TI Designs
Solar Inverter Gateway Featuring AM335x

TEXAS INSTRUMENTS

TI Designs

TI Designs provide the foundation that you need including methodology, testing and design files to quickly evaluate and customize the system. TI Designs help *you* accelerate your time to market.

Design Resources

|	
TIDEP0044	Tool Folder Containing Design Files
AM3358	Product Folder
TMDXEVM3358	Product Folder
Sitara SDK	Product Folder

TI E2E™ Community

ASK Our E2E Experts
WEBENCH® Calculator Tools

Design Features

- Supports Co-Existence Of Wi-Fi®, CAN, RS-232, USB, Display, And Industrial Ethernet
- Compatible With TI's Power Line Communications Solutions
- Enables Development Of Real-World Solar Inverter Gateway Applications With Use Of Example Schematics, BOM, Design Files, And Links To Software

Featured Applications

- Solar Inverter Gateway
- Solar Microinverter Gateway
- Grid Communications
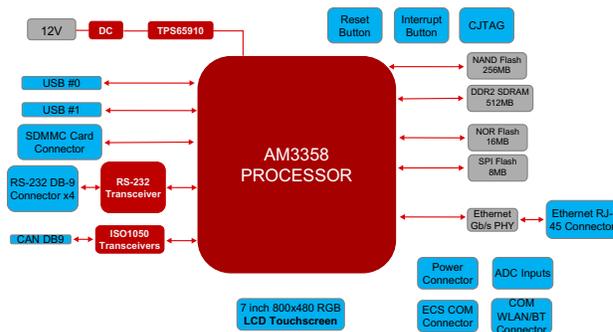
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General Texas Instruments High Voltage Evaluation (TI HV EVM) User Safety Guidelines

WARNING

Always follow TI's setup and application instructions, including use of all interface components within their recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and those working around you. Contact TI's Product Information Center http://support/ti./com for further information.

Save all warnings and instructions for future reference.

Failure to follow warnings and instructions may result in personal injury, property damage, or death due to electrical shock and burn hazards.

The term TI HV EVM refers to an electronic device typically provided as an open framed, unenclosed printed circuit board assembly. It is **intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise and knowledge of electrical safety risks in development and application of high voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments**. If you are not suitable qualified, you should immediately stop from further use of the HV EVM.

1. Work Area Safety

    (a) Keep work area clean and orderly.

    (b) Qualified observer(s) must be present anytime circuits are energized.

    (c) Effective barriers and signage must be present in the area where the TI HV EVM and its interface electronics are energized, indicating operation of accessible high voltages may be present, for the purpose of protecting inadvertent access.

    (d) All interface circuits, power supplies, evaluation modules, instruments, meters, scopes and other related apparatus used in a development environment exceeding 50Vrms/75VDC must be electrically located within a protected Emergency Power Off EPO protected power strip.

    (e) Use stable and nonconductive work surface.

    (f) Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.

2. Electrical Safety
    As a precautionary measure, it is always a good engineering practice to assume that the entire EVM may have fully accessible and active high voltages.

    (a) De-energize the TI HV EVM and all its inputs, outputs and electrical loads before performing any electrical or other diagnostic measurements. Revalidate that TI HV EVM power has been safely de-energized.

    (b) With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment connection, and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.

    (c) After EVM readiness is complete, energize the EVM as intended.

    WARNING: WHILE THE EVM IS ENERGIZED, NEVER TOUCH THE EVM OR ITS ELECTRICAL CIRCUITS AS THEY COULD BE AT HIGH VOLTAGES CAPABLE OF CAUSING ELECTRICAL SHOCK HAZARD.

3. Personal Safety

    (a) Wear personal protective equipment (for example, latex gloves or safety glasses with side shields) or protect EVM in an adequate lucent plastic box with interlocks to protect from accidental touch.

Limitation for safe use:

EVMs are not to be used as all or part of a production unit.

1 Design Overview

Solar Inverter Gateways add communication functions to solar energy generation systems to enable system monitoring, real-time feedback, system updates, and more. This TI design describes the implementation of a solar inverter gateway using display, Ethernet, USB, and CAN on the TMDXEVM3358 featuring TI's AM335x processor.

Table 1. Key System Specifications

FUNCTION	DESCRIPTION
Display	7-inch resistive touch, WVGA, 800 × 480
USB	USB OTG 2.0, host or device, plus microUSB AB connector
RGMII	One Gb / s Ethernet PHY and RJ-45 connector
CAN	One CAN transceiver and DB9 male connector
RS-232	Three RS-232 connectors DB9 male
Cortex-A8 Performance	Up to 1 GHz, 2000 DMIPs, with NEON SIMD coprocessor

2 System Description

The AM335x general purpose EVM, TMDXEVM3358, is well suited for the development of applications for the solar inverter gateway. While solar inverters convert solar power to AC power and perform measurements, solar inverter gateways analyze the measured information, convert to applicable communications protocols, and communicate the information to multiple end systems.

Having a wide array of peripherals is key to support the different interfaces used by the end systems, which can range from the power grid to plant management systems to a home user. Information about energy generation, efficiency, and system health may be transmitted over Wi-Fi or Ethernet to web-based products provided by inverter manufacturers for system monitoring. Wi-Fi or Ethernet connectivity can also be used to provide firmware updates to the solar inverter gateway.

In addition to these standard uses of Ethernet in gateways today, Ethernet connectivity in solar inverter gateways may be expanded in the future to offer greater connectivity to the power grid through use of industrial protocols. Some public organizations, such as the California Public Utilities Commission (CPUC), are currently considering recommending or requiring the use of industrial Ethernet protocols such as IEC61850 to communicate inverter data to grid automation systems in a standardized way. The intent is to keep the power grid stable as more distributed energy sources are added to the grid by increasing the communication between generating systems such as solar systems and the grid. IEC61850 is the current international standard for grid communications, and its use with solar inverters could provide a proven and common way for all solar inverters to receive commands from and report information to the utilities. This interoperability would allow utilities to use renewable resources in a more intelligent, coordinated, and efficient manner.

A USB port can be broken out on the gateway to enable connectivity options for home users. It may be preferred to offer optional USB dongles for Wi-Fi, Zigbee®, Z-Wave®, or other popular home automation wireless protocols rather than have all interfaces built in to the standard gateway when users will typically only use a single technology.

Communication over RS-232 or RS-485 (Modbus) or CAN allows the solar inverter gateway to connect to the inverters themselves or to the larger system for plant communications in a commercial setting, and can also be used to connect to third-party systems such as power meters if needed.

Power line communication may also be used to connect the inverters or micro-inverters to the gateway, and it has the advantage of not needing additional wiring or wireless configuration. Many solar-inverter-gateway products also include a display so that data can be read at the unit.
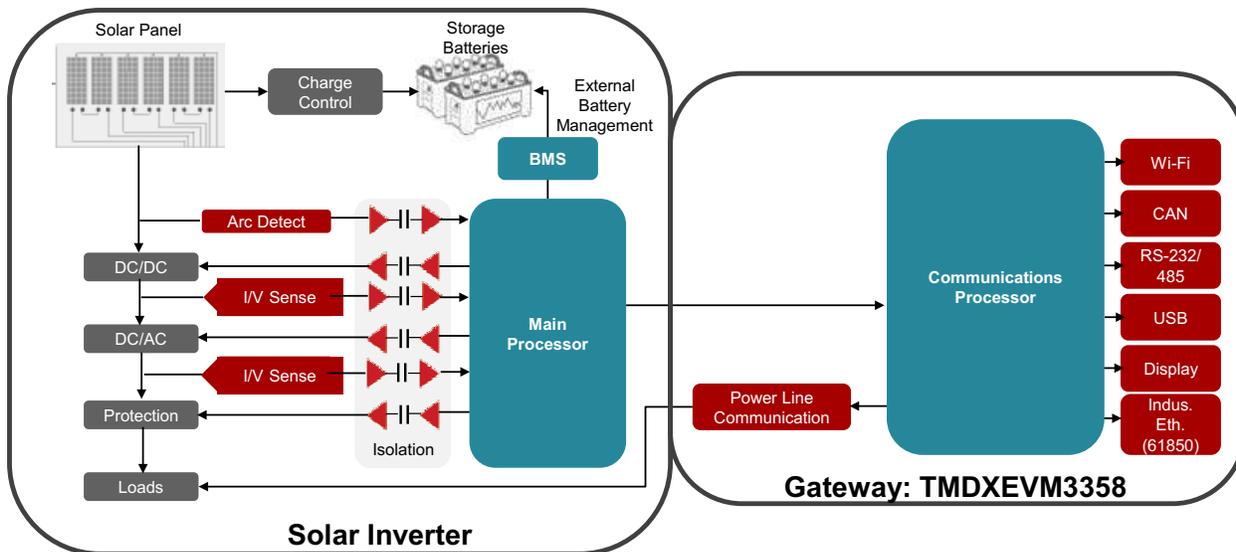
Figure 1. Solar Inverter Gateway Block Diagram Based on TMDXEVM3358

2.1 AM335x

AM335x has a wide range of peripherals and enough performance to run the various communication protocol stacks needed such as TCP / IP, or the substation automation standard IEC61850, which may be required by government organizations for solar inverter gateways in the future. This requirement is being considered by California's Public Utilities Commission in Rule 21 Phase 2. AM335x's ARM® Cortex®-A8 processor provides up to 2000 DMIPs and supports all interfaces commonly used in solar inverter gateways: two ports of Gigabit Ethernet, USB, two CAN interfaces, display, and six UART interfaces, which can be used for RS-232 or RS-485. Additionally, the AM335x is power efficient and can achieve total power consumption below 1 W with deep sleep as low as 3 mW.
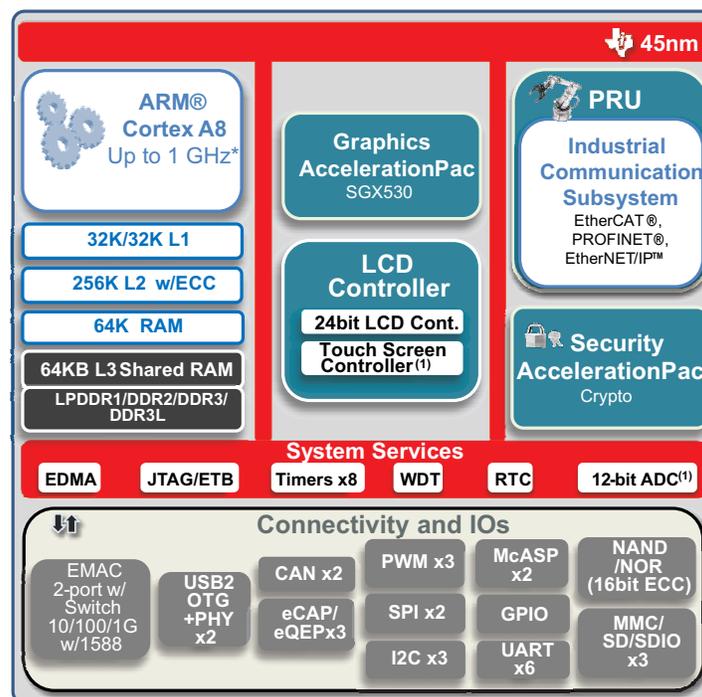
Figure 2. AM335x Block Diagram

3   Block Diagram
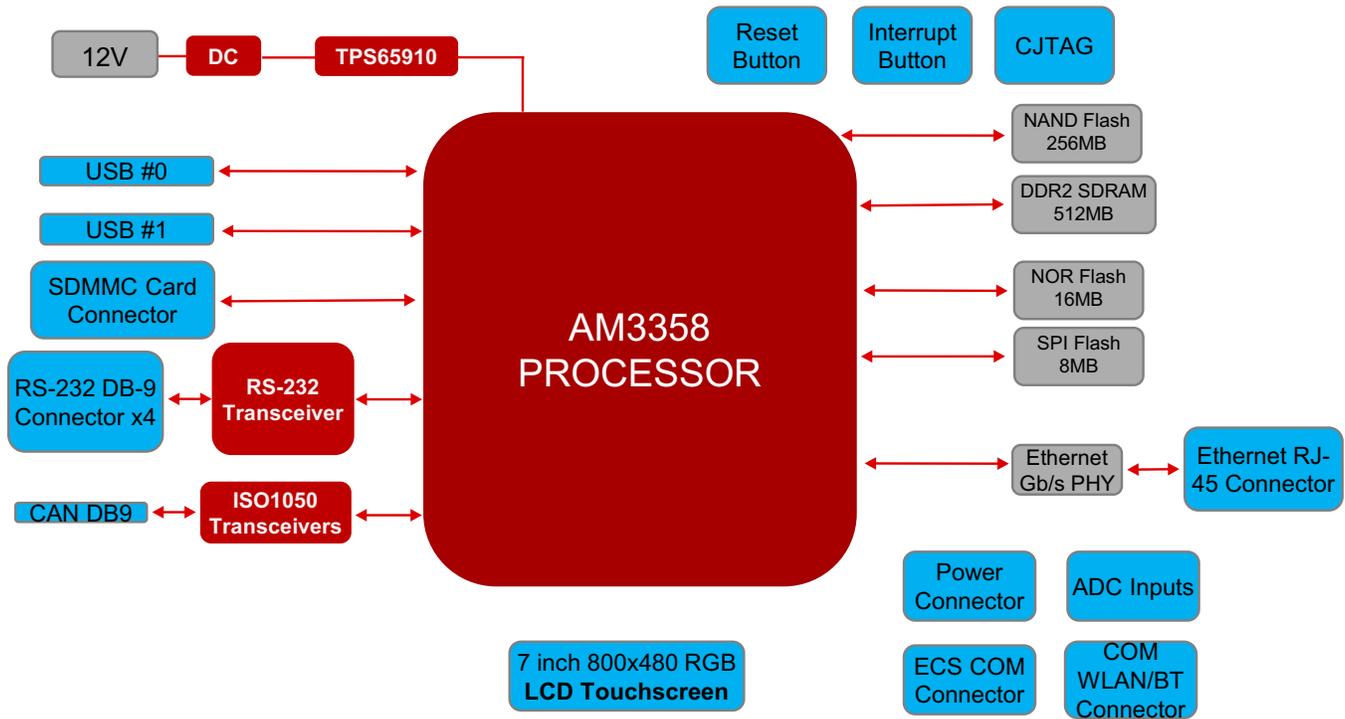
Figure 3. TMDXEVM3358 Block Diagram

4   Highlighted Products

4.1   AM335x

AM335x includes the following features:

- Up to 1-GHz Sitara™ARM® Cortex®-A8 32-Bit RISC Processor
  - NEON™ SIMD Coprocessor
  - 32KB of L1 Instruction and 32KB of Data Cache With Single-Error Detection (Parity)
  - 256KB of L2 Cache With Error Correcting Code (ECC)
  - 176KB of On-Chip Boot ROM
  - 64KB of Dedicated RAM
- On-Chip Memory (Shared L3 RAM)
- External Memory Interfaces (EMIF)
  - mDDR(LPDDR), DDR2, DDR3, DDR3L Controller:
    - mDDR: 200-MHz Clock (400-MHz Data Rate)
    - DDR2: 266-MHz Clock (532-MHz Data Rate)
    - DDR3: 400-MHz Clock (800-MHz Data Rate)
    - DDR3L: 400-MHz Clock (800-MHz Data Rate)
    - 16-Bit Data Bus
    - 1GB of Total Addressable Space
  - General-Purpose Memory Controller (GPMC)
- Programmable Real-Time Unit Subsystem and Industrial Communication Subsystem (PRU-ICSS)
  - Supports Protocols such as EtherCAT®, PROFIBUS, PROFINET, EtherNet/IP™, and More

- – Peripherals Inside the PRU-ICSS:
  - • One UART Port With Flow Control Pins, Supports up to 12 Mbps
  - • One Enhanced Capture (eCAP) Module
  - • Two MII Ethernet Ports that Support Industrial Ethernet, such as EtherCAT
  - • One MDIO Port
- • Peripherals
  - – Up to Two USB 2.0 High-Speed OTG Ports With Integrated PHY
  - – Up to Two Industrial Gigabit Ethernet MACs (10, 100, 1000 Mbps)
    - • Integrated Switch
    - • Each MAC Supports MII, RMII, RGMII, and MDIO Interfaces
    - • Ethernet MACs and Switch Can Operate Independent of Other Functions
    - • IEEE 1588v2 Precision Time Protocol (PTP)
  - – Up to Two Controller-Area Network (CAN) Ports
    - • Supports CAN Version 2 Parts A and B
  - – Up to Six UARTs
    - • All UARTs Support IrDA and CIR Modes
    - • All UARTs Support RTS and CTS Flow Control
    - • UART1 Supports Full Modem Control
  - – LCD Controller
    - • Up to 24-Bit Data Output; 8 Bits per Pixel (RGB)
    - • Resolution up to 2048 × 2048 (With Maximum 126-MHz Pixel Clock)
    - • Integrated LCD Interface Display Driver (LIDD) Controller
    - • Integrated Raster Controller
    - • Integrated DMA Engine to Pull Data from the External Frame Buffer Without Burdening the Processor via Interrupts or a Firmware Timer
    - • 512-Word Deep Internal FIFO
    - • Supported Display Types:
      - • Character Displays - Uses LIDD Controller to Program these Displays
      - • Passive Matrix LCD Displays - Uses LCD Raster Display Controller to Provide Timing and Data for Constant Graphics Refresh to a Passive Display
      - • Active Matrix LCD Displays - Uses External Frame Buffer Space and the Internal DMA Engine to Drive Streaming Data to the Panel
  - – 12-Bit Successive Approximation Register (SAR) ADC
    - • 200K Samples per Second
    - • Input can be Selected from any of the Eight Analog Inputs Multiplexed Through an 8:1 Analog Switch
    - • Can be Configured to Operate as a 4-Wire, 5-Wire, or 8-Wire Resistive Touch Screen Controller (TSC) Interface
- • Security
  - – Crypto Hardware Accelerators (AES, SHA, PKA, RNG)

5   System Design Theory

Solar inverter systems typically consist of two processing subsystems, one for the inverting, typically a specialized MCU such as TI's C2000 MCUs, and one for communications. The communications subsystem is typically housed in a separate enclosure from the inverter and is referred to as a gateway ("solar inverter gateway"), which performs the communications tasks for the system, communicating with the system owner, the plant, the utility grid, and the cloud.

We provide a reference hardware platform, TMDXEVM3358, and related Linux drivers for the communication processor side of the system. The TMDXEVM3358 includes a seven-inch resistive touch display screen and breaks out two USB ports, four RS-232 DB-9 male connectors, one CAN male DB-9 connector, and one gigabit Ethernet PHY, as well as other system peripherals like I^2C expanders and memory. The TMDXEVM3358 also has a connector for additional Wi-Fi or Bluetooth® module via TI's WL1835. These interfaces allow for the board to be used to develop systems for the solar inverter gateway, which require peripherals such as Ethernet to connect to web based services, CAN or RS-485 to connect to remote inverters, and USB and display for simple HMI communications.

The Linux SDK provides drivers and simple example code for USB, display, and Ethernet as well as CAN and UART for RS-232 to enable developers to get started communicating over the on-board peripherals quickly.

6   Getting Started Hardware

The TMDXEVM3358 can be used as an evaluation board for getting started with a solar inverter gateway design based on AM335x. Refer to the Hardware User's Guide for a detailed description of system peripherals and information on system configuration for startup, and more related to the TMDXEVM3358.

For moving beyond the evaluation board, a number of resources will be helpful to get the design started such as the AM335x Hardware Design Guide and information on AM335x Power Solutions. Further resources for AM335x designs can be found on the AM335x portal.

7   Getting Started Software

To get started programming the AM335x General Purpose EVM, first boot the device using the provided micro SD card for Linux. The device will then display a set of OS demos that can be accessed to learn about Linux performance on the AM3358. Check for the latest version of Linux for the AM335x here.

For more information on how to get started with the Linux software development kit (SDK) for AM335x, please see the Processors SDK Linux Getting Started Guide, which contains information on starting Linux development. Further resources on the Linux SDK such as training, how to guides, and release notes can be found on the Sitara Linux Software Developer's Guide. The AM335x Software Design Guide provides a walkthrough of designing software for the AM335x processor, and it includes links to useful documentation, application reports, and design recommendations.

8   Design Files

8.1   Purchasing the TMDXEVM3358 AM335x General Purpose EVM

The TMDXEVM3358 AM335x General Purpose EVM can be purchased from the TI Store. Please refer to TMDXEVM3358.

8.2   Schematics

To download the schematics, see the design files at TIDEP0044.

8.3   Bill of Materials

To download the bill of materials (BOM), see the design files at TIDEP0044.

8.4   PCB Layout

To download the PCB layout, see the design files at TIDEP0044.

8.5 Gerber Files

To download the Gerber files, see the design files at TIDEP0044.

8.6 Software Files

To download the software files, see the design files at TIDEP0044.

8.7 Alternative Platforms

For those whose solar inverter gateway design or development does not require RS-232 or CAN connectivity, the TMDSSK3358 is a lower cost alternative to the TMDXEVM3358 which still provides Ethernet, USB, and display connectivity. The TMDSSK3358 is a lower feature set board which is also based on the AM335x processor; please refer to TMDSSK3358 for more information on the TMDSSK3358 such as schematics, bill of materials, and purchasing. Details of differences between the TMDXEVM3358 and TMDSSK3358 are shown in the chart below.

Table 2. Differences between the TMDXEVM3358 and TMDSSK3358

Feature	TMDXEVM3358	TMDSSK3358
Memory	512MB DDR2 + 256MB NAND Flash	256MB DDR3
Processor	AM3358	AM3358
Speed	720 MHz	720 MHz
Display	7" LCD Resistive Touchscreen	4.3" LCD Resistive Touchscreen
Resolution	WVGA 800 × 400	wQVGA 780x273
MMC / SD	2 full	1 micro
USB	OTG (Host or Device)	1x OTG (Host or Device), 1x Host
Ethernet	10 / 100 / 1000	10 / 100 / 1000
I / O Expansion	Yes	None
UART	4	None
CAN	Yes	None
Wi-Fi / Bluetooth Connector	Yes	None
Linux, Android, and StarterWare	Yes	Yes
PMIC	TPS65910	TPS65910
Debug	20 pin JTAG connector	XDS100 emulator onboard via USB

9 References

1. G3 Power Line Communications Data Concentrator on BeagleBone Black Platform (TIDEP0023)
2. TPS65910 product folder (TPS65910)
3. Smart Home and Energy Gateway Reference Design (TIEP-SMART-ENERGY-GATEWAY)

10 About the Author

ELLEN BLINKA is a Product Marketing Engineer at Texas Instruments, where she is responsible for applications of ARM and DSP processors in the smart grid and energy segment. Ellen earned her Master of Engineering in Electrical Engineering (MEn) from Texas A&M University in College Station, TX.

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