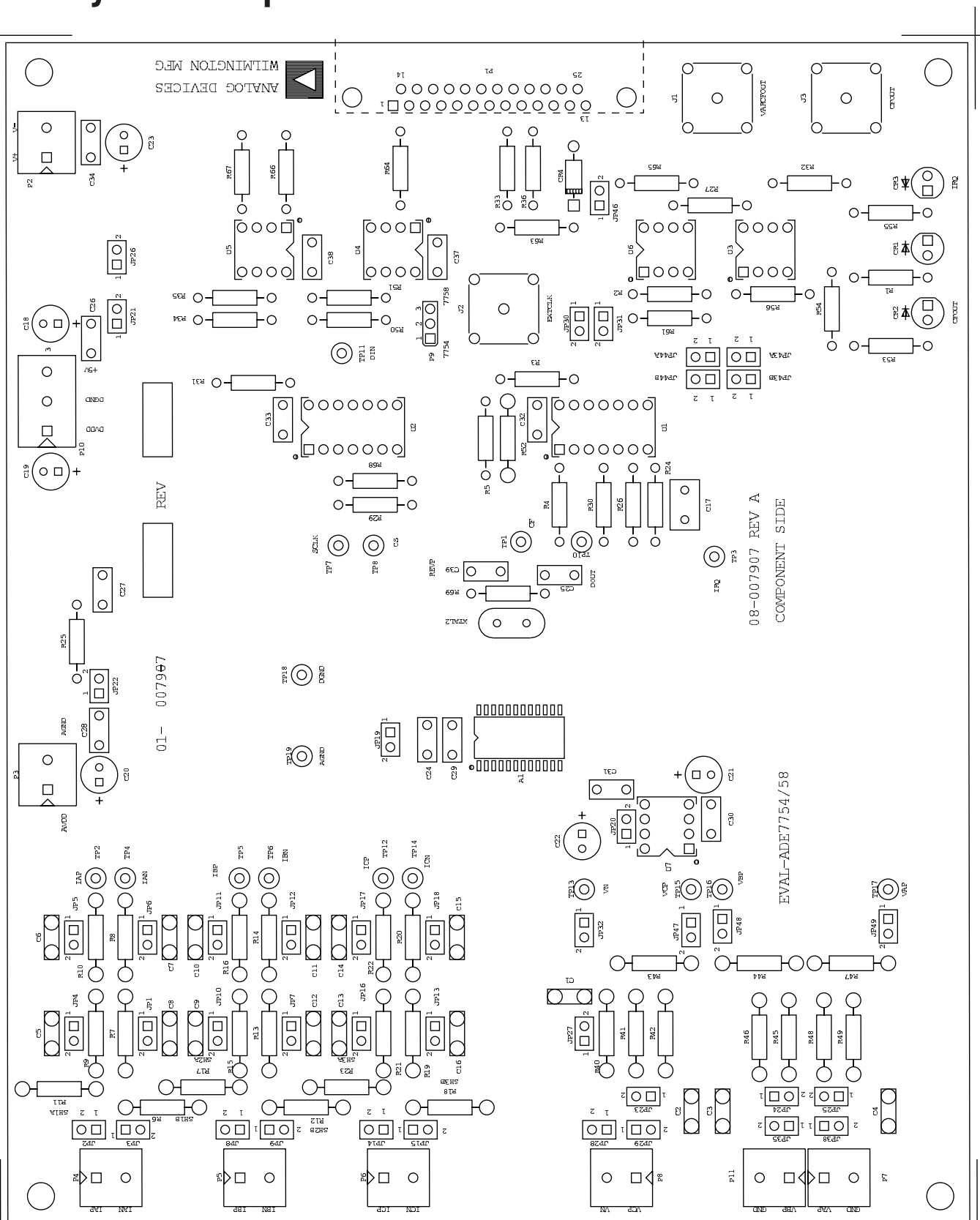
Designator	Value	Description
R4, R24, R26, R29-R31	10kΩ, 5%, ¼W	Resistor, no special requirements
R5, R7, R9, R13, R15, R19, R21, R32-R36, R50-51	100Ω, 5%, ¼W	Resistor, no special requirements
R6, R11-12, R17-18, R23, R52	51Ω, 5%, ¼W	Not placed unless external clock is being used
R8, R10, R14, R16, R20, R22, R40, R43-44, R47	1kΩ, 0.1%, ¼W	±15 ppm/°C Resistor, good tolerance, used as part of the analog filter network.These resistors are not soldered, but are plugged into PCB pin sockets for easy modification by the customer. Low drift WELWYN RC55 Series, FARNELL part no. 339-179
R25	10Ω, 5%, ¼W	Resistor, no special requirements
R38-39	20Ω, 5%, ¼W	Resistor, no special requirements
R41-42, R45-46, R48-49	499kΩ, 0.1%, ¼W	Pin socketed, ±15 ppm/°C Low drift, WELWYN RC55 Series. Farnell part no. 338-484
R53-56, R61, R63-68	820Ω, 5%, ¼W	Resistor, no special requirements
R69	0Ω, 10%, ¼W	
C1-16	33nF, 10%, 50 volt	X7R Capacitor, part of the filter network. These resistors are not soldered, but are plugged into PCB mount sockets for easy modification by the customer. SR15 series AVX-KYOCERNA, FARNELL part no. 108-948C5,
C17	220pF	PANASONIC ECQ-P1H221JZ
C18-23	10uF, Tantalium	Power supply decoupling capacitors, 10%, 16V
C25, C39	22pF, ceramic	Gate oscillator load capacitors, FARNELL part no. 108-927
C24, C26-34, C37-38	100nF, 25V	Power supply decoupling capacitors, 10%, X7R type, AVX-KYOCERNA, FARNELL part no. 108-950
C11, C21, C50, C51,		
CR1-3	LED	Low current, Red, FARNELL part no. 637-087
CR4	Diode	1N4001, Motorola
J1-3	BNC connector	Straight square, 1.3mm holes, 10.2mm x 10.2mm FARNELL part no. 149-453
JP1-29, JP32, JP35, JP38, JP46-49	2 Pin header	2-Pin, 0.025 Sq., 0.01 Ctrs, Compnt Corp., CSS-02-02
JP43A-B, JP44A-B,	2 Pin header x 2	2-Pin, 0.025 Sq., 0.01 Ctrs, Compnt Corp., CSS-02-02U1
P9	3 Pin header x 2	2-Pin, 0.025 Sq., 0.01 Ctrs, Compnt Corp., CSS-02-02U1
	ADE7758	Supplied by Analog Devices Inc.
U1-2	74HC08	Quad CMOS AND gates
U3-6	HCPL2232	HP Optical Isolator
U7	AD780	2.5V reference, Supplied by Analog Devices Inc.
XTAL	10 MHz	Quartz Crystal, HC-49(US)
P1	D-Sub 25 way male	AMP 747238-4 Right angle "D-Sub" 8mm PCB mount, DigiKey no. 747238-4

P2-8	screw terminal	15A, 2.5mm cable screw terminal sockets. WEILAND part no. 25.161.0253
P10	screw terminal	15A, 2.5mm cable screw terminal sockets. WEILAND part no. 25.161.0353

Evaluation board schematic (rev.A)

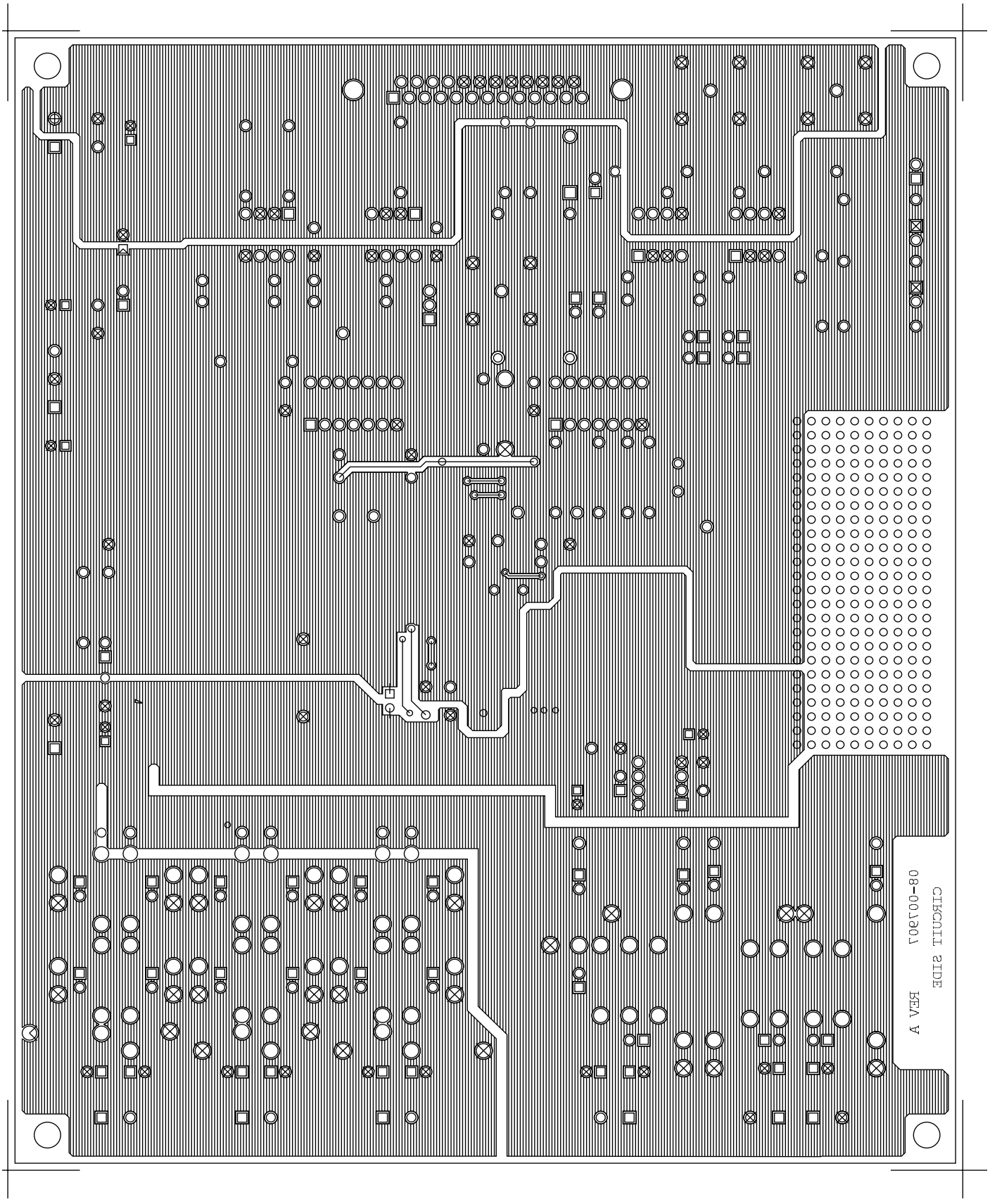


PCB layout - Component Placement



EVAL-ADE7758EB

PCB layout - Component Side



PCB layout - Solder Side

