Evaluating the **ADE9078** High Performance, Polyphase Energy Metering Analog Front End (AFE)

### FEATURES
- Full featured evaluation board for the **ADE9078**
- PC control in conjunction with the system demonstration platform (**EVAL-SDP-CB1Z**)
- PC software for control and data analysis (time and frequency domain)
- Standalone capability

### EVALUATION KIT CONTENTS
- **ADE9078** evaluation board

### ADDITIONAL EQUIPMENT NEEDED
- **EVAL-SDP-CB1Z** (must be ordered separately)
  - Includes a mini USB cable
- Current transformers or Rogowski coils for 3-phase current channels and the neutral channel
- Precision current and voltage signal source
- PC running Windows XP SP2, Windows Vista, or Windows 7 with USB 2.0 port

### AVAILABLE RESOURCES
- **Documents**
  - **ADE9078** data sheet
  - **EVAL-ADE9078EBZ** user guide
- **Required software**
  - **EVAL-ADE9078EBZ** evaluation software
- **Design and integration files**
  - Schematics, layout files, and bill of materials

### GENERAL DESCRIPTION
The **EVAL-ADE9078EBZ** evaluation board allows the performance of the **ADE9078** energy metering IC to be evaluated in a context very close to an actual 3-phase meter implementation. The kit requires purchasing a second board, the controller board for the system demonstration platform (**EVAL-SDP-CB1Z**). The **ADE9078** evaluation kit includes evaluation software, written in LabVIEW®, that provides access to the registers and features of the device using a PC interface.

Consult the **ADE9078** data sheet in conjunction with this user guide when using the evaluation board.

### TYPICAL EVALUATION BOARD SETUP

![Figure 1. The EVAL-ADE9078EBZ (on the Left) Connected to the EVAL-SDP-CB1Z SDP Interface Board (on the Right)](image-url)
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REVISION HISTORY
9/2016—Revision 0: Initial Version
Figure 2.
EVALUATION BOARD HARDWARE

OVERVIEW

The EVAL-ADE9078EBZ and the EVAL-SDP-CB1Z boards are both required to evaluate the ADE9078.

Order the EVAL-SDP-CB1Z when ordering the EVAL-ADE9078EBZ evaluation board; the evaluation kit and the EVAL-SDP-CB1Z are purchased and packaged separately, but must be used together.

The EVAL-ADE9078EBZ board is connected to the Blackfin® SDP board (also referred to as SDP-B or EVAL-SDP-CB1Z) using the 120-pin connector, P9, on the ADE9078 evaluation board. The EVAL-SDP-CB1Z consists of an ADSP-BF527 microcontroller that handles all the communications from the PC to the ADE9078 device that populates the evaluation board.

POWERING UP THE EVALUATION BOARDS

To power up the ADE9078 evaluation board, it is required to either connect an external 3.3 V power supply to the VDD test point, connect a 5 V power supply to the EXT_5V test point, or connect a 9 V dc adapter to the barrel connector on the board.

Power the ADE9078 externally by connecting a 3.3 V supply to the VDD test point or a 5 V to 16 V dc supply to the EXT_5V test point or barrel jack. When using an external supply, connect Pin 1 and Pin 2 at J3. Connect Pin 2 and Pin 3 to power the ADE9078 with internal isolated power from the SDP-B board.

ANALOG INPUTS

Current and voltage signals are connected at the test pins placed on the evaluation board. All analog input signals are filtered using the on-board antialiasing filters before the signals are connected to the ADE9078. The components used on the board are the recommended values to be used with the ADE9078.

Current Sense Inputs—the IAP, IAN, IBP, IBN, ICP, ICN, INP, and INN Test Pins

Figure 3 shows the structure used for the Phase A current channel in the evaluation board. The same signal path is used for the other current channels. Therefore, the explanation in this section applies to other current channels on the evaluation board, such as Phase B, Phase C, and the neutral phase.

E1A and E2A are ferrite beads that filter any high frequency noise present on the wires. Immediately following the ferrite beads, there are four protection diodes per current channel used for overcurrent protection. The antialiasing filter network appears after the protection network.

The signal path board configurations for the current transformer and the Rogowski coil sensors are different from each other. Figure 4 shows an example of a current transformer sensor configuration. The burden resistors, R1A and R2A, are populated per the full-scale current and the current transformer turns ratio of the application. The C1A and C2A capacitors are not populated because only one stage of the RC filter is sufficient in this configuration. The RC filter combination of 1 kΩ and 22 nF provides a low-pass filter with a cutoff frequency of 7.2 kHz. The current transformer turns ratio and the burden resistor values must be chosen such that the IAP to AGND and IAN to AGND potentials do not exceed ±0.5 V peak.
Figure 5 shows an example of a configuration using a Rogowski coil current sensor. The burden resistors, R1A and R2A, are not used in this configuration and are therefore removed from the board. Because Rogowski coil sensors have a gain that increases with frequency (20 dB/decade), the high frequency components of the current signal are amplified by a larger factor. Therefore, two stages of RC filtering are required to attenuate the high frequency components and to avoid aliasing. The R3A and R4A resistors must be 100 Ω and are used in conjunction with the C1A and C2A capacitors to form a low-pass filter with a cutoff frequency of 72 kHz. This first stage is followed by the 1 kΩ/22 nF RC filter combination that provides a cutoff frequency of 7.2 kHz. The Rogowski coil must be chosen such that the IAP to AGND and IAN to AGND potentials do not exceed ±0.5 V peak.

*Figure 5. Example of a Rogowski Coil Connection*

**Phase Voltage Sense Inputs—the VAP and VAN, VBP and VBN, and VCP and VCN Test Pins**

Figure 6 shows the Phase A voltage channel signal path on the evaluation board. The same signal path is also replicated on the Phase B and Phase C channels; therefore, the description in this section applies to Phase B and Phase C channels.

E3AP is a ferrite bead that filters any high frequency noise present on the wires. There are three 330 kΩ resistors connected in series, forming an attenuation network with a 1 kΩ resistor, R11A. This setup provides an attenuation ratio of 990:1. The R11A and C5A RC combination and the R10A and C6A RC combination have the same cutoff frequency as that of the RC filters used on the current channels. This matching is essential to avoid large phase errors between the voltage and current signals. If a different attenuation ratio is preferred, replace the R7A, R8A, and R9A resistors with alternate resistors. The resistors must be chosen such that the maximum signal at the VAP pin is ±0.5 V peak with respect to AGND. The Phase A line is connected to the VAP test point and the neutral line (in the case of the 3-phase, 4-wire wye configuration) is connected to the NEUTRAL test point. The NEUTRAL test point is tied to the AGND potential of the ADE9078.

**Figure 6. Phase A Voltage Input Structure on the Evaluation Board**

**SETTING UP THE EVALUATION BOARD AS AN ENERGY METER**

Figure 7 shows a typical setup for the ADE9078 evaluation board. In this example, an energy meter for a 3-phase, 4-wire, wye distribution system is shown. Current transformers sense the phase currents and are connected as shown in Figure 7. The line voltages are connected directly to the board as shown. The board is supplied from one power supply (see the Powering Up the Evaluation Boards section for more information).
Figure 8 shows a typical setup for the ADE9078 evaluation board as an energy meter for a 3-phase, 3-wire, delta distribution system. The Phase B voltage is considered a reference and is therefore tied to the NEUTRAL test point on the evaluation board.

Using the Evaluation Board with Another Microcontroller

It is possible to manage the ADE9078 evaluation board with a different microcontroller mounted on another board. The evaluation board can be connected to this second board through the P2 connector. The SDP Blackfin board, in this case, is unused and not connected. If nonisolated signals are to be used with the external microcontroller, then the P7 connector can be used. In this case, the U7, U8, U10, and U11 isolators must be removed from the ADE9078 evaluation board. Note that P2 and P9 have isolated signals, whereas P4 is nonisolated.
EVALUATION BOARD SOFTWARE

The EVAL-ADE9078EBZ is supported by Windows®-based software that allows the user to access all the functionality of the ADE9078. The software communicates with the SDP Blackfin board using the USB. The SDP microcontroller communicates with the ADE9078 placed on the evaluation board to process the requests sent from the PC.

INSTALLING THE DRIVERS

When using the ADE9078 evaluation tools for the first time, a driver must be installed to allow successful communication. Find the SDPDiversNET.exe driver in the evaluation software package in the SDP Drivers folder.

To install the driver, use the following procedure:

1. When the setup wizard appears, click Next, and follow the installation instructions.

2. When installation is complete, click Finish to close the window.

Connect the USB cable from the PC to the SDP-B board. Windows detects the device and locates the correct driver automatically.

INSTALLING AND UNINSTALLING THE ADE9078 SOFTWARE

The ADE9078 evaluation software is supplied with the evaluation software package. It contains an installer to install the ADE9078 evaluation software. The program to be installed is a LabVIEW-based program that runs on the PC.

When running the software on a PC that does not have LabVIEW 2014 for the first time, run the installer. The installer installs a LabVIEW run-time engine that enables the PC to open the evaluation software executable without any issues. This installer is available in the LabView\InstallationFiles folder. If LabView 2014 is available on the PC, then the executable can be directly opened from the Executable folder.

To install and launch the ADE9078 evaluation software, use the following procedure:

1. Double-click InstallationFiles\setup.exe. This launches the setup program that automatically installs all the software components, including the uninstall program, and creates the required directories.

2. To launch the software, go to Start/All Programs/ADE9078 and click ADE9078_Evaluation_Software. When the software is run for the first time, right click on ADE9078_Evaluation_Software and select run as the administrator.

Both the ADE9078 evaluation software program and the run-time engine are uninstalled using the add/remove programs option in the control panel.

Before installing a new version of the ADE9078 evaluation software, use the following procedure:

1. Uninstall the previous version of the evaluation software.

2. Select the add/remove programs option in the Windows control panel.

3. Select the program to uninstall and click the Add/Remove button.

FRONT PANEL

When the software executable is opened, the front panel window of the evaluation software appears, as shown in Figure 10. When opened for the first time, the software searches for two files: one file is the register file, ADE9078_reg_map.bin, and the other is the SDP microcontroller code file, ADE9000.ldr. These files can be found in the evaluation software package. After manually choosing the location of these files the first time, the ADE9000coms.ini file is updated with their file paths. This update allows the software to find the files correctly during the next run. See the Troubleshooting section if any issues arise.

The software recognizes the device on the evaluation board, (the ADE9078) and displays the device features in the IC being evaluated indicator of the window. The SDP code version and the version register value of the IC are displayed in their corresponding indicators on the window. If the ADE9078 is present on the board, then the Power Mode Selection list box is displayed on the front panel window and the user can choose one of the power modes—PSM0, PSM1, PSM2, or PSM3—from the available options. The user can evaluate the IC in either PSM0 mode or PSM1 mode; the registers cannot be accessed in the PSM2 mode or the PSM3 mode of the ADE9078.
There are three different operations that can be performed using the buttons present in the left pane of the front panel window (see Figure 10). These operations are enacted using the following buttons:

1. **Set SCLK.** Clicking this button opens a window, as shown in Figure 11. Set the SPI clock frequency for communication between the ADE9078 and the Blackfin microcontroller unit (SDP) using this window. The intended SCLK frequency value is entered on the SCLK control and the Check if Valid button is clicked. Clicking the Check if Valid button rounds off the clock frequency to the closest possible setting that is possible in the Blackfin microcontroller unit. Finally, the Set SCLK button is clicked to set the SCLK frequency in the Blackfin microcontroller unit and the window closes.

2. **Software reset.** Clicking on this button performs a software reset on the ADE9078. A pop-up dialog box appears confirming the completion of the reset operation.

3. **Hardware reset.** Clicking on this button performs a hardware reset on the ADE9078. A pop-up dialog box appears confirming the completion of the reset operation.
EVALUATION SOFTWARE FUNCTIONS

The right pane of the front panel window (see Figure 10) consists of eight buttons, each of which can be used to evaluate a particular functionality of the ADE9078. The functionalities that can be evaluated are represented by the following buttons:

- Read/Write registers
- Powers and Energies
- RMS
- Waveform buffer
- Angle
- Quick Startup
- Interrupts
- Power Quality

Clicking on any of these eight buttons opens up a corresponding window. To close any of these windows, the same button must be clicked again on the front panel. Multiple windows can be left open on the monitor to evaluate different features at the same time. It is recommended that the Quick Startup window be executed first to ensure that all the initializations are performed correctly.

READ/WRITE REGISTERS BUTTON

The first button on the right pane of the front panel is the Read/Write registers button. Clicking on this button opens a window, as shown in Figure 12. There are four tabs available within this window, as follows:

- Single access
- Sequential access
- All register access
- Read on Interrupt

Each tab helps perform read/write operations to the ADE9078 at different capacities.

**Single Access Tab**

The Single access tab contains a Name selection box. Clicking on the down arrow on the selection box opens up a list of all the registers within ADE9078. Any of the registers can be selected for communication purposes. After the registers are selected, the Address box and Length box are updated on the screen. Alternatively, the address of the register can be written first, which updates the register name and the length fields. The individual bit fields within the register can be accessed via the Bitfield box. Data can be written to and read from the IC using the Write and Read buttons. The white boxes in the window denote the description of the register and the corresponding bit fields. Figure 12 shows the window when the Single access tab is selected.

![Read/Write registers Window—Single access Tab](image-url)

Figure 12. Read/Write registers Window—Single access Tab
Sequential Access Tab

The Sequential access tab allows the user to perform four different operations, either reads or writes, in a particular order. The Enable checkboxes at the beginning of each of the steps (Step 1 through Step 4) can be selected to enable that particular step. When all the required settings are entered, click the Execute Sequence button to perform the operations in sequence. Figure 13 shows the window when the Sequential access tab is selected.

All Register Access Tab

The All register access tab allows the user to read from all the registers on the device and to write all writable registers with a single button click. Clicking on the Read and display all registers button reads the registers and outputs the results to the Register values table. After entering the file path for saving the register values, click the Save data to file button to generate a text file with all the register values. Any notes for reference can be added to the file using the Notes box. The saved text file can also be edited and used to write back to the registers. When attempting to write back to the registers, edit the hexadecimal register value in the text file and specify the file path next to the Read from file and update display button (perform this action before clicking the button). Clicking this button updates the table in the window with the values from the file. At this point, clicking the Write register values from display button writes to all the writable registers within the ADE9078. Figure 14 shows the window with the All register access tab selected.
Figure 14. Read/Write registers Window—All register access Tab
**Read on Interrupt Tab**

The **Read on Interrupt** tab allows the user to read any particular register on any particular interrupt event. Examples of cases where using this tab may be useful are as follows:

- Reading the AVRMS register result on each DREADY interrupt.
- Reading the AWATTHR_HI register result every EGYRDY interrupt.

The register and the interrupt can be selected from their respective boxes on the window. The number of desired register reads is entered in the **No. of interrupts** box. Clicking the **Read on interrupts** button at this point performs the read operation and the results are available in the **Read-back values** table. The readback values can be saved to a file using the **Save data to a file** button provided in the window. Figure 15 shows the window when the **Read on Interrupt** tab is selected.
POWERS AND ENERGIES

The next functionality available in the evaluation software is powers and energies, located in the Powers and Energies window. This window has three tabs, as follows:

- Powers
- Energies
- CF

Powers Tab

The Powers tab allows the user to read from all the instantaneous powers and accumulated powers available in the ADE9078. When using the evaluation software with the ADE9078, certain register displays are grayed out, indicating that they are not available on the IC. Before evaluating the accumulated powers, it is recommended to set the Power update rate (ms) box and click the Set button next to it. This action writes to the PWR_TIME register accordingly. Figure 16 shows the window when the Powers tab is selected in the evaluation software. The signal path for the independent current and voltage channels is found in the RMS section.

![Figure 16. Powers Tab](image)
**Energies Tab**

The **Energies** tab allows the user to set the EP_CFG register and the EGY_TIME register correctly and to read the energy results from the ADE9078. Figure 17 shows the Energies tab window. On the left half of the window, there are different options available for the user, such as selecting if accumulation must be turned on and, if so, must the accumulation be a samples-based accumulation or a line cycle-based accumulation. After all selections are made, click the Set button to write to the registers appropriately. The right half of the window displays the energy results.

![Figure 17. Energies Tab](image-url)
**CF Tab**

The CF tab allows the user to configure the CFx pins of the ADE9078. There is a wide range of configurability available in the ADE9078 with respect to the functionality of the four CFx pins. Some of the major settings that affect the CFx pins results include the phases enabled in each CFx pin, the type of energy represented, and the CFxDEN register values. These settings can be set using the CF tab window, as shown in Figure 18. There are additional functionalities muxed onto the CF3 and CF4 pin, which can also be controlled using this window. Common threshold settings such as WTHR, VATHR, and VATHR can also be set. The CFx low pulse width can be fixed at a particular value and the options available in the window, such as enabling the corresponding check boxes for each of the CFx pins and setting a value for the CF_LTMR bit field, are used to execute this pulse width setting.

![CF Tab Window](image_url)

*Figure 18. CF Tab*
RMS WINDOW

The RMS window allows the user to visualize the datapath inside the ADE9078, as well as to configure the high-pass filter, the integrator, the programmable gain amplifier (PGA) gain levels, the ADC_REDIRECT register values, and the VCONSEL and ICONSEL settings, and to view the results. Perform the configuration changes by making the changes to the respective boxes in the window and clicking the Write button, located on the bottom right corner of the signal path. The different gain and offset registers can also be accessed via the tabs within this window.

There are several tabs within the RMS window. The first tab is the Continuous monitor tab, shown in Figure 19. The current and voltage RMS results are shown separately on the screen. When using the evaluation software with the ADE9078, some of the register indicators on screen are grayed out, indicating that they are unavailable on the ADE9078.

There are individual tabs present for each of the voltage and current channels. Under each of these tabs, there are multiple subtabs. The IA and VA tabs are shown in Figure 20 and Figure 21, respectively. VB and VC are very similar to the VA datapath; IB and IC are very similar to the IA datapath. The multipoint gain and phase calibration can be enabled and disabled using the Disabled button located at the bottom left half of each tab within the RMS window. The state of this button controls the multipoint gain and phase register accessibility. Figure 22 shows the IN tab. Under the IN tab, there are two subtabs: Total RMS and ISUM.
Figure 21. **RMS Window—VA Tab (Total RMS Subtab)**

Figure 22. **RMS Window—IN Tab (ISUM Subtab)**
WAVEFORM BUFFER WINDOW

The Waveform Buffer window has two sections. The top half of the window controls the different settings of the waveform buffer. Different settings, such as the operation mode, specifying which channels burst, the source of the waveforms, and the number of samples to be collected are selected from this section of the window. After all the settings are designated, click the Run button to start the filling process of the buffer. After the filling is complete, the buffer samples are plotted in the time domain under the Waveforms tab. Figure 23 shows the Waveform Buffer window with the Waveforms tab selected.

If the FFT tab is selected, the window appears as shown in Figure 24. The FFT of all the waveforms is computed and plotted automatically based on the waveforms.

The window allows the user to save the waveform and FFT data into a text file. The waveform and FFT display images can be saved to a .bmp file as well.
ANGLE WINDOW

The Angle window is shown in Figure 25. This window allows the user to visualize the angles of three voltage and three current channels with respect to each other. On the left side of the window, all nine angle register values are displayed. Using these register results, the angles are computed in degrees and displayed in their respective boxes. The dial to the right of the screen gives a phasor like representation of the six signals. The frequency values are displayed below the dial. These values are computed from the xPERIOD register values. The Angle window does not require the user to perform a write. The user can save the values in the window to a file, perform a single read of the screen quantities, or perform a continuous update of the quantities using the respective buttons in the window.

![Figure 25. Angle Window](image-url)
QUICK STARTUP WINDOW

The Quick Startup window is the first window that must be accessed by the user when using the evaluation software. There are three tabs within this window: the Configuration tab, the Input circuitry tab, and the Startup procedure tab. The Startup procedure tab is the main tab that performs the quick start-up routine, as well as all the necessary initializations. However, before the start-up routine and the initializations, make sure that the inputs are operating in the correct 3-phase configuration and that they are not overranging the analog-to-digital converters (ADCs).

The Configuration tab accepts the user response on a few parameters and selects the appropriate VCONSEL and ICONSEL settings for the user. The Input circuitry tab can be used as a quick calculator for determining if the input signal exceeds the current channel and the voltage channel ADCs inside ADE9078. By feeding in the system parameters and input signals, along with the PGA setting, the software calculates the signal level at the ADCs. If the signal level exceeds the full-scale range of the ADCs, the indicator turns red. This indication signals to the user that the system parameters must be adjusted.

The Startup procedure tab performs the following initialization steps, which must be completed sequentially:

1. Sets the PGA for all channels.
2. Sets SELFREQ and VLEVEL.
3. Enables the integrator and sets DICOEFF. This step is skipped for everything except the di/dt sensor.
4. Enables the DSP.
5. Disables the CFx pulse outputs, enables the energy and powers functionality, and reads all the energy registers on reset.
6. Performs a quick gain calibration and obtains calibration conversion constants, such as V/LSB, A/LSB, and Wh/LSB.
7. Obtains the CFxDEN values from the meter constant and writes these values to the registers.
8. Enables CF1 and CF2 and configures them such that CF1 denotes the sum of all the total active energy of the phases and CF2 denotes the sum of all the total reactive energy phases.

These steps must be performed sequentially. The user must click on the buttons in each step to perform the operation. The calibration constants can be saved to a file for future use.
Figure 27. Quick Startup Window—**Input circuitry** Tab

Figure 28. Quick Startup Window—**Startup procedure** Tab
INTERRUPTS WINDOW

The **Interrupts** window displays the status of all the interrupt events. The individual bits of the STATUS0 and STATUS1 registers are shown as green LEDs in the window (see Figure 29). If the LED is lit, it indicates that the corresponding status bit is set to 1. Next to each of the LEDs, there is a checkbox that represents the corresponding MASKx bits. If the MASKx bits must be set, enable the corresponding checkbox and click the **Write Mask Registers** button. Use the **Write '1' to all set status bits** button to reset all status bits simultaneously. If specific values must be written to the status bits, write to the bits using the controls on the left side of the screen.

View the IRQx pin logic level by clicking the **Check IRQx pin logic state** button. If the LED is lit, this means that the pin is in a logic low state. If the **Auto Clear** button is clicked, the interrupts available on the pins are reset on the fly. The IRQx pins can be monitored on a scope to understand the rate at which the interrupts are being set. The **Route all events to IRQ1 pin** button sets the configuration bit that routes all interrupt events to be accessible via the IRQ1 pin.

![Figure 29. Interrupts Window](image-url)
POWER QUALITY WINDOW

The Power Quality window allows the user to access all the power quality features of the ADE9078. The window is subdivided into three tabs, as follows:

- Voltage monitor
- Current monitor
- Power Factor and THD

Voltage Monitor Tab

The Voltage monitor tab is shown in Figure 30. This tab evaluates the DIP, SWELL, ZX, ZXTOUT, VPEAK, and phase sequence error detection features. When using the ADE9078, the DIP and the SWELL features are grayed out. This window allows the user to configure all the control inputs for the features and to monitor the status bits as LEDs. The corresponding mask bits can also be set using the checkboxes in the window.

Current Monitor Tab

The Current monitor tab is shown in Figure 31. This window is organized in the same way as the voltage monitor window. The IPEAK, ZX, and OI power quality features are accessible in this tab.
Power Factor and THD Tab

The Power Factor and THD tab is shown in Figure 32. This window reads all the power factor and total harmonic distortion (THD) register results from the device, converts these results to meaningful results, and displays them. The THD calculations are not available in ADE9078, therefore, these calculations are grayed out when the evaluation software is used with the ADE9078.

![Power Quality Window—Power Factor and THD Tab](image)
TROUBLESHOOTING

If the software does not detect the SDP-B board, the message shown in Figure 33 is displayed.

If this message appears, take the following steps:

1. Verify that the SDP Blackfin board is connected to the PC using the USB cable. The window in Figure 34 pops up on the task bar; Windows then installs any other necessary drivers.
2. After the installation is complete, click Rescan.
3. When another window appears, check if the LED on the board is flashing; if so, click Select.
EVALUATION BOARD SCHEMATICS AND ARTWORK

Figure 35. Evaluation Board Silkscreen

Figure 36. Evaluation Board Layout, Top Layer
Figure 37. Evaluation Board Layout, Bottom Layer
Figure 39. Evaluation Board Schematic, Part 2
Figure 40. Evaluation Board Schematic, Part 3
## ORDERING INFORMATION

### BILL OF MATERIALS

**Table 1.**

<table>
<thead>
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<th>Reference Designator</th>
<th>Qty</th>
<th>Description</th>
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<td>GRM188R60J-475KE19</td>
</tr>
<tr>
<td>C3, C4, C18</td>
<td>3</td>
<td>Capacitor, monolithic CER X5R</td>
<td>4.7 μF</td>
<td>10</td>
<td>6.3</td>
<td>0602C0G1L683J</td>
</tr>
<tr>
<td>C19, C20</td>
<td>2</td>
<td>Capacitor, monolithic CER C0G, 0402</td>
<td>18 pF</td>
<td>5</td>
<td>50</td>
<td>GM318R71E104K</td>
</tr>
<tr>
<td>C23, C25, C27 to C30, C35 to C37</td>
<td>9</td>
<td>Capacitor, CER X7R</td>
<td>0.1 μF</td>
<td>5</td>
<td>10</td>
<td>TP-104-01-06</td>
</tr>
<tr>
<td>C3A to C6A, C3B to C6B, C3C to C6C, C3N, C4N</td>
<td>14</td>
<td>Capacitor, CER multilayer C0G</td>
<td>0.022 μF</td>
<td>5</td>
<td>50</td>
<td>C2012C0G1H223J</td>
</tr>
<tr>
<td>CF1, CF2, CS, PM0, PM1, TP5, TP6, MISO, MOSI, SCLK, IRQ0, IRQ1, CF3/ZX, RESET, CF1_ISO to CF4_ISO, CF4/EVENT</td>
<td>19</td>
<td>Connector; PCB test point, gray</td>
<td>Gray</td>
<td>N/A</td>
<td>N/A</td>
<td>TP104-01-08</td>
</tr>
<tr>
<td>CR1, CR8</td>
<td>2</td>
<td>Diode, LED green SMD</td>
<td>CMD28-21VGCTR8T1</td>
<td>N/A</td>
<td>1</td>
<td>2.1</td>
</tr>
<tr>
<td>CR2</td>
<td>1</td>
<td>Diode, Zener TVS</td>
<td>1.55MC15AT3G</td>
<td>N/A</td>
<td>15</td>
<td>1.55MC15AT3G</td>
</tr>
<tr>
<td>CR9</td>
<td>1</td>
<td>LED, blue, surface-mount</td>
<td>CMD67-21UBC/IR8 (blue)</td>
<td>N/A</td>
<td>5</td>
<td>4.5</td>
</tr>
<tr>
<td>D1A to D4A, D1B to D4B, D1C to D4C, D1N to D4N</td>
<td>16</td>
<td>Diode, high speed switching</td>
<td>TS4148 RZ</td>
<td>N/A</td>
<td>100</td>
<td>TS4148 RZ</td>
</tr>
<tr>
<td>D5 to D56</td>
<td>6</td>
<td>LED red, surface-mount</td>
<td>LN208R8ARA (red)</td>
<td>N/A</td>
<td>2.5</td>
<td>LN208R8ARA</td>
</tr>
<tr>
<td>E1A, E1B, E1C, E1N, E2A, E2B, E2C, E2N, E3AP, E3BP, E3CP</td>
<td>11</td>
<td>Inductor chip ferrite bead, 0805</td>
<td>1500 Ω</td>
<td>25</td>
<td>N/A</td>
<td>BLM21BD152SN1D</td>
</tr>
<tr>
<td>IAN, IBN, ICN, INN</td>
<td>4</td>
<td>Connector; PCB test point, blue</td>
<td>Blue</td>
<td>N/A</td>
<td>N/A</td>
<td>TP104-01-06</td>
</tr>
<tr>
<td>IAP, IBP, ICP, INP</td>
<td>4</td>
<td>Connector; PCB test point, yellow</td>
<td>Yellow</td>
<td>N/A</td>
<td>N/A</td>
<td>TP104-01-04</td>
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<tr>
<td>JP3</td>
<td>1</td>
<td>Connector; PCB header, 2.54 mm, 3 position, vertical</td>
<td>22-03-2031</td>
<td>N/A</td>
<td>N/A</td>
<td>22-03-2031</td>
</tr>
<tr>
<td>NEUTRAL</td>
<td>1</td>
<td>Connector; PCB test point, white</td>
<td>White</td>
<td>N/A</td>
<td>N/A</td>
<td>TP104-01-09</td>
</tr>
<tr>
<td>P1</td>
<td>1</td>
<td>Connector; PCB—use E022246 for 4-pin power jack from the CN4P_V6 folder</td>
<td>PJ-002AH-SMT</td>
<td>N/A</td>
<td>N/A</td>
<td>PJ-002AH-SMT</td>
</tr>
<tr>
<td>P7</td>
<td>1</td>
<td>Connector; PCB BERG header ST male, 20-pin</td>
<td>PEC10DAAN</td>
<td>N/A</td>
<td>N/A</td>
<td>PEC10DAAN</td>
</tr>
<tr>
<td>P9</td>
<td>1</td>
<td>Connector; PCB board to board receptacle ST, 0.6 mm pitch</td>
<td>FX8-1205-SV(21)</td>
<td>N/A</td>
<td>N/A</td>
<td>FX8-1205-SV(21)</td>
</tr>
<tr>
<td>R1, R29, R30</td>
<td>3</td>
<td>Resistor, precision thick film chip, R1026</td>
<td>499</td>
<td>1</td>
<td>N/A</td>
<td>ERJ-8ENF4990V</td>
</tr>
<tr>
<td>R10A, R10B, R10C, R11A, R11B, R11C</td>
<td>6</td>
<td>Resistor, film SMD, 0603</td>
<td>1 kΩ</td>
<td>0.1</td>
<td>N/A</td>
<td>ERA-3YEB102V</td>
</tr>
<tr>
<td>R11, R12, R19, R23</td>
<td>4</td>
<td>Resistor, thick film chip</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
<td>ERJ-6GEY0R00V</td>
</tr>
<tr>
<td>R15, R25 to R28</td>
<td>5</td>
<td>Resistor, precision thick film chip, R0805</td>
<td>10 kΩ</td>
<td>1</td>
<td>N/A</td>
<td>ERJ-6ENF1002V</td>
</tr>
<tr>
<td>R2 to R7</td>
<td>6</td>
<td>Resistor, precision thick film chip, R0805</td>
<td>750</td>
<td>1</td>
<td>N/A</td>
<td>ERJ-6ENF7500V</td>
</tr>
<tr>
<td>R33 to R35, R37</td>
<td>4</td>
<td>Resistor, precision thick film chip, R0805</td>
<td>100 kΩ</td>
<td>1</td>
<td>N/A</td>
<td>ERJ-6ENF1003V</td>
</tr>
<tr>
<td>R3A, R3B, R3C, R3N, R46, R4A, R4B, R4C, R4N</td>
<td>9</td>
<td>Resistor, film SMD, 0603</td>
<td>0</td>
<td>5</td>
<td>N/A</td>
<td>ERJ-3GEY0R00V</td>
</tr>
<tr>
<td>R5A, R5B, R5C, R5N, R6A, R6B, R6C, R6N</td>
<td>8</td>
<td>Resistor, precision thick film chip, R0603</td>
<td>1 kΩ</td>
<td>1</td>
<td>N/A</td>
<td>ERJ-3EKF1001V</td>
</tr>
<tr>
<td>Reference Designator</td>
<td>Qty</td>
<td>Description</td>
<td>Value</td>
<td>Tolerance</td>
<td>Voltage (V)</td>
<td>Part Number</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----</td>
<td>-------------</td>
<td>-------</td>
<td>-----------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>R7A to R9A, R7B to R9B, R7C to R9C</td>
<td>9</td>
<td>Resistor, high voltage thin film flat chip</td>
<td>33 kΩ</td>
<td>0.1</td>
<td>N/A</td>
<td>TNPV1206330KBE-EN</td>
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<tr>
<td>S1</td>
<td>1</td>
<td>5W SM mechanical keyswitch</td>
<td>B3S1000</td>
<td>N/A</td>
<td>N/A</td>
<td>B3S1000</td>
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<tr>
<td>U1, U12</td>
<td>2</td>
<td>Analog Devices, Inc. IC, 800 mA, ultralow noise, high PSRR, RF linear regulator (3.3 V output)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>ADM7150ACPZ-3.3</td>
</tr>
<tr>
<td>U10, U11</td>
<td>2</td>
<td>Analog Devices IC, quad-channel digital isolator</td>
<td>N/A</td>
<td>2.7 to 5.5</td>
<td>N/A</td>
<td>ADuM3401CRWZ</td>
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<tr>
<td>U3</td>
<td>1</td>
<td>IC, 32k bits, I2C serial EEPROM</td>
<td>24LC32A-I/MC</td>
<td>N/A</td>
<td>N/A</td>
<td>24LC32A-I/MC</td>
</tr>
<tr>
<td>U4</td>
<td>1</td>
<td>IC, 3.3 V to 5-tap economy timing element</td>
<td>DS1100LU-30+</td>
<td>N/A</td>
<td>N/A</td>
<td>DS1100LU-30+</td>
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<tr>
<td>U5</td>
<td>1</td>
<td>IC, tiny logic UHS inverter</td>
<td>NC7S2045P5X</td>
<td>N/A</td>
<td>N/A</td>
<td>NC7S2045P5X</td>
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<tr>
<td>U6</td>
<td>1</td>
<td>IC-TTL, single D-type flip-flop with asynchronous clear</td>
<td>SN74LV11G175D</td>
<td>N/A</td>
<td>N/A</td>
<td>SN74LV11G175-DCKR</td>
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<tr>
<td>U7</td>
<td>1</td>
<td>Analog Devices IC, 2.5 kV, isolated dc-to-dc converter</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>ADuM5000ARWZ</td>
</tr>
<tr>
<td>U8</td>
<td>1</td>
<td>Analog Devices IC, V, 3.75 kV, 6-channel, SPI isolator digital isolator for SPI with delay clock</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>ADuM3150ARZ</td>
</tr>
<tr>
<td>U9</td>
<td>1</td>
<td>Analog Devices IC, high performance, polyphase, energy metering AFE</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>ADE9078</td>
</tr>
<tr>
<td>VAN, VBN, VCN</td>
<td>3</td>
<td>Connector; PCB test point, brown</td>
<td>Brown</td>
<td>N/A</td>
<td>N/A</td>
<td>TP104-01-01</td>
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<tr>
<td>VAP, VBP, VCP</td>
<td>3</td>
<td>Connector; PCB test point, violet</td>
<td>Violet</td>
<td>N/A</td>
<td>N/A</td>
<td>TP104-01-07</td>
</tr>
<tr>
<td>VDO, VBUS</td>
<td>2</td>
<td>Connector; PCB test point, red</td>
<td>Red</td>
<td>N/A</td>
<td>N/A</td>
<td>TP104-01-02</td>
</tr>
<tr>
<td>Y1</td>
<td>1</td>
<td>IC, crystal SMD, low profile</td>
<td>12.288 MHz</td>
<td>N/A</td>
<td>N/A</td>
<td>ADE9078</td>
</tr>
</tbody>
</table>

1 N/A means not applicable.

I2C refers to a communications protocol originally developed by Philips Semiconductors (now NXP Semiconductors).

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