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Battery Management and Auxiliary Power Supply Options for E-Meters

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TIDM-AUX-MODULE	Design Page
MSP430F67791A	Product Folder
TPS77033	Product Folder
EVM430-F6779	Tool Folder

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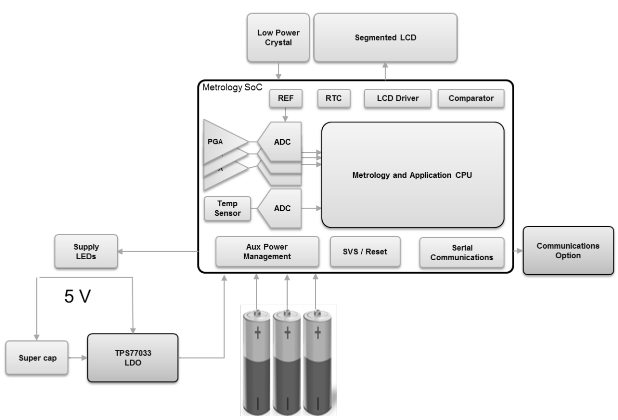
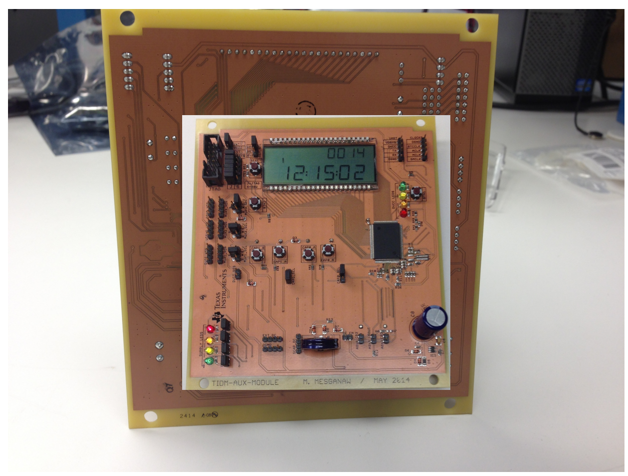
Design Features

- Two Types of Power Sources for the Auxiliary Supply of the Host MCU:
  - Independent Regulator with Super-Cap Backup
  - Two AAA Batteries
- Separate Power Supply for Real-Time Clock (RTC)
- Automatic Time Capture of External Events for Tamper Detection
- Automated or Manual Switching of Power Supply
- Automated Power Supply Monitoring

Featured Applications

- Energy Meters
- Flow Meters





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1 System Description

Many systems often require functionality in the absence of a primary power supply. If the primary power supply fails, an alternative power supply must be used to ensure basic functionality for critical systems that should never go offline.

One example of a system that should withstand the absence of a primary power supply is an electric meter, which is used to measure energy consumption. An electric meter is primarily powered from Mains voltage; however, during a power blackout, requirements mandate that the system cannot turn off in the absence of the Mains. In addition, despite the absence of the Mains supply, some tasks must still be performed, such as keeping track of time or case tamper detection. Meter designs fulfill this requirement by using alternative power sources such as back-up batteries, super capacitors, power from a current transformer sensor, or other methods. These alternative power sources are activated when the Mains voltage is not available. To interface the primary power supply with the alternative power supply and switch between these power supplies typically require external components, which add to the cost of the meter design. In addition, using external components limits the flexibility in configuring how the primary and auxiliary supplies interface with each other and when to switch between the different supplies.

In Texas Instrument's MSP430F67xx smart meter MCUs, an integrated auxiliary supply system module is available to flexibly operate the chip from its primary power supply or its auxiliary power supplies. This module reduces the number of external components necessary, reducing the bill of material (BOM) costs in the often cost-sensitive application of energy metering.

2 Design Features

2.1 AUX Module Description

The auxiliary (AUX) power supply allows multiple power sources to power the MSP430 in addition to the power source connected to DVCC and AVCC. Figure 1 shows the functional block diagram of the AUX module within the MSP430F67xx devices:

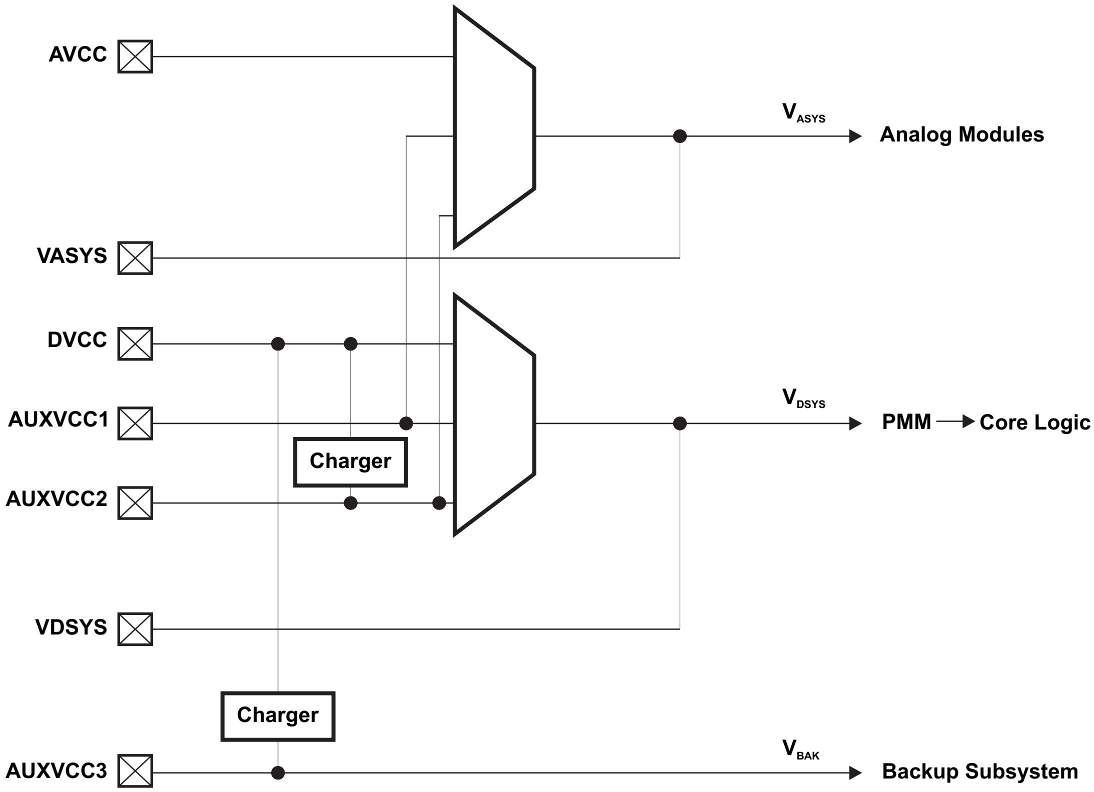

Figure 1. AUX Module Functional Block Diagram

As shown in Figure 1, VASYS supplies the power to the analog modules. Similarly, the digital core of the device is supplied by VDSYS. VASYS and VDSYS can be supplied from the primary supply (DVCC and AVCC) or two auxiliary supplies (AUXVCC1 or AUXVCC2). When using an auxiliary supply, both VASYS and VDSYS are switched to the same auxiliary supply. The selected power supply can be changed in the software or can be selected automatically in the hardware using a user-specified threshold voltage. When switching supplies, full functionality is maintained.

AUXVCC1 and AUXVCC2 supplies differ primarily in two ways. First, AUXVCC2 has a charger present, which can be used to charge any capacitors connected to AUXVCC2. Second, at startup, the chip could be started from either AUXVCC1 or DVCC, depending on which supply has the higher voltage. In software, the AUXVCC2 supply can be prioritized for switching before AUXVCC1 or vice versa.

For hardware switching, the MSP430F67xx's SVM module monitors the currently used power supply. When this voltage falls below the SVMH level, it triggers to switch to any other valid supply. The health status of possible supplies to switch to is updated by a low-power comparator, as shown in Figure 2:

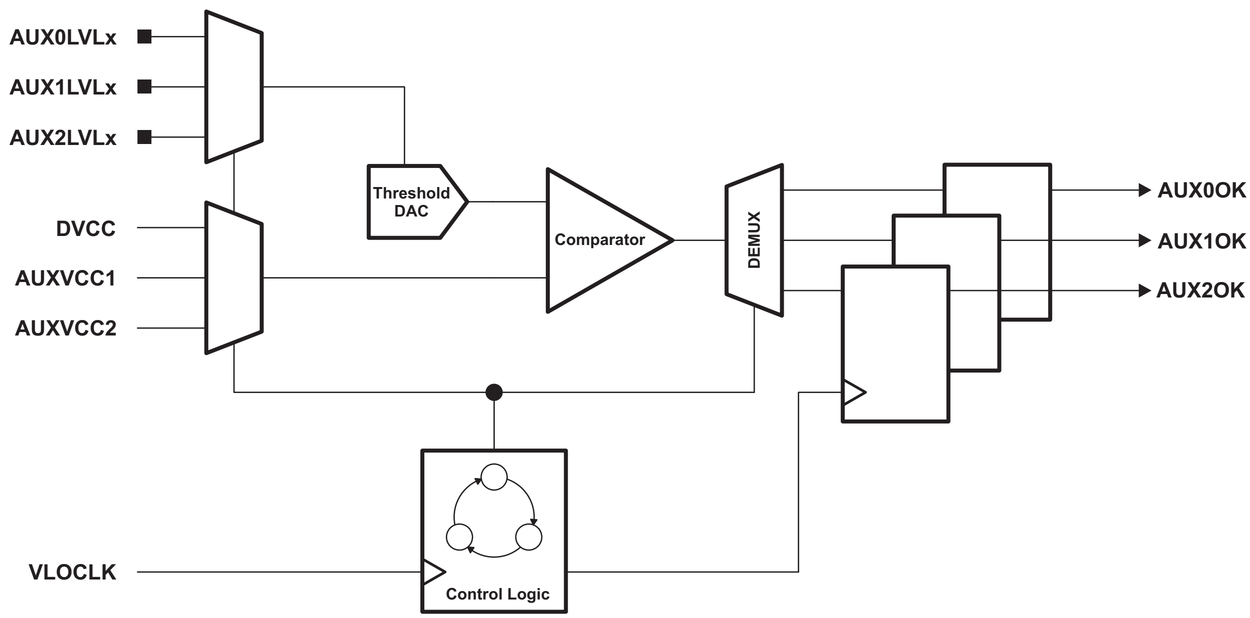

Figure 2. Auxiliary Supply Monitor Block Diagram

When DVCC, AUXVCC1, and AUXVCC2 are not currently in use and are not software controlled, these power supplies are monitored using a low-power comparator. These supplies are compared to a supply-specific user-defined threshold to determine their health statuses. For example, if DVCC supplies the device and AUXVCC1 and AUXVCC2 are hardware controlled, then AUXVCC1 and AUXVCC2 are monitored. If AUXVCC1 supplies the device and AUXVCC2 is software controlled, only DVCC is monitored. If all unselected supplies are controlled by software, then the automatic monitoring is disabled. For AUXVCC1 or AUXVCC2, switching does not occur when a supply is deemed valid by the low-power comparator; instead, switching occurs based on the SVM trigger. In contrast, for DVCC, switching can occur whenever the low-power comparator indicates that DVCC (also referred to as AUX0) is valid.

If two supplies are monitored, they are monitored in a time-division multiplexing scheme clocked by the very low oscillator (VLO). During one VLO clock period, one supply is compared against its AUXxLVLx threshold; during another VLO clock period, the other supply is compared against its own AUXxLVLx threshold. The corresponding voltages for each user-defined threshold level for both SVMH and the AUXxLVL are shown in Table 1 (from SLAS983):

Table 1. SVM_H/AUXLVL Levels and Corresponding Voltages

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{Monitor}$	Auxiliary supply threshold level (same as high-side SVM)	General	V_{SVMH} (SVSMHRRLx = AUXLVLx) X – 5%	V_{SVMH} (SVSMHRRLx = AUXLVLx)	V_{SVMH} (SVSMHRRLx = AUXLVLx) X + 5%	V
		AUXLVLx = 0	1.65	1.75	1.85	
		AUXLVLx = 1	1.85	1.95	2.05	
		AUXLVLx = 2	2.05	2.15	2.25	
		AUXLVLx = 3	2.15	2.25	2.35	
		AUXLVLx = 4	2.30	2.40	2.55	
		AUXLVLx = 5	2.57	2.70	2.83	
		AUXLVLx = 6	2.90	3.00	3.20	
		AUXLVLx = 7	2.90	3.00	3.20	

Besides AUXVCC1 and AUXVCC2, there is one more auxiliary supply: AUXVCC3. AUXVCC3 is used to power a backup subsystem, which contains a real-time clock (RTC) module with a 32-kHz crystal oscillator, some backup RAM, and up to two digital I/O pins. AUXVCC3 is independent of VDSYS, which allows the RTC to keep functioning while the rest of the chip has no power. In addition, a charger on AUXVCC3 allows capacitors connected to the auxiliary supply to be charged internally by DVCC (AUXVCC3 is not a possible source for VDSYS and VASYS as is the case for AUXVCC1 and AUXVCC2). Also, since AUXVCC3 is the power source for the low frequency oscillator, power must be available at this auxiliary supply (whether externally or through the internal charger) to properly use the RTC or use the low frequency oscillator as a clock reference into the FLL.

For more details on the AUX module, refer to the User's Guide for the MSP430 F5xx and MSP430x6xx Family (SLAU208).

2.2 Design Components

2.2.1 MSP430F67791A

The MSP430F67xx(A) devices all have the AUX module. However, out of all the MSP430F67xx(A) devices, the AUX module within the MSP430F6779(1)A and its variants have the most features compared to the AUX module of the other F67xx(A) devices. When compared to the F672x and F673x, the F6779(1)(A) has the ability to take a time capture of external events. Also, when compared to the F6779(1), the F6779(1)A chips have the ability to lock the RTC to reduce the necessary amount of reconfiguration under specific reset conditions. Because the AUX module within the MSP430F6779(1)A has the most features, the MSP430F67791A is used specifically to showcase the ability of the F67xx AUX module in this TI Design.

2.2.2 JTAG For Debugging

A JTAG interface is available in this design for programming and debugging the MSP430F67791A. Headers are available to choose between using 4-wire JTAG or 2-wire SBW programming. By connecting a FET tool to the JTAG interface and making the proper selection, DVCC can be powered from the FET tool. Alternatively, DVCC and the debugger can be powered from an external source. To enable debugging regardless of whether the primary supply or the auxiliary supply is used to power the chip, the FET tool can be powered from VDSYS via jumper.

2.2.3 LCD

The LCD controller on the MSP430F67xx(A) can support up to 8-mux displays and 320 segments. The controller is also equipped with an internal charge pump that can be used for good contrast. In the current design, the LCD controller is configured to work in 4-mux mode using 160 segments with a refresh rate set to ACLK/64, which is 512 Hz. In this particular design, the LCD is used to display information about the power status of the primary and auxiliary supplies or the RTC time.

2.2.4 Status LEDs

In this design, one LED is provided for each auxiliary supply, and five LEDs are provided for DVCC. Four DVCC-powered LEDs are also present in addition to the one DVCC LED. Please note that these LEDs are powered from their respective supplies and can be used as a crude supply-health status indicator, and each supply LED can only be used when its corresponding supply is present. For example, in the case where DVCC is not present and the chip is being powered from AUXVCC1, the DVCC supply LED (or any other external components that use DVCC as a power source) will not work because it is powered from DVCC, which is not available; however, the AUXVCC1 supply LED will work since AUXVCC1 is present.

2.2.5 User Buttons

This design has six event-simulation buttons with four usable buttons (select buttons through the jumpers). Two buttons connect to the port interrupt pins on the MSP430F67791A. One of these buttons connect to DVCC and the other button connects to VDSYS. Please note that the button connected to VDSYS will work as long as either DVCC, AUXVCC1, or AUXVCC2 is present because it powers the switched supply used to power the chip. However, the DVCC switch will only work when DVCC is available. To avoid drawing too much current from VDSYS and VASYS, the pull-up resistor of the VDSYS button is selected to be a high value.

The other two buttons are connected to the RTCCAP pins. These RTCCAP pins are powered from AUXVCC3 and can be used to log the RTC time whenever a simulated external event occurs. One typical application for this is meter case tampering. By connecting a switch to a meter case, the switch is either pressed or unpressed whenever the meter case is opened, which the connected processor can detect. By connecting the switch input to the RTCCAP pin, the processor can also record when the meter case opened.

2.2.6 Comparator

The MSP430F67791A also has a comparator module independent of the AUX module. The integrated comparator can be connected externally to AUXVCC3 to determine when the voltage is below a certain threshold without having to constantly measure the AUXVCC3 supply using the ADC10 and having to perform a software check to determine when the measured reading is too low. As a result, it can save CPU cycles for threshold-voltage monitoring. A typical use-case for this may be for when a battery is present on AUXVCC3 and an alert must be provided when the battery is too low. By connecting AUXVCC3 to the comparator, it can be compared to determine when its voltage has passed the *low voltage* threshold so that it could alert the user to change the AUXVCC3 battery.

Alternatively, the comparator can be used to monitor the input voltage of a regulator to determine when its voltage is dropping. Since the regulator input voltages are typically too high for the MSP430, these voltages may need to be divided down. In this design, two resistor footprints are provided between the comparator input and AGND to allow for any necessary voltage division to interface to the MSP430.

2.2.7 UART

This design has UART headers that can be used for communication. The UART signals are at TTL levels. These signals can connect to an RS-232 port through a UART-to-RS-232 interface, such as TIDA-00163.

2.2.8 Power Sources

Since many e-meter designs have an LDO connected to the primary supply, this design adds the TPS77033 LDO as a possible power source. By supplying 5-9 V to the *EXT_DC* header, the LDO produces a 3.3-V signal that can be connected to any of the power supplies by selecting the proper supply header configuration. In addition, the 5-to-9-V input can be used to charge the onboard super capacitor to approximately 5 V. The super capacitor can then be connected to the LDO input so that if there is an absence of voltage on the *EXT_DC* header, the super capacitor can provide voltage to the LDO input. This connection results in a 3.3-V regulator output when there is sufficient voltage on the super capacitor. In this design, the super capacitor is placed on the input of the LDO because the LDO input can support a larger voltage than the LDO output. As a result, by using the TPS77033 LDO, the super capacitor can be charged to a higher voltage, thereby increasing the time that the chip can run off the super capacitor than if the super capacitor was put on the LDO output. In addition, by putting the super capacitor on the LDO input, the chip voltage remains constant at 3.3 V while the super capacitor has enough voltage, despite the fact that the super capacitor voltage is falling.

NOTE: Because AUXVCC2 and AUXVCC3 have their own internal chargers that can charge caps to DVCC, the super capacitor charging circuitry may be more relevant to the AUXVCC1 power supply. Also, the charging resistor in this design may need to modified to fulfill a user’s required charging time and maximum current consumption restraints.

Another power source for AUXVCC1, AUXVCC2, and AUXVCC3 is the onboard batteries on the back side of the board. Each of the auxiliary power supplies has its own set of batteries so that these supplies can be powered from different physical sources. When the battery power source option is selected for an auxiliary supply power source, the battery is interfaced to the auxiliary supply through diodes.

AUXVCC3's battery diode powers AUXVCC3 by either DVCC (through the internal DVCC charger) or the battery. Figure 3 shows a typical use-case for this scenario. In this scenario, DVCC is connected to a Mains-derived power source with the internal charger enabled and AUXVCC3 is connected through a diode to an external battery. When Mains is available, DVCC allows AUXVCC3 to be powered from mains, which is more than sufficient to supply AUXVCC3. When there is a power outage, the battery then powers AUXVCC3 and keeps the RTC functional, despite the rest of the chip not having power. In this configuration, because there is no power to any of the auxiliary power supplies, no processing can be done when DVCC is not present, regardless of whether AUXVCC3 has power.

NOTE: Whenever AUXVCC1 or AUXVCC2 is not intended to be used, all unused supplies must be connected to DVSS and disabled in the software.

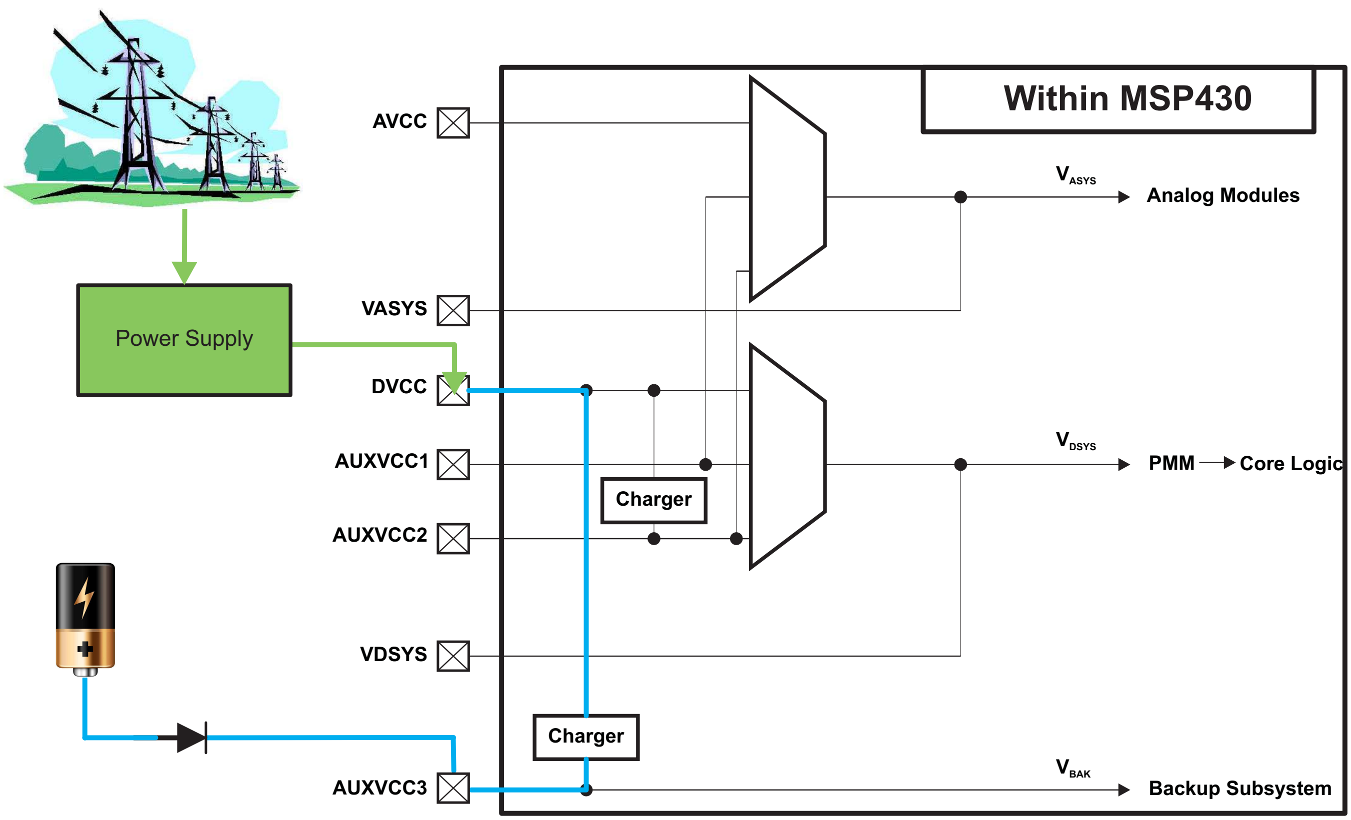

Figure 3. AUX Configuration for RTC-Only Back-Up Power

As an alternative, AUXVCC3 can instead be connected to VDSYS and a battery can be connected to one of the auxiliary power supplies, as shown in the scenario in Figure 4:

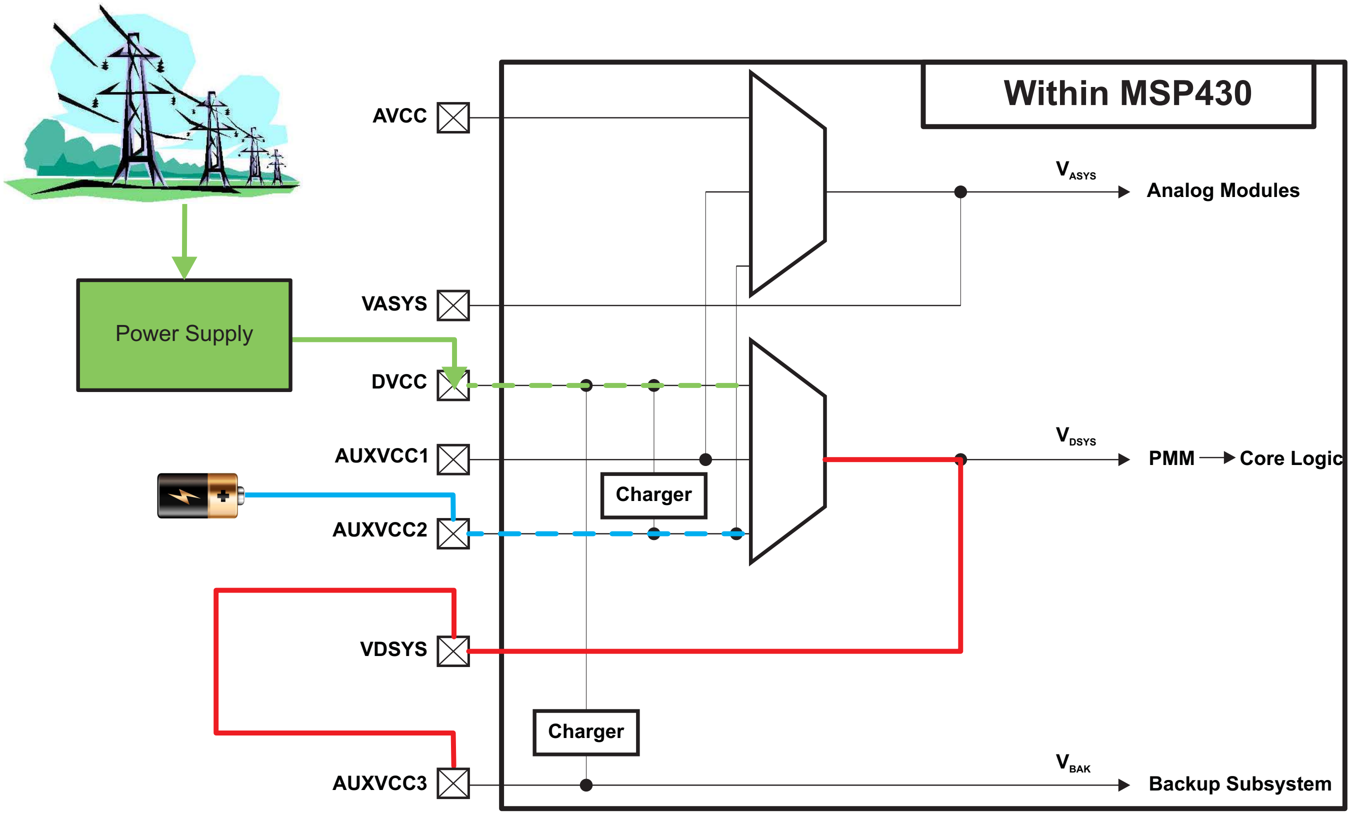

Figure 4. AUX Configuration for RTC and MSP430 Back-Up Power

In this scenario, AUXVCC3 will be powered by whichever supply is powering the chip. Also, because AUXVCC2 is available, the MSP430 can process in the absence of mains voltage. However, since the chip is being powered in this scenario, the current consumption from the battery would be greater than the case shown in Figure 3. To help mitigate this, the MSP430 can be placed in a low-power mode when running on a battery.

2.2.9 Header and Jumper Settings

Table 2. Header Names and Jumper Settings

HEADER (OR OPTION NAME)	TYPE	MAIN FUNCTIONALITY	VALID USE-CASE
A1_LE	2-Pin Jumper Header	AUX1_LED Enable	To conserve power, the AUX1_LED has a header option that could be used to disable it. Place a jumper here to enable this LED.
A2_LE	2-Pin Jumper Header	AUX2_LED Enable	To conserve power, the AUX2_LED has a header option that could be used to disable it. Place a jumper here to enable this LED.
A3_LE	2-Pin Jumper Header	AUX3_LED Enable	To conserve power, the AUX3_LED has a header option that could be used to disable it. Place a jumper here to enable this LED.
AUX1_HDR	4-Pin Header	AUXVCC1 Monitor and External Power Input	This is not a jumper header. This header can be used to measure AUXVCC1 or provide external power to it. To use external power, make sure that no jumpers are enabled in AUX1_SEL and provide voltage directly to this header.
AUX1_SEL	3×2-Pin Jumper Header	AUXVCC1 Power Source Select	Place a jumper in the “B” option to power this supply from battery. Place a jumper in the “G/V” option to disable this supply by connecting it to GND. Place a jumper in the “R” option to connect this supply to the LDO. Do not place a jumper here, and provide power to AUX1_HDR to power AUXVCC1 from an external bench supply.
AUX2_HDR	4-Pin Header	AUXVCC2 Monitor and External Power Input	This is not a jumper header. This header can be used to measure AUXVCC2 or provide external power to it. To use external power, make sure that no jumpers are enabled in AUX2_SEL and provide voltage directly to this header.
AUX2_SEL	3×2-Pin Jumper Header	AUXVCC2 Power Source Select	Place a jumper in the “B” option to power this supply from battery. Place a jumper in the “G/V” option to disable this supply by connecting it to GND. Place a jumper in the “R” option to connect AUXVCC2 to the LDO. Do not place a jumper here, and provide power to AUX2_HDR to power AUXVCC2 from an external bench supply.
AUX3_HDR	4-Pin Header	AUXVCC3 Monitor and External Power Input	This is not a jumper header. This header can be used to measure AUXVCC3 or provide external power to it. To use external power, make sure that no jumpers are enabled in AUX3_SEL and provide voltage directly to this header.
AUX3_SEL	3×2-Pin Jumper Header	AUXVCC3 Power Source Select	Place a jumper in the “B” option to power this supply from battery. Place a jumper in the “G/V” option power AUXVCC3 by VDSYS. Place a jumper in the “R” option to connect AUXVCC3 to the LDO. Do not place a jumper here, and provide power to AUX3_HDR to power AUXVCC3 from an external bench supply.
CAP0_SEL	3-Pin Jumper Header	RTCCAP0 Push-Button Selection	Place a jumper at the bottom two pins of this jumper header to connect CAP0_A (powered from VDSYS) to RTCCAP0. Place a jumper at the top two pins of this jumper header to connect CAP0_B (powered from AUXVCC3) to RTCCAP0. Recommended use-case is to place jumper on top two-pins.

Table 2. Header Names and Jumper Settings (continued)

HEADER (OR OPTION NAME)	TYPE	MAIN FUNCTIONALITY	VALID USE-CASE
CAP1_SEL	3-Pin Jumper Header	RTCCAP1 Push-Button Selection	Place a jumper at the bottom two pins of this jumper header to connect CAP1_B (powered from AUXVCC3) to RTCCAP0. Place a jumper at the top two pins of this jumper header to connect CAP1_A (powered from VDSYS) to RTCCAP1. Recommended use-case is to place jumper on bottom two pins.
CB2	2-Pin header	Comparator Input 2 Header	This is not a jumper header. This header is fed into the “CB2” comparator input. Two resistor footprints are available in case it is desired to divide down a voltage and feed it into CB2.
CB3	2-Pin header	Comparator Input 3 Header	This is not a jumper header. This header is fed into the “CB3” comparator input.
CBOUT	2-Pin header	Comparator Output	This is not a jumper header. This is the output of the comparator module.
Clocks	5-Pin Header	Clock Output Header	This is not a jumper header. Probe here to measure the MCLK, SMCLK, and ACLK clocks. The RTCCLK clock is also provided for RTC calibration.
D_LE	2-Pin Jumper Header	DVCC_LED Enable	To conserve power, the DVCC_LED has a header option that could be used to disable it. Place a jumper here to enable this LED.
DBG_PWR	4-Pin Jumper Header	JTAG Power Selection	This is the unnamed 4-pin header near the JTAG connector. Please note that only one jumper should be placed between two of four positions. Two jumpers should not be placed on this jumper. Place a jumper between “INT” and “DVCC” to power DVCC from the FET tool. Place a jumper between “EXT” and “DVCC” to power the FET tool externally from “DVCC”. Place a jumper between “EXT” and “VDSYS” to power the FET tool from VDSYS. This option will enable debugging irrespective of what is the power supply for VDSYS.
DGND	4-Pin Header	DGND	This is not a jumper header. This header is placed near the “EXT_DC” header to facilitate connecting an external bench supply to the “EXT_DC” header.
DGND_HDR	4-Pin Header	DGND	Not a jumper header, probe here for GND voltage. Connect negative terminal of bench or external power supply when powering the board externally.
DVCC_HDR	4-Pin Header	DVCC Monitor and External Power Input	This is not a jumper header. This header can be used to measure DVCC or provide external power to it. To use external power, make sure that a jumper does not exist on the DVCC_REG header.
DVCC_REG	2-Pin Jumper Header	DVCC Regulator Select	Place a jumper here to connect DVCC to the LDO output.
EXT_DC	4-Pin Header	LDO/Super Cap Input Voltage	This is not a jumper header. Connect the positive terminal of bench or external power supply here to provide voltage to the input of the LDO to provide the 3.3 V LDO output. This header is also used as the source to charge the super capacitor, when it is enabled. Please note that the voltage applied here should be 5 V.

Table 2. Header Names and Jumper Settings (continued)

HEADER (OR OPTION NAME)	TYPE	MAIN FUNCTIONALITY	VALID USE-CASE
J	Jumper Header Option	4-Wire JTAG Programming Option	Place jumpers at the J header options of all of the six JTAG communication headers to select 4-wire JTAG. There are six headers that jumpers must be placed at to select a JTAG communication option. Each of these six headers have a J option and an S option to select either 4-wire JTAG or SBW. To enable 4-wire JTAG, all of these headers must be configured for the J option. To enable SBW, all of the headers must be configured for the S option.
S	Jumper Header Option	SBW JTAG Programming Option	Place jumpers at the S header options of all of the six JTAG communication headers to select SBW. There are six headers that jumpers must be placed at to select a JTAG communication. Each of these six headers that have a J option and an S option to select either 4-wire JTAG or SBW. To enable 4-wire JTAG, all of these headers must be configured for the J option. To enable SBW, all of the headers must be configured for the S option.
SC_EN	2-Pin Jumper Header	Super Capacitor Enable	Place a jumper here to enable the super capacitor. By placing a jumper here, the super capacitor would get charged from the “EXT_DC” header and it will supply voltage to the LDO input when there is no voltage at “EXT_DC”.
SCAP_DC	4-Pin Header	Super Capacitor Voltage Monitor	This is not a jumper header. Probe here to measure the voltage of the super capacitor.
UART	5-Pin Header	UART Communication Header	This is not a jumper header. This header can be interfaced to a UART to RS-232 converter to allow communication from the MSP430F67791A and a computer.
VDSYS_HDR	4-Pin Header	VDSYS Monitor	This is not a jumper header. Probe here to measure the voltage that is currently being used to power the chip.

3 Block Diagram

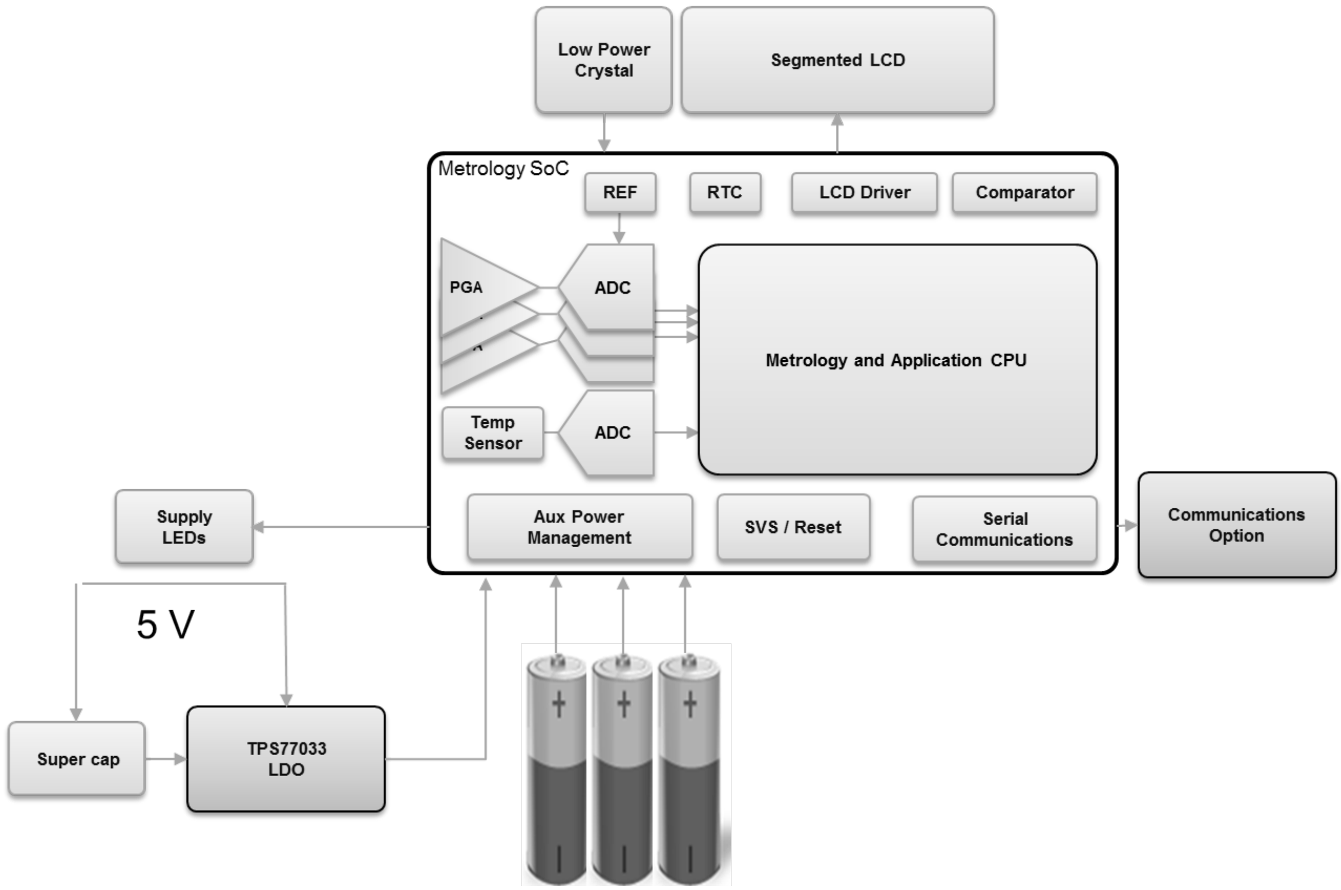

Figure 5. System Block Diagram

4 Software Description

Table 3. Code Examples Descriptions

SOFTWARE NAME	BRIEF DESCRIPTION
MSP430F6779_AUX_01.c	• Software controlled switching of the AUX supplies • LCD displays the supply selected to power the chip (DVCC, AUXVCC1, or AUXVCC2) • Pressing BTN2 switches the selected supply
MSP430F6779_AUX_02.c	• Software controlled switching of the AUX supplies • LCD displays the supply selected to power the chip (DVCC or AUXVCC1) • Pressing BTN2 switches the selected supply between DVCC and AUXVCC1 • AUXVCC2 is disabled
MSP430F6779_AUX_03.c	• Hardware controlled switching of the AUX supplies • Bottom row of the LCD displays the RTC time • AUXVCC3 is connected to VDSYS. As a result, the RTC will be powered regardless of whether AUXVCC1, AUXVCC2, or DVCC is powering the chip • Switching occurs at SVSMH level 4 • AUXVCC1 and AUXVCC2 are determined as valid supplies when its voltage exceeds level 5 • DVCC is considered valid when it exceeds level 6 • When both AUX1 and AUX2 are valid supplies, AUX2 has a higher priority than AUX1 for switching • When AUXVCC1 or AUXVCC2 voltage is present and the voltage drops below the AUX threshold, the corresponding AUX status LED is turned off and the empty battery segment on the LCD blinks • Whenever a supply switch occurs, the supply that is switched to is displayed on the top row of the LCD (such as "AU0" for DVCC, "AU1" for AUX1, and "AU2" for AUX2)
MSP430F6779_AUX_04.c	• Hardware controlled switching of the AUX supplies • Bottom row of the LCD displays the RTC time • AUXVCC3 is connected to VDSYS. As a result, the RTC will be powered regardless of whether AUXVCC1 or DVCC is powering the chip • Switching occurs at SVSMH level 4 • AUXVCC1 is determined as a valid supply when its voltage exceeds level 5 • DVCC is considered valid when it exceeds level 6 • AUXVCC2 is disabled • Whenever a supply switch occurs, the supply that is switched to is displayed on the top row of the LCD (such as "AU0" for DVCC and "AU1" for AUX1) • When AUXVCC1 voltage is present and the voltage drops below the AUX threshold, the AUX1 status LED is turned off and the empty battery segment on the LCD blinks
MSP430F6779_AUX_05.c	• AUXVCC3 supply used to power only the RTC • RTCLOCK feature enabled • AUXVCC3's DVCC charger is enabled. As a result, when DVCC is available, AUXVCC3 is powered from DVCC. When it is not available, it is powered from the battery through the diode connected to AUXVCC3 • Make sure the EVM's AUXVCC3 selection jumper is put on the "B" (battery) option
MSP430F6779_AUX_06.c	• AUXVCC3 supply used to power only the RTC • RTCLOCK feature enabled • AUXVCC3's DVCC charger is disabled. As a result, AUXVCC3 is powered through the battery whether DVCC is present or not • Make sure the EVM's AUXVCC3 selection jumper is put on the "B" (battery) option
MSP430F6779_AUX_07.c	This code example adds to the conditions mentioned for MSP430F6779_AUX_06.c a low battery alert for AUXVCC3 In addition: • If AUXVCC3 is below 2.5 V, an empty battery sign blinks on the LCD. Otherwise, a full battery sign is displayed on the LCD • An external connection must be made from AUXVCC3 to CB3 on the EVM for this code example to properly function

Table 3. Code Examples Descriptions (continued)

SOFTWARE NAME	BRIEF DESCRIPTION
MSP430F6779_AUX_08.c	• A variable, "BCD_Initial" , is converted to a binary number and added to the binary number "BIN_INITIAL". The result is then converted to a BCD number to index into the lookup table for the LCD code needed to display the corresponding characters • The BCD to binary and binary to BCD conversion registers are used to go from one representation to another.
MSP430F6779_AUX_09.c	This code example adds to the conditions mentioned for MSP430F6779_AUX_06.c alarm and event notifications. In addition: • If DVCC is available, the bell segment on the LCD blinks for 10 seconds at the beginning of every minute. This is done through having an event every minute. • If DVCC is available, the timer segments on the LCD blinks for one minute whenever the alarm time occurs. This alarm time is every hour at the two-minute mark. • After segment blinking, the segments still remain on.
MSP430F6779_AUX_10.c	This code example adds to the conditions mentioned for MSP430F6779_AUX_03.c measurement of VDSYS and a selected AUX supply. In addition: • The selected AUX supply to measure can be toggled by pressing BTN2. • The top row of the LCD displays the VDSYS voltage. • The bottom row displays the supply selected by the AUXADCSEL bits. • The possible measured supplies are AUX0(DVCC), AUX1, AUX2, and AUX3.
MSP430F6779_AUX_11.c	• Hardware controlled switching of the AUX supplies • The bottom row of the LCD displays the RTC time. AUXVCC3 is connected to VDSYS. As a result, the RTC will be powered regardless of whether AUXVCC1 or DVCC is powering the chip • Switching occurs at SVSMH level 4 • AUXVCC1 and AUXVCC2 are determined as valid supplies when its voltage exceeds level 5 • DVCC is considered valid when it exceeds level 6 • When both AUX1 and AUX2 are valid supplies, AUX1 has a higher priority than AUX2 for switching • When running off of DVCC, active mode is used • When running off of AUXVCC1, LPM0 mode is used • When running off of AUXVCC2, LPM3.5 mode is used • Source of the last reset (SYSRSTIV) is displayed on the top row of the LCD • When the source of the last reset was exiting from LPM3.5 mode, LED1 is turned ON and the top row should display "08" as the reset source • The RTC still keeps track of time after entering LPM3.5 mode. Once DVCC is available again, pressing this push button, allows exiting LPM3.5 mode • The act of pressing a push-button is used to simulate a wake-up event that informs the MCU that DVCC is available again • The RTCLOCK bit is not used
MSP430F6779_AUX_12.c	This code example uses the conditions mentioned for MSP430F6779_AUX_11.c except that RTCLOCK is used.
MSP430F6779_AUX_13.c	This code example uses the conditions mentioned for MSP430F6779_AUX_11.c except that AUX2 has higher priority than AUX1. In addition: • When running off of AUXVCC1, LPM3.5 mode is used • When running off of AUXVCC2, LPM0 mode is used
MSP430F6779_AUX_14.c	This code example uses the conditions mentioned for MSP430F6779_AUX12.c with the addition of tamper detection with time event capture on RTCCAP0(RTCCAP1 is disabled) In addition: • AUXVCC1 is disabled • When a tamper detection event hasn't occurred, "none" is displayed on the top row of the LCD • When a tamper detection event has occurred by pressing the CAP0_B button (with the jumper for CAP0_SEL placed on the top two positions), the minute and seconds of the tampering time is displayed on the top row of the LCD along with a blinking "!" symbol on the LCD • When multiple tamper events have occurred, only the time of the first tamper event is logged • By pressing the BTN2 pushbutton when DVCC is available, the tamper events are cleared, which allows the next tamper event to be recorded and displayed on the LCD • In the case a tamper event is detected when in LPM3.5 mode, LPM3.5 mode is exited

Table 3. Code Examples Descriptions (continued)

SOFTWARE NAME	BRIEF DESCRIPTION
MSP430F6779_AUX_15.c	• Tamper detection with time capture on RTCCAP0(RTCCAP1 disabled) • AUXVCC1 and AUXVCC2 should be connected to ground • AUXVCC3's DVCC charger is disabled so that AUXVCC3 is powered through the battery whether DVCC is present or not • The bottom row of the LCD displays the RTC time • When a tamper detection event hasn't occurred, "none" is displayed on the top row of the LCD • When a tamper detection event has occurred by pressing the CAP0_B button (with the jumper for CAP0_SEL placed on the top two postions), the minute and seconds of the tampering time is displayed on the top row of the LCD along with a blinking "!" symbol on the LCD • When multiple tamper events have occurred, only the time of the first tamper event is logged. • By pressing the BTN2 pushbutton when DVCC is available, the tamper events are cleared, which allows the next tamper event to be recorded and displayed on the LCD • Make sure the EVM's AUXVCC3 selection jumper is put on the "B" (battery) option
MSP430F6779_AUX_16.c	• This code example uses the conditions mentioned for MSP430F6779_AUX_15.c except that RTCCAP1 is used instead of RTCCAP0. The proper push-button to use is CAP1_B (with the jumper for CAP1_SEL placed on the bottom two positions)

5 Test Results

By running the code examples on this TI Design, the functionality of the AUX module can be shown. Because some of the code examples may be similar to other examples, Section 5.1 discusses only a subset of the entire code example set.

5.1 Code Examples

5.1.1 AUX01 Code Example

To demonstrate this example, load the AUX01 code example and provide power to DVCC. In the following configuration, DVCC is powered by the FET tool (connect a jumper between the INT and DVCC positions on the JTAG jumper header). AUXVCC1, AUXVCC2, and AUXVCC3 are powered from their batteries by selecting the *B* option on the corresponding AUX select jumper headers. Since all of the supplies are powered and all of the supply-related LEDs for the jumper headers are populated, all of the supply LEDs are turned on. The selected supply to power the chip is DVCC as shown in Figure 6.

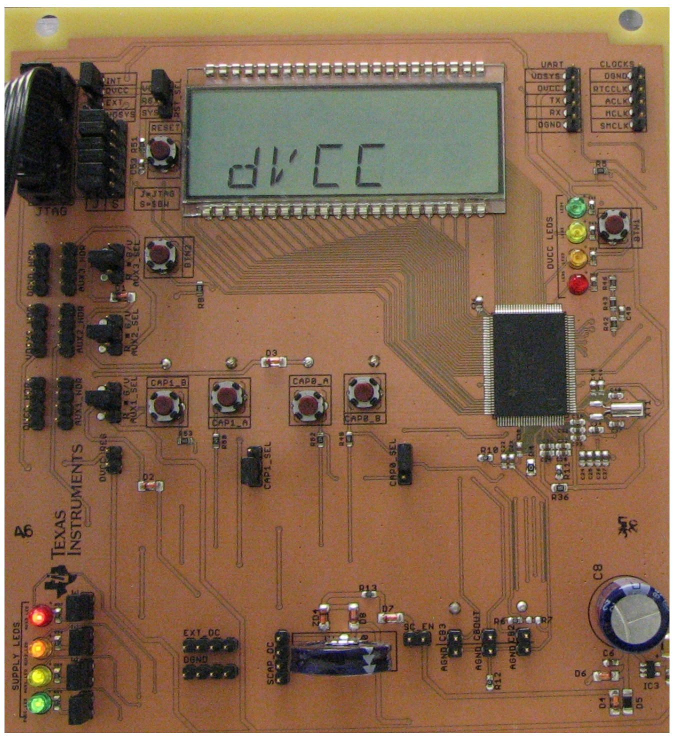

Figure 6. AUX01 Code Example: Chip Powered from DVCC

Pressing BTN2 switches the selected supply used to power the chip. For this example, BTN2 is pressed until AUXVCC2 is selected as the supply used to power the chip, as shown by the LCD in the picture below. To verify that AUXVCC2 is the supply used to power the chip, the power sources at DVCC and AUXVCC1 are removed. The power source at DVCC is removed by removing the FET tool from the JTAG header and the power at AUXVCC1 is removed by selecting the *G/V* option on the AUX1_SEL header. As a result, the LEDs for DVCC and AUXVCC1 should be off as seen in Figure 7; however, the LCD and other LEDs should still be on.

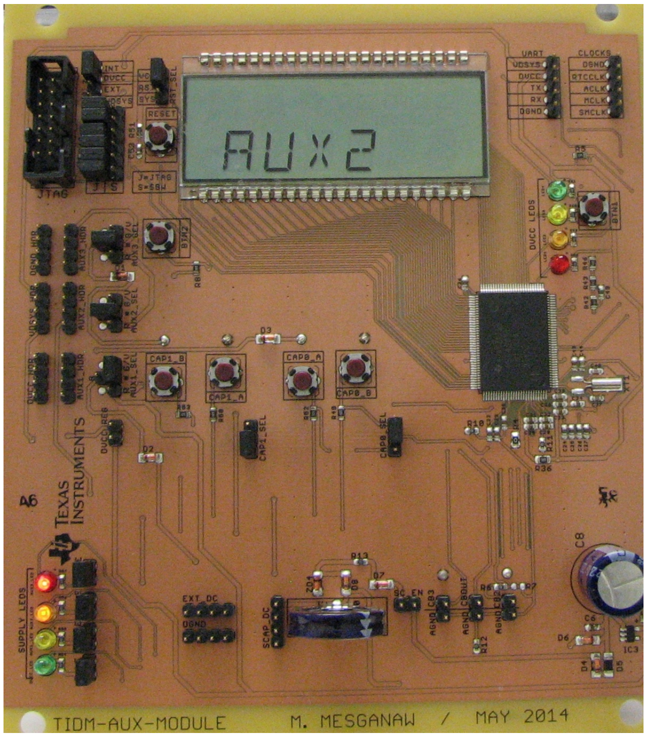

Figure 7. AUX01 Code Example: Chip Powered from AUXVCC2

5.1.2 AUX03 Code Example

In the configuration used for testing the AUX03 code, DVCC is powered by the FET tool. AUX1 and AUX2 are powered from their batteries by selecting the *B* option on the corresponding AUX select jumper headers. AUXVCC3 is connected to VDSYS by selecting the *G/V* option on the AUX3_SEL header. As a result, AUXVCC3 is powered regardless of whatever supply is selected, which can be seen by the AUXVCC3 LED being regardless of whether DVCC, AUXVCC1, or AUXVCC2 powers the chip. After loading the example, the bottom row of the LCD displays the time. Because no supply switching has occurred, nothing is displayed on the top row of the LCD as shown in Figure 8.

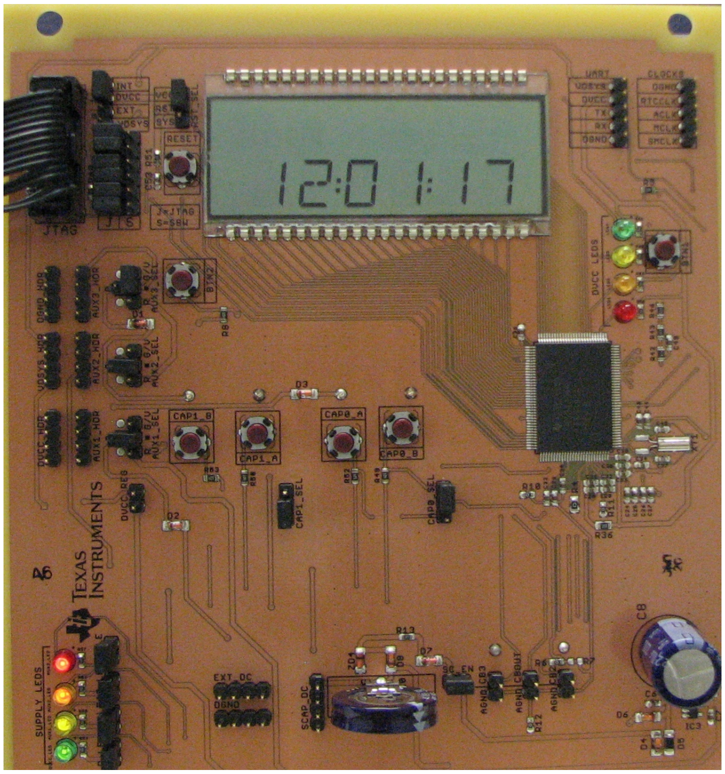

Figure 8. AUX03 Code Example: Initial Condition Before Switching Occurs

By removing the DVCC power source by disconnecting the FET tool, AUXVCC2 is automatically switched to for powering the chip power supply, as shown by the LCD. AUXVCC2 is selected since in the software it was set to have a higher priority than AUXVCC1. Figure 9 shows the result of removing DVCC.

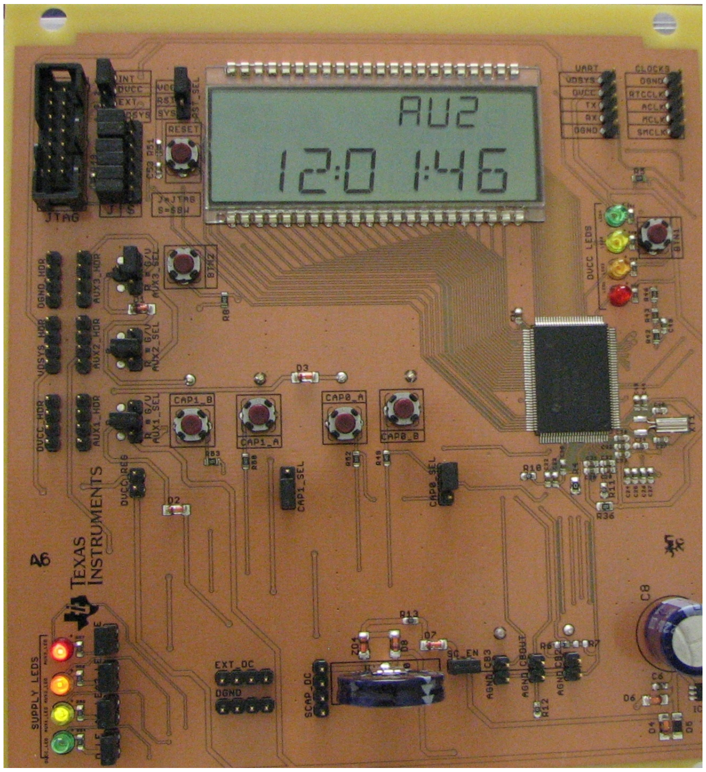

Figure 9. AUX03 Code Example: Chip Being Powered from AUXVCC2

When AUXVCC2 is removed afterwards, AUXVCC1 is selected as the chip power supply, as shown in Figure 10. If DVCC returns at any point, the chip power supply is automatically switched to DVCC, regardless of whether the current supply used to power the chip falls below the SVM level. Switching to DVCC is denoted as *AU0* on the top row of the LCD as shown in Figure 10.

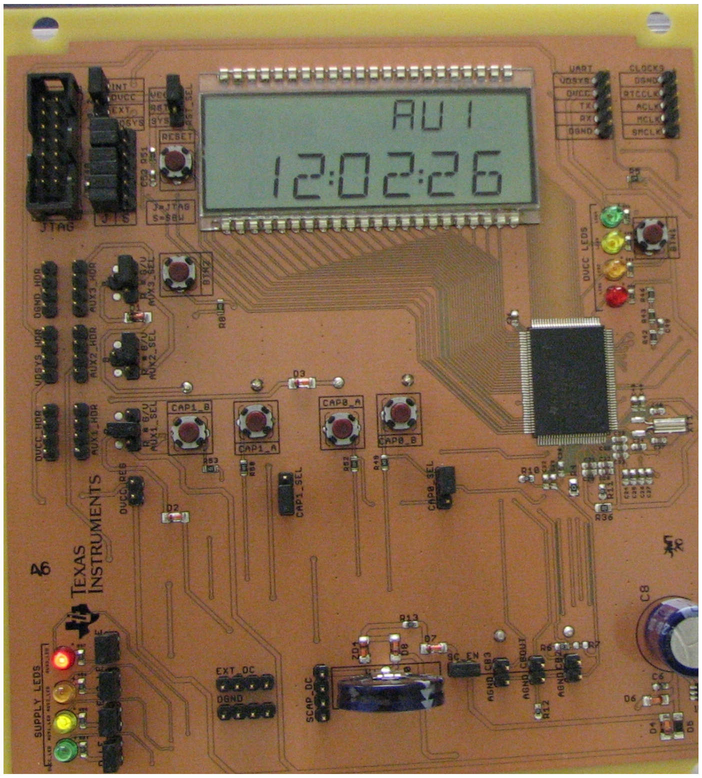

Figure 10. AUX03 Code Example: Chip Being Powered from AUXVCC1

For this example, whenever AUXVCC1 is not used to power the chip and its voltage drops below its corresponding valid voltage threshold, an empty battery symbol blinks on the LCD as shown in Figure 11. The empty battery symbol also blinks on the LCD under the same conditions for AUXVCC2. This condition is simulated here by removing AUXVCC1 or AUXVCC2 when powering the chip from DVCC.

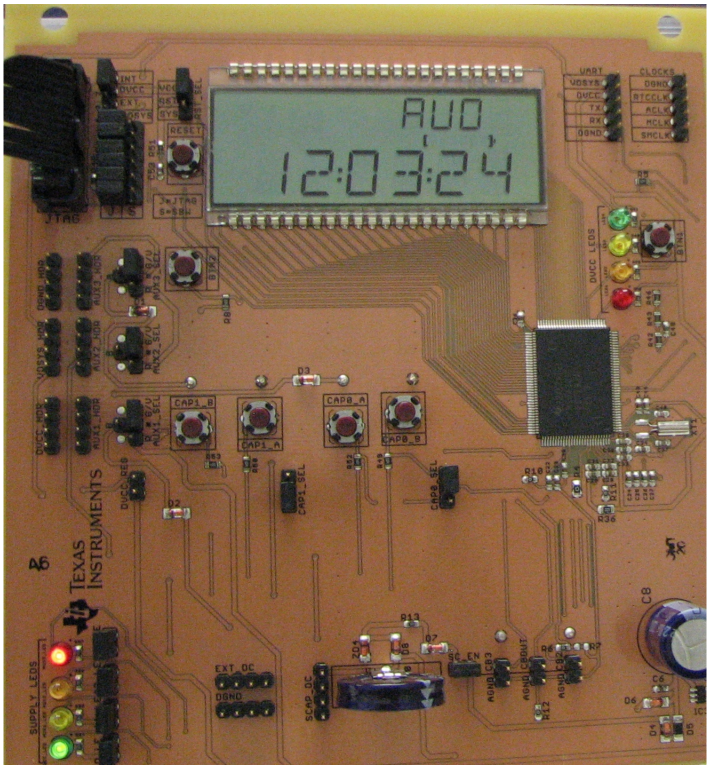

Figure 11. AUX03 Code Example: Chip Supply Switched Back to DVCC; AUXVCC1 and AUXVCC2 Invalid

5.1.3 AUX07 Code Example

For this example, load the AUX07 code example. In this configuration, DVCC is powered by the FET tool and AUXVCC3 is powered by its battery by selecting the *B* option on the AUX3_SEL jumper header. AUXVCC1 and AUXVCC2 are connected to GND via the *G/V* option on their corresponding AUX select jumper headers. In addition, CB3 is connected to the AUXVCC3 header by the orange wire shown below. After a reset, the RTC time may not be displayed on the LCD and it may need to be initialized by pressing the BTN2 button. After a system reset, nothing is displayed on the top line of the LCD; however, when AUXVCC3 drops below the user-defined threshold (2.5 V), an empty battery symbol blinks on the LCD as shown in Figure 12. This condition is simulated by removing the jumper connecting AUXVCC3 from its battery.

NOTE: Removing this jumper stops the RTC from counting on the LCD since the RTC is not powered.

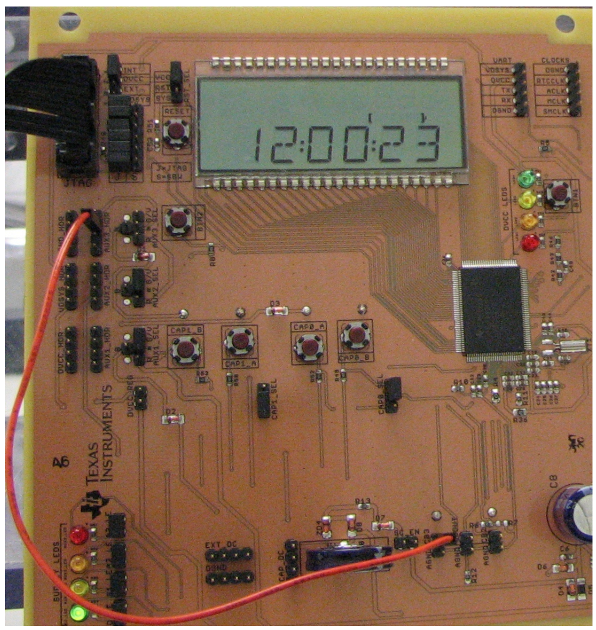

Figure 12. AUX07 Code Example: AUXVCC3 Voltage Falls Below 2.5-V Threshold

After AUXVCC3 drops below the user-defined threshold and returns back, the empty battery segment stops blinking and a full battery symbol is shown on the LCD, which is shown in Figure 13. This condition is simulated by reconnecting the jumper that selects the AUXVCC3 battery. Please note that since the RTC's supply lost power by disconnecting it from its battery, the RTC needs to be reconfigured and re-initialized by pressing BTN2.

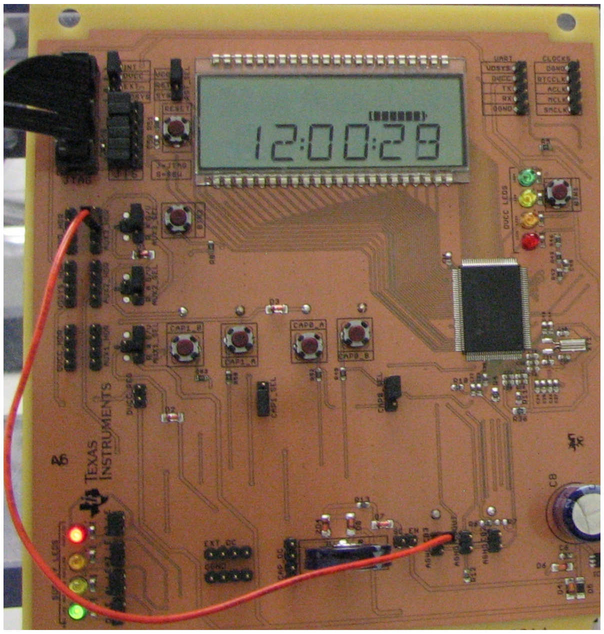

Figure 13. AUX07 Code Example: AUXVCC3 Voltage Rises Above 2.5-V Threshold After Falling Below It

5.1.4 AUX10 Code Example

In this code example, the VDSYS voltage is displayed on the top row of the LCD. With hardware switching enabled, the voltage value of VDSYS could either be DVCC, AUXVCC1, or AUXVCC2. On the bottom row, either DVCC, AUXVCC1, AUXVCC2, or AUXVCC3 is displayed. By pressing BTN2, the supply whose voltage is displayed on the bottom is toggled between these four different supplies. In Figure 14, DVCC is used to power the chip. As a result, the VDSYS voltage is at the DVCC voltage, which is 3.3 V, as shown on the top row of the LCD. On the bottom row of the LCD, the AUXVCC2 voltage is displayed.

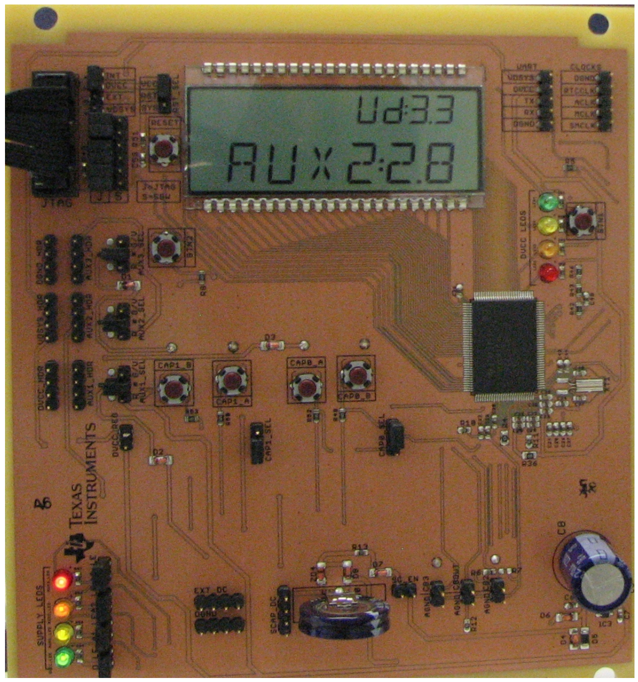

Figure 14. AUX10 Code Example: AUXVCC2 and VDSYS Voltage Measurement Results

5.1.5 AUX12 Code Example

In the configuration used for testing the AUX12 code example, DVCC is powered from the FET tool, AUXVCC3 is powered from VDSYS, AUXVCC1 is powered from its battery, and AUXVCC2 is also powered from its battery. After loading the code, the RTC is reset whenever voltage first is applied to AUXVCC3.

NOTE: After flashing the code, it may be necessary to provide a power cycle on AUXVCC3 (by removing the jumper at AUXVCC3 and placing it back) followed by providing a reset (by pressing the *RESET* pushbutton). This pushbutton ensures that the RTC gets properly initialized if another RTC-related code previously flashed on the board is tested.

The reset source (as determined by the SYSRSTIV register) is printed on the top row of the LCD and the RTC time on the bottom row. In Figure 15, the reset source value of *2* corresponds to the last reset being caused by a brownout. For this example, active mode is used when running from DVCC, LPM0 mode is used when running from AUXVCC1, and LPM3.5 is used when running from AUXVCC2. When running in LPM0 mode, the incrementing RTC time is still displayed on the LCD since the LCD is updated in the RTC ISR and MCLK is enabled by default within an ISR. In this code example's sequence, the chip is originally running from DVCC. By removing DVCC, the chip runs off of AUXVCC1 in LPM0 mode except within the ISR routines.

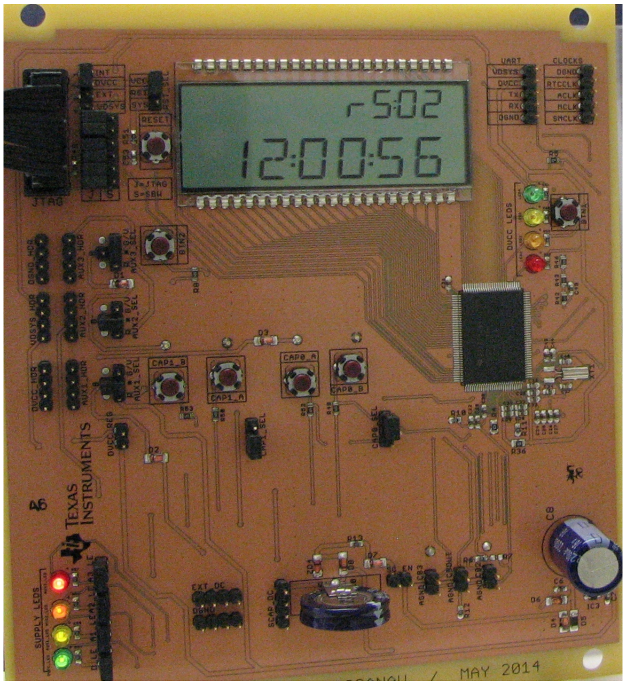

Figure 15. Code Example: Chip Powered from DVCC/AUXVCC1; Previously Reset Due to Brownout

After removing DVCC, AUXVCC1 is then removed, which causes the chip to be powered from AUXVCC2 and the chip to enter LPM3.5 mode. When entering LPM3.5 mode, all of the LEDS and the LCD are turned off, as shown in Figure 16. As a result, the RTC time is not shown on the LCD, giving the appearance that the RTC stopped counting; however, the RTC still keeps track of time within the LPM3.5 mode, and the LCD shows the correct RTC time whenever voltage at DVCC returns and LPM3.5 mode is exited.

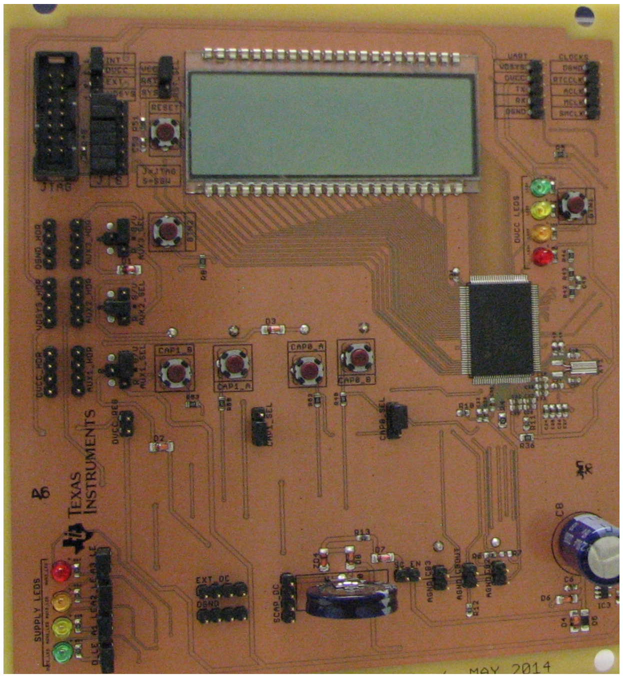

Figure 16. AUX12 Code Example: Chip Powered from AUXVCC2 (LPM3.5 Mode)

When DVCC returns after entering LPM3.5, press BTN1 to cause a reset. The reset source value of 08 is displayed on the LCD. In addition, as an indication that the cause of a reset was exiting LPM3.5, LED1 of the DVCC LEDs is turned on as shown in Figure 17.

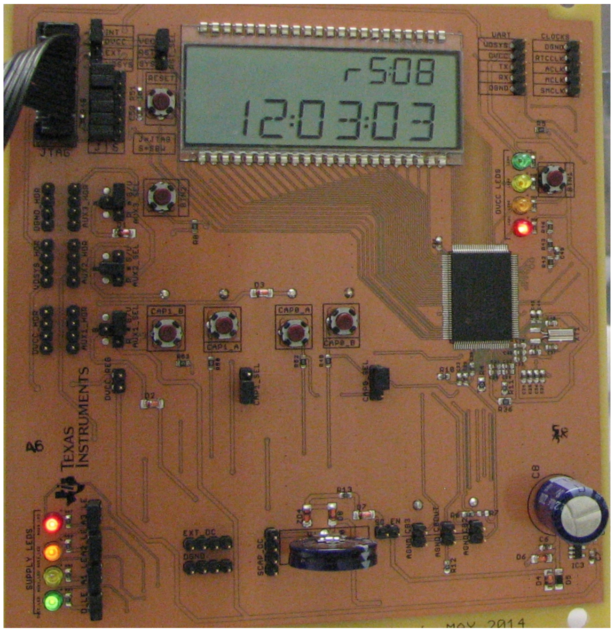

Figure 17. AUX12 Code Example: Chip Powered from DVCC Again; Previously Reset Due to LPM3.5 Exit

5.1.6 AUX14 Code Example

For this example, DVCC is powered from the FET tool, AUXVCC3 is powered from VDSYS, AUXVCC2 is powered from its battery, and AUXVCC1 is connected to GND. After loading the code, the RTC is reset whenever voltage is first applied to AUXVCC3. Since AUXVCC3 is powered from VDSYS, the example should be powered regardless of whether DVCC or AUXVCC2 is powering the chip.

NOTE: After flashing the code, it may be necessary to provide a power cycle on AUXVCC3 (by removing the jumper at AUXVCC3 and placing it back) followed by providing a reset (by pressing the *RESET* pushbutton). This pushbutton ensures that the RTC gets properly initialized if another RTC-related code previously flashed on the board is tested.

After loading the code, if there was no previous tamper detected, the LCD would have *nonE* printed on its top row as shown in Figure 18. The bottom row should always display the RTC time.

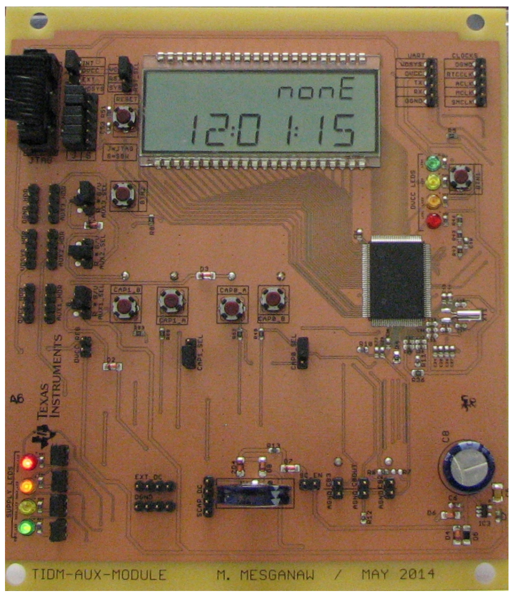

Figure 18. AUX14 Code Example: Initial Condition, No Tamper Event

For this example, active mode is used when running from DVCC and LPM3.5 is used when running from AUXVCC2 (unless a tamper event occurs while running in LPM3.5 operation). In this code example's sequence, the chip originally runs from DVCC. Subsequently, the voltage at DVCC is removed, which causes the chip to be powered from AUXVCC2 and the chip to enter LPM3.5 mode. When entering LPM3.5 mode, all of the LEDs and the LCD are turned off as shown in Figure 19. As a result, the RTC time is not shown on the LCD, which may make it seem that the RTC stopped counting; however, the RTC still keeps track of time within LPM3.5, and the LCD shows the correct RTC time whenever the LCD is enabled again.

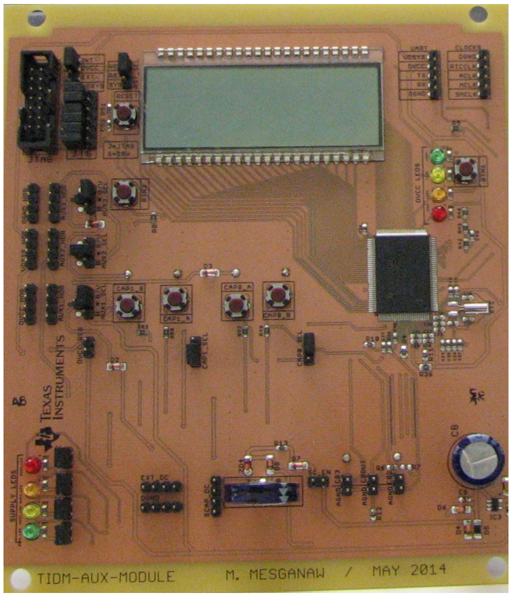

Figure 19. AUX14 Code Example: Chip Powered from AUXVCC2, LPM3.5 Mode, No Tamper Event

While in LPM3.5 mode, if CAP0_B is pressed when there is no existing tamper event, the chip continues to be powered from AUXVCC2, but exits LPM3.5 mode. The minute and second in which the button was pressed (02:13 in the Figure 20) when the chip was in LPM3.5 mode should now be displayed. If a previous tamper event occurred and was not cleared by pressing BTN2, pressing CAP0_B would have no result. If the chip is currently in LPM3.5 mode, DVCC returns, and BTN1 is then pressed, the chip will also exit LPM3.5 mode. After exiting LPM3.5 mode, LED1 of the DVCC LEDs should be turned on if voltage at DVCC is available.

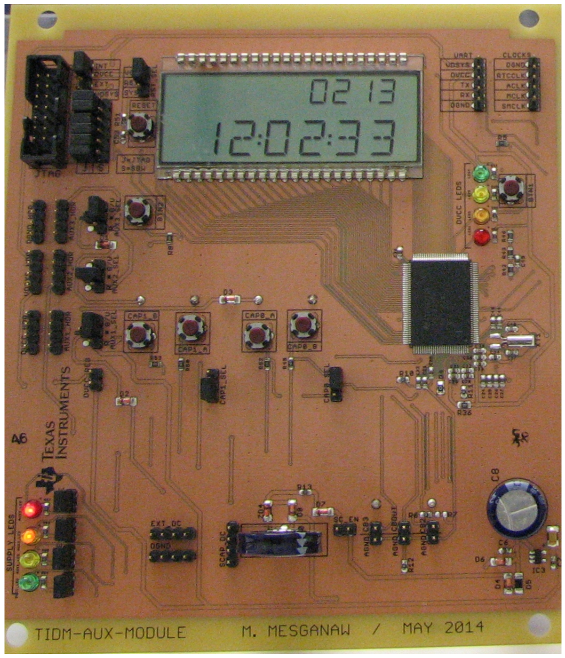

Figure 20. AUX14 Code Example: Chip Powered from AUXVCC2, Active Mode, Tamper Event

At this point, pressing CAP0_B afterwards does not cause a new event to be generated and the LCD's top row does not update until BTN2 is pressed to clear the previous time capture event. The top row not updating is shown in Figure 21:

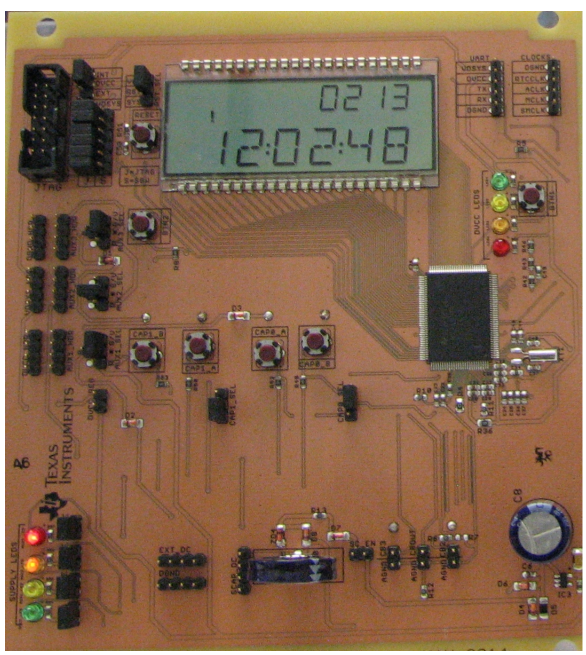

Figure 21. AUX14 Code Example: Active Mode, New Tamper Events Not Logged

By pressing BTN2, the RTC event is cleared, which is shown in Figure 22.

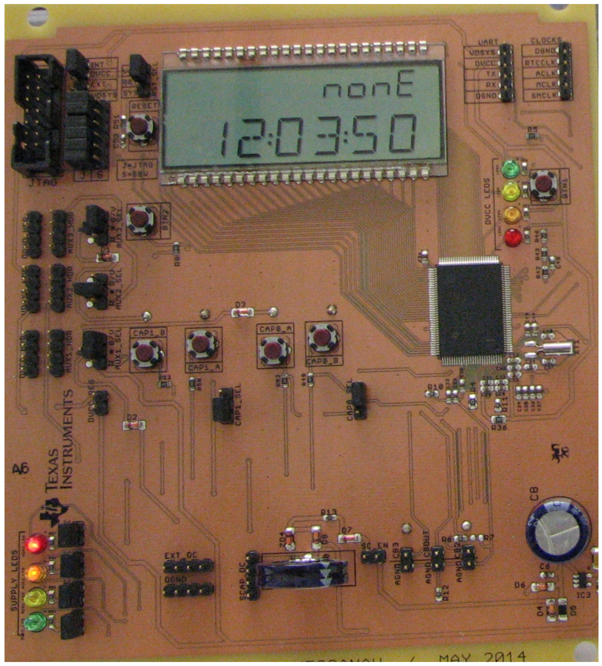

Figure 22. AUX14 Code Example: Previous Tamper Event Cleared

After the event is cleared, press CAP0_B to register the new tamper event. The minute and second of the time capture of the new event (04:03 in Figure 23) is now displayed on the LCD.

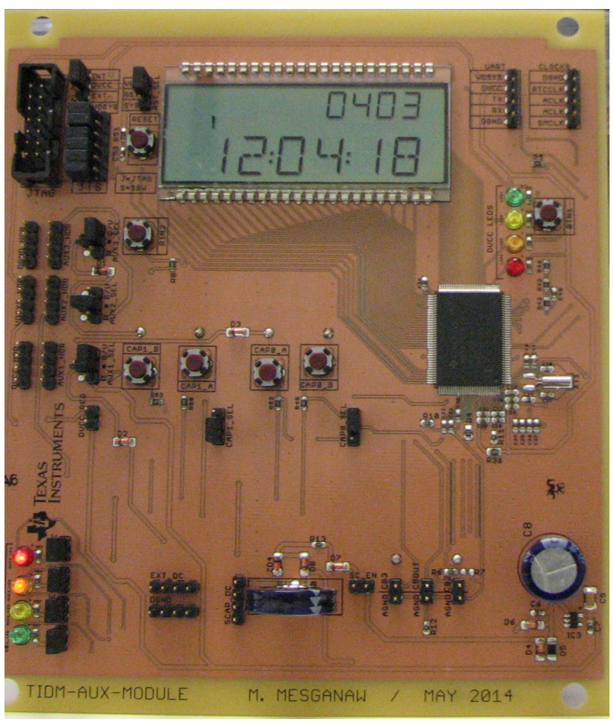

Figure 23. AUX14 Code Example: New Tamper Event Detected

5.1.7 AUX15 Code Example

This example corresponds to the AUX15 code example. For this example, DVCC is powered from the FET tool, AUXVCC3 is powered from the battery, AUXVCC2 is connected to ground, and AUXVCC1 is also connected to GND. After loading the code, the RTC is reset whenever voltage first is applied to AUXVCC3.

NOTE: After flashing the code, it may be necessary to provide a power cycle on AUXVCC3 (by removing the jumper at AUXVCC3 and placing it back) followed by providing a reset (by pressing the *RESET* pushbutton). This pushbutton ensures that the RTC gets properly initialized if another RTC-related code previously flashed on the board is tested.

If there was no previous tamper detect, the LCD would have *nonE* printed on its top row, as shown in Figure 24. The bottom row should display the RTC time.

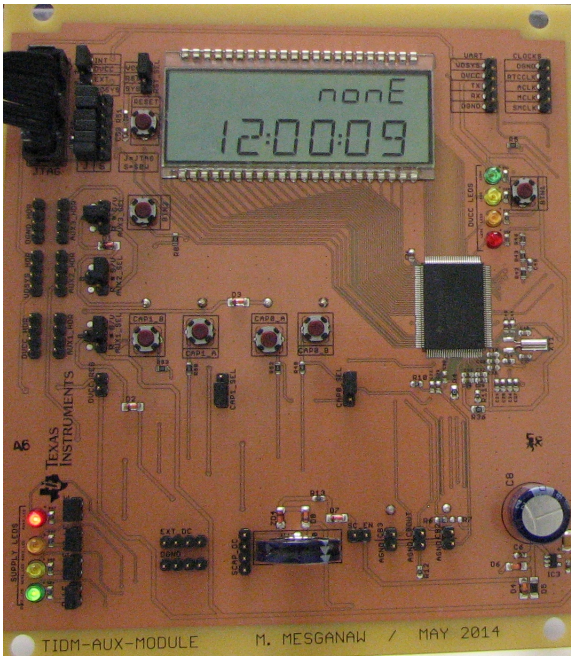

Figure 24. AUX15 Code Example: Initial Condition, No Tamper Event

Fifteen seconds after running (12:00:15), the FET tool is removed. By removing the FET tool, the power to the chip (VDSYS) is also removed (with the exception of the chip components that are powered by AUXVCC3, such as the RTC and back-up RAM) . The result is shown in Figure 25. Although the main power is removed, the RTC is still counting and the event capture functionality is still functional.

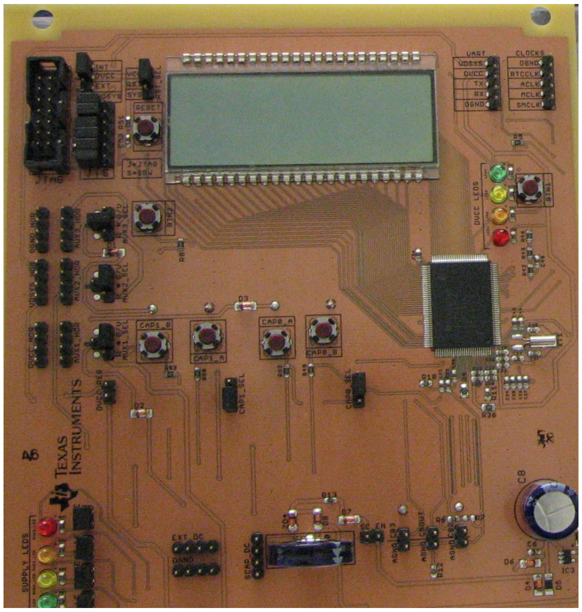

Figure 25. AUX15 Code Example: Power to Majority of Chip Removed (VDSYS), Tamper Event

Seventeen seconds later (12:00:32), the time capture pushbutton is pressed. However, since the chip is not powered, this action cannot be indicated until power is restored. Thirteen seconds later, the FET tool is reconnected to the JTAG connector, powering the chip again. Once the power is returned, the LCD turns back on. On the bottom row of the LCD, the updated time is displayed. This time reflects the correct time (for example, the time is not 30 seconds too late due to the time where VDSYS was not available). In addition, the top row displays the minute and second (00:32) when the tamper event occurred, despite VDSYS not being available when this tamper event occurred. The LCD will only display the time of the first tamper event, and any other presses of CAP0_B would have no effect. The LCD screen at this time can be seen below in Figure 26:

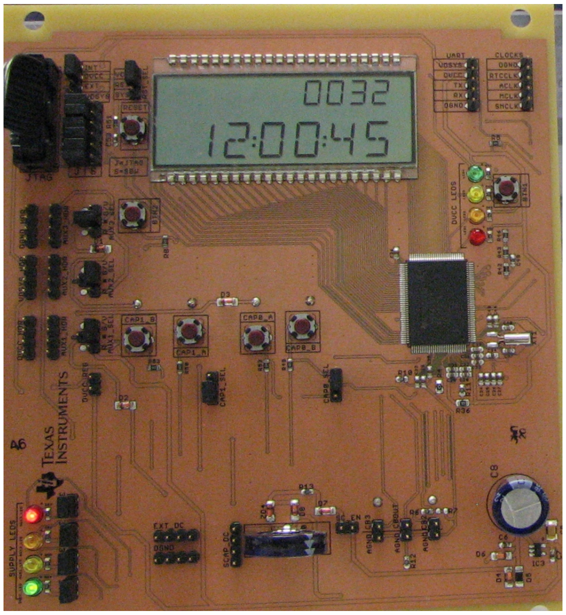

Figure 26. AUX15 Code Example: Power Restored (VDSYS), Tamper Event

At this point, Pressing CAP0_B afterwards does not cause a new event to be generated and the LCD's top row does not update until BTN2 is pressed to clear the previous time capture event. The top row not updating is shown in Figure 27:

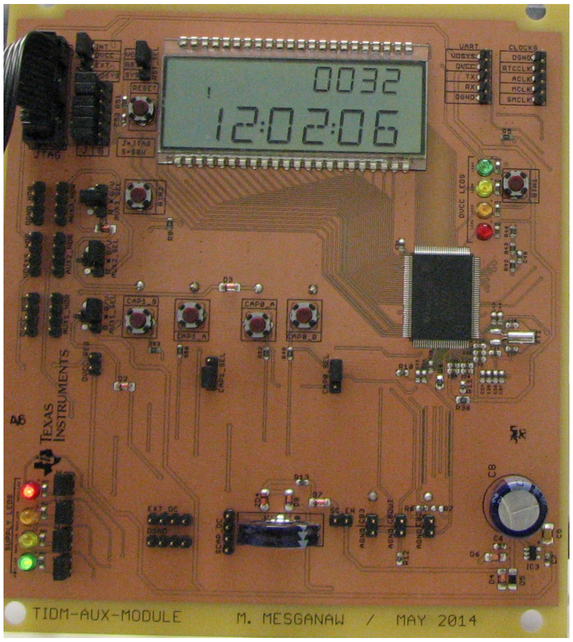

Figure 27. AUX15 Code Example: New Tamper Events Not Logged

By pressing BTN2, the RTC event is cleared as shown in Figure 28.

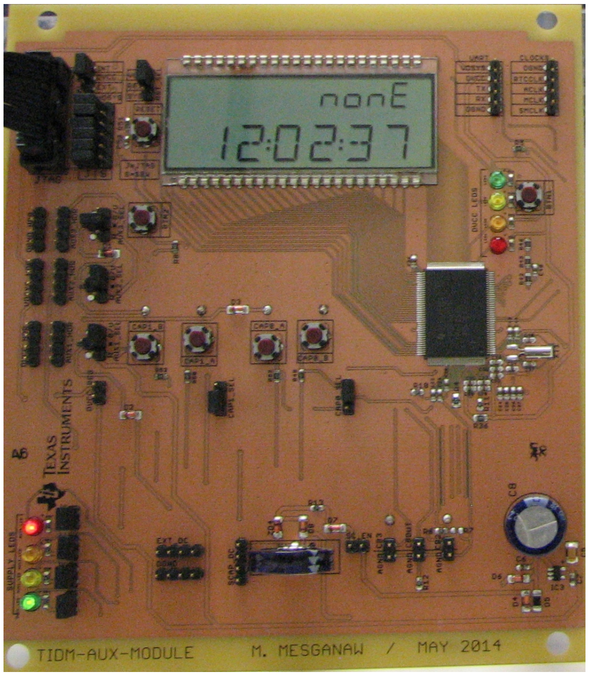

Figure 28. AUX15 Code Example: Previous Tamper Event Cleared

After the event is cleared, pressing CAP0_B registers the new tamper event. The minute and second of the time capture (02:48) of the new event is now displayed on the LCD (Figure 29).

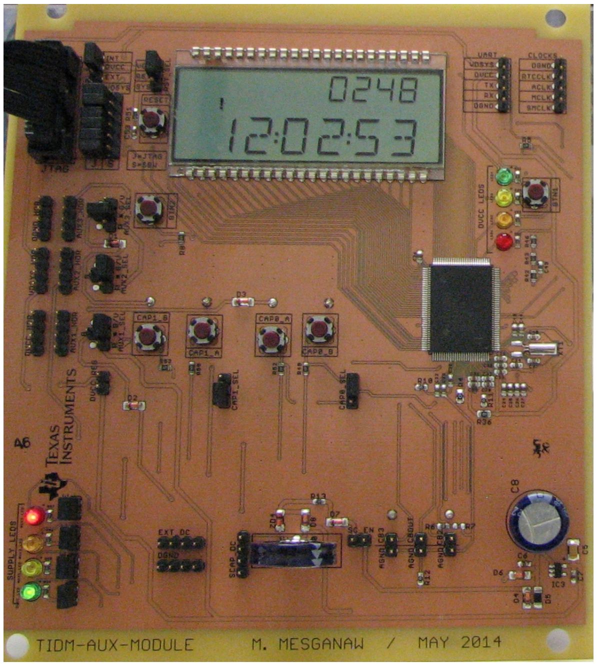

Figure 29. AUX15 Code Example: New Tamper Event Detected

5.2 *Miscellaneous Tests*

5.2.1 Measured Clock Frequencies

While running the AUX01 code example, the frequencies of the clocks on the *Clocks* header were measured. The results are shown in Table 4.

Table 4. Measured Clock Frequencies

CLOCKS	FREQUENCY
RTCCLK	511.9458 Hz (no RTC calibration applied)
ACLK	32,764.532 Hz
SMCLK	1,048,465 Hz
MCLK	1,048,465 Hz

Super Cap Testing

While running the AUX03 code example, tests on the super capacitor were performed. In this code, the chip is in active mode regardless of which supply is being used. In addition, the jumpers enabling the supply LEDs were removed.

For testing, DVCC was originally supplied from the FET tool and AUXVCC1 was powered from the regulator. The super capacitor charging circuitry was enabled by placing a jumper on the *SC_EN* jumper and AUXVCC1 was connected to the LDO output. The voltage at DVCC was then removed, which caused the chip to be powered from AUXVCC1. In the testing, 5 V was provided to the *EXT_DC* header to charge the capacitor for a couple of hours, which resulted in a voltage of 4.5 to 4.6 V. During charging, a maximum current of 35 mA was initially drawn from the 5-V power supply due to the capacitor charging. As time passed, this current diminished and eventually dropped to 2 mA.

After charging the super capacitor, the 5-V power supply was removed, which allowed the chip to be powered through the super capacitor's voltage applied to the input of the LDO. The super capacitor was measured at various times, which is shown in Table 5. After the super capacitor voltage dropped below 3.3 V, measurements on DVCC were also made since DVCC's voltage would start to drop and not be constantly regulated to approximately 3.3 V.

Table 5. Measured DVCC and Super Capacitor Voltages

TIME SINCE SUPER CAPACITOR POWER SOURCE REMOVED	SUPER CAPACITOR VOLTAGE	DVCC VOLTAGE
0 minutes	4.6 V	—
1 minute	4.5 V	—
20 minutes	3.7 V	—
30 minutes	3.3 V	3.1 V
60 minutes	2.4 V	2.2 V
80 minutes, 15 seconds	2.0 V	1.8 V

In the test, the chip was able to run of the super capacitor for 80 minutes and 15 seconds before reaching the recommended 1.8-V DVCC voltage limit of the MSP430F67791A for a PMM Core level of 0.

6 Design Files

6.1 Schematics

To download the schematic, see the design files at TIDM-AUX-MODULE.

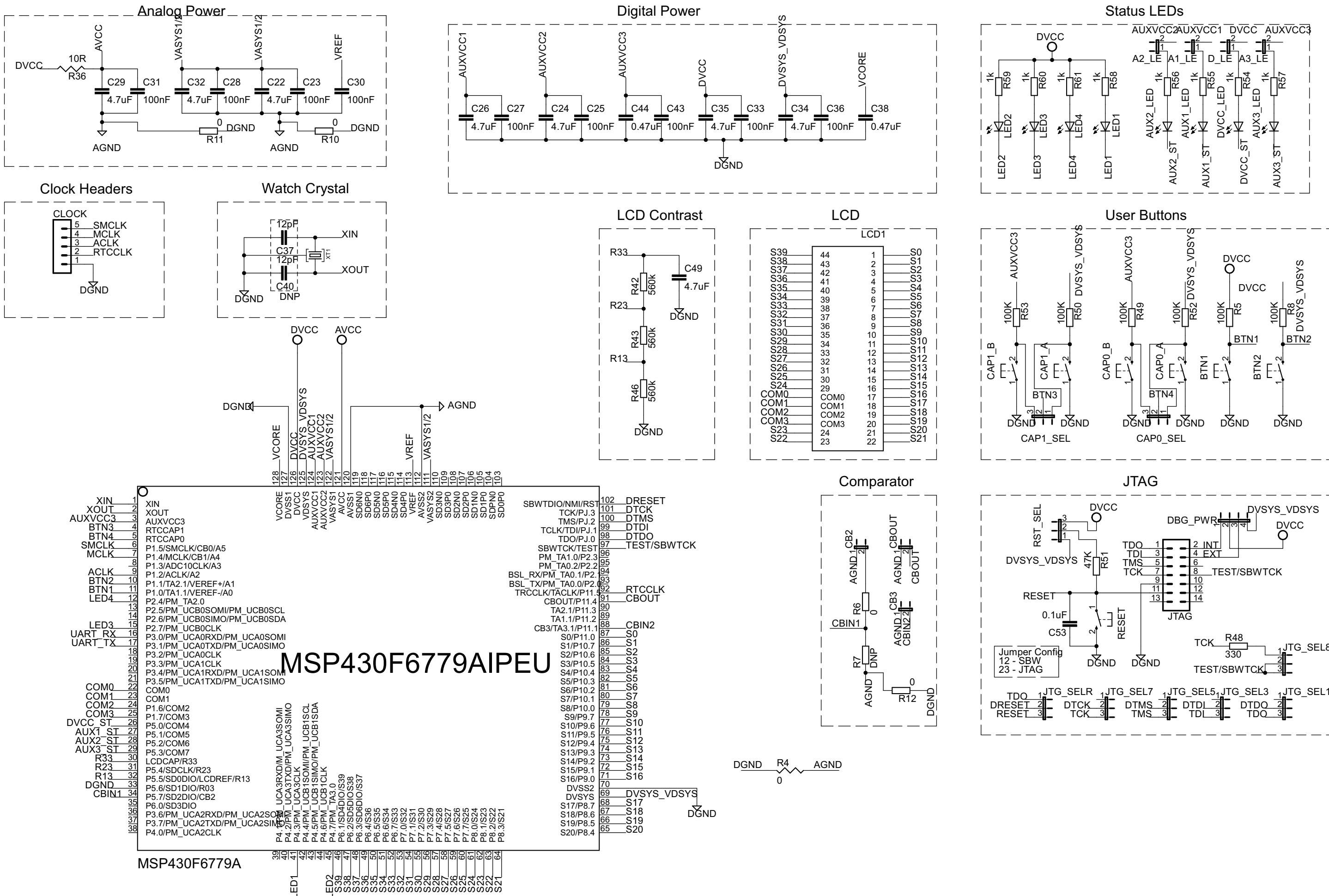

Figure 30. TIDM-AUX-MODULE Schematic Page 1

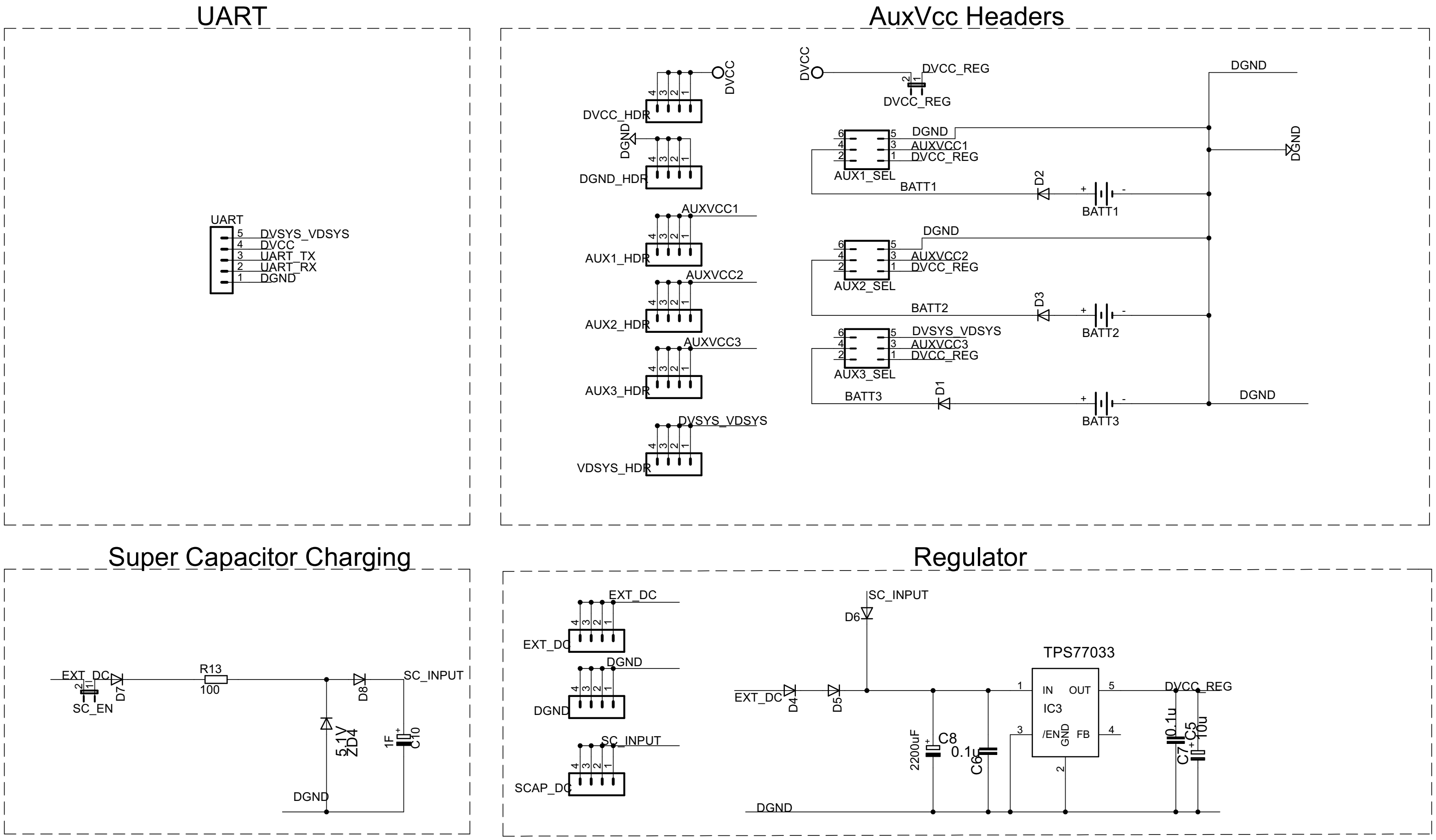

Figure 31. TIDM-AUX-MODULE Schematic Page 2

6.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDM-AUX-MODULE.

Table 6. BOM

ITEM	QTY	REFERENCE	VALUE	PART DESCRIPTION	DIGIKEY PARTNUMBER
1	9	A1_LE, A2_LE, A3_LE, D_LE, DVCC_REG, SC_EN, CB2, CB3, CBOUT	—	Conn Header Vert SGL 2-Pos Gold	3M9447-ND
2	10	DGND, AUX1_HDR, AUX2_HDR, DBG_HDR, AUX3_HDR, DVCC_HDR, DGND_HDR, VDSYS_HDR, SCAP_DC, EXT_DC	—	Conn Header Vert SGL 4-Pos Gold	3M9449-ND
3	2	AUX2_LED, LED2	Orange	LED 3.1 mm, 610 nm, Orange Transparent	511-1245-ND
4	2	DVCC_LED, LED4	Green	LED 3.1 mm, 563 nm, Green Transparent	511-1247-ND
5	2	AUX3_LED, LED1	Red	LED 3.1 mm, 650 nm, Red Transparent	511-1249-ND
6	2	AUX1_LED, LED3	Yellow	LED 3.1 mm, 585 nm, Yellow Transparent	511-1251-ND
7	1	MSP430F6779A	MSP430F67791AIPEU		Will be provided by TI
8	7	BTN1, BTN2 , RESET, CAP0_A, CAP0_B, CAP1_A, CAP1_B	—	Switch Tactile SPST-NO 0.02 A, 15 V	P8079SCT-ND
9	9	CAP0_SEL, CAP1_SEL, JTG_SEL1, JTG_SEL3, JTG_SEL5, JTG_SEL7, JTG_SEL8, JTG_SELR, RST_SEL	—	Conn Header Vert SGL 3-Pos Gold	3M9448-ND
10	2	CLOCK, UART	—	Conn Header Vert SGL 5-Pos Gold	961105-6404-AR
11	1	LCD1	TI_160SEG_LCD		Will be provided by TI
12	1	XT1	32.768 KHZ	Crystal 32.768 KHZ, 6 pF SMD	300-8341-1-ND
13	1	JTAG	—	Conn Header 14-Pos Straight Gold	MHC14K-ND
14	7	D1, D2, D3, D4, D6, D7, D8	—	Diode Schottky 30 V, 0.2 A LLDS	568-1609-1-ND
15	1	IC3	TPS77033	IC Reg LDO 3.3 V, 50 MA SOT23-5	296-11051-1-ND
16	1	ZD4	5.1 V	Diode Zener 5.1 V, 500 MW LLDS	568-4874-1-ND
17	1	C5	10 u	Cap Tant 10 µF, 6.3 V 20% 1206	399-3685-1-ND
18	2	C6, C7	0.1 u	Cap Cer 0.1 µF 50 V 20% Y5V 0603	311-1366-1-ND
19	1	C8	2200 µF	Cap Alum 2200 µF 10 V 20% Radial	P5128-ND
20	8	C22, C24, C26, C29, C32, C34, C35, C49	4.7 µF	Cap Cer 4.7 µF, 10 V 10% X5R 0603	311-1455-1-ND
21	10	C23, C25, C27, C28, C30, C31, C33, C36, C43, C53	100 nF	Cap Cer 0.1 µF, 50 V Y5V 0603	311-1343-1-ND
22	2	C37, C40	12 pF	Cap Cer 12 pF, 50 V 5% NPO 0603	311-1059-1-ND (alt: 1276-1254-1-ND)
23	2	C38, C44	0.47 µF	Cap Cer 0.47 µF, 16 V 10% X7R 0603	311-1428-1-ND
24	1	C10	1 F	Cap Super 1 F, 5.5 V AXIAL	338-3569-ND

Table 6. BOM (continued)

ITEM	QTY	REFERENCE	VALUE	PART DESCRIPTION	DIGIKEY PARTNUMBER
25	1	R13	100	Res 100 Ω 1/10 W 5% 0603 SMD	RMCF0603JT100RCT-ND
26	8	R54, R55, R56, R57, R58, R59, R60, R61	1 k	Res 1 KΩ 1/10 W 5% 0603 SMD	RMCF0603JT1K00CT-ND
27	6	R5, R8, R49, R50, R52, R53	100 K	Res 100 KΩ 1/8 W 5% 0805 SMD	RMCF0805JT100KCT-ND
28	3	R42, R43, R46	560 k	Res TF 560 KΩ 1% 0.125W 0805	RMCF0805FT560KCT-ND
29	1	R36	10 R	Res 10 Ω 1/8 W 5% 0805 SMD	RMCF0805JT10R0CT-ND
30	1	R7	DNP		
31	1	R4	0	Res 0.0 Ω 1/8 W 0805 SMD	RMCF0805ZT0R00CT-ND
32	1	R48	330	Res 330 Ω 1/10 W 5% 0603 SMD	RMCF0603JT330RCT-ND
33	1	R51	47 K	Res 47 KΩ 1/10 W 5% 0603 SMD	RMCF0603JT47K0CT-ND
34	4	R6, R10, R11, R12	0	Res 0.0 Ω 1/10 W 0603 SMD	RMCF0603ZT0R00CT-ND
35	6	AUX1_SEL, AUX2_SEL, AUX3_SEL	—	Conn Header Vert SGL 3-Pos Gold	3M9448-ND
36	3	BATT1, BATT2, BATT3		Holder Battery 2-Cell AAA PC MNT	2468K-ND
37	1	D5	0	Res 0.0 Ω 1/4 W Jump 1206 SMD	311-0.0ERCT-ND

6.3 PCB Layer Plots

To download the layer plots, see the design files at TIDM-AUX-MODULE.

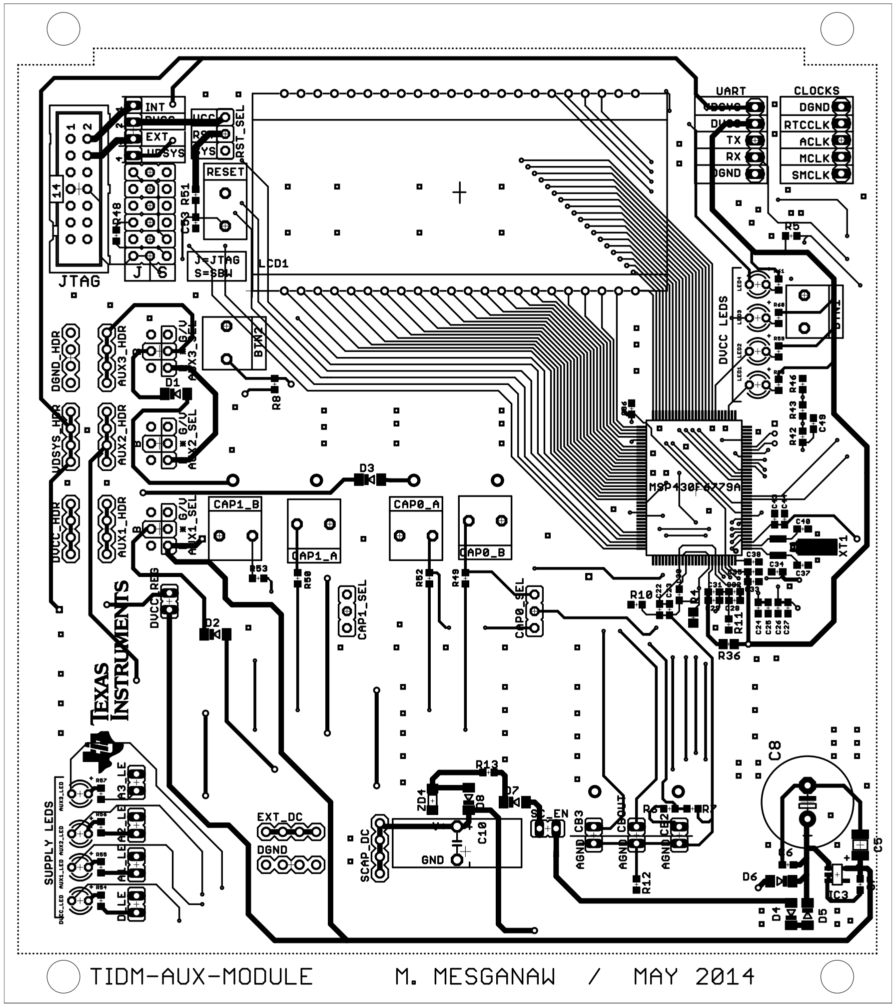

Figure 32. Top Layer Plot

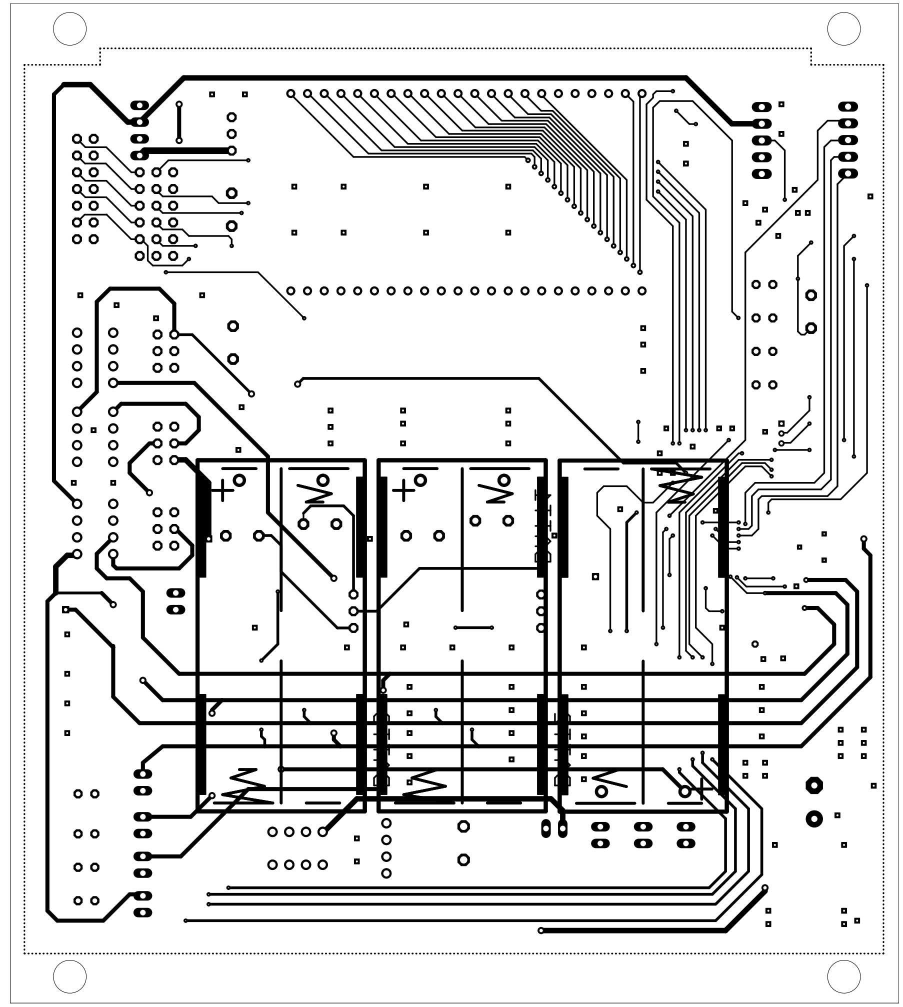

Figure 33. Bottom Layer Plot

6.4 CAD Project Files

To download the CAD project files, see the design files at TIDM-AUX-MODULE.

6.5 Gerber Files

To download the Gerber files, see the design files at TIDM-AUX-MODULE.

6.6 Software Files

To download the software files, see the design files at TIDM-AUX-MODULE.

7 References

1. MSP430F67791A User Manual (SLAU208)

8 About the Author

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