Application Report
SNOA564F–June 2011–Revised December 2012

AN-2154 RD-195 DC Arc Detection Evaluation Board

ABSTRACT

The RD-195 reference design includes the SM73201-ARC-EV PCB which is a UL1699B compliant Photo-Voltaic Arc Detect System with a minimal footprint of less than 50mm x 30mm. The reference design utilizes a proprietary dynamic filtering technique to effectively detect the signature of arcing conductors in the presence of highly noisy real world environments. The analog path requires less than 50mW of power to implement the active filtering. The operation range of the device covers the industrial temperature range of -40°C to +85°C.

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1 Introduction

The RD-195 reference design includes the SM73201-ARC-EV PCB which is a UL1699B compliant Photo-Voltaic Arc Detect System with a minimal footprint of less than 50mm x 30mm. The reference design utilizes a proprietary dynamic filtering technique to effectively detect the signature of arcing conductors in the presence of highly noisy real world environments. The analog path requires less than 50mW of power to implement the active filtering. The operation range of the device covers the industrial temperature range of -40°C to +85°C.

2 Features

- 1,000V isolation
- Effective detection at maximum DC string current of 15A
- Simple LED arc detection flag
- Self Test Capability
- Industrial Temperature Range (-40°C to +85°C)
- Small PCB footprint for active area of less than 50mm x 30mm, single sided
- Low power requirement < 400mW, analog power < 50mW

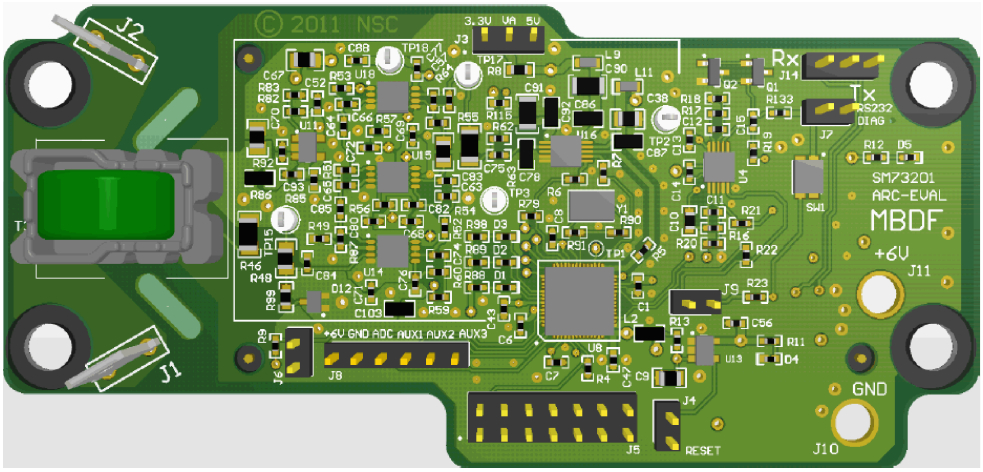

Figure 1. Evaluation board

WARNING

DANGER: HIGH VOLTAGE! In normal operation of this evaluation board potentially hazardous voltages may be present. Use of this board should be restricted to those with appropriate training and experience in handling high voltages. Appropriate safety precautions and personal protective equipment must be used to avoid possible damage, injury, and/or death.

(1)

3 Connection

The multiple connections on the Evaluation Board are labeled. Refer to the table below for a description of their usage.

Connection	Usage
J1	String Current A. J1 is a Flag connector.
J2	String Current B. J2 is a Flag connector.
J3	VA connection: If R8 shunt is not stuffed a jumper between 5V and VA must be present for operation.
J4	Reset: momentarily short these pins to reset the system.
J11/J8p1	Positive supply. Provide 5.4V< Vin <12.5V, with >90mA. J11 can use a banana plug.
J9	Install to generate continuous NOISE signal.
J10/J8p2	Ground. J10 can be connected with a banana plug.
J14	RS232 interface; {Pin1:Txout, Pin2:Gnd, Pin3:Rxin}.

4 Quick Setup Procedure

Step 1: Connect 6V power supply positive to +6V pin of J8 (J8p1) and negative to GND pin of J8 (J8p2). Alternatively connect positive terminal to J11 and negative terminal to J10.

Step 2: Verify proper LED pattern: GREEN LED is on, YELLOW LED is blinking, RED LED is off.

5 LED functionality

Upon power-up, the green LED will turn on. The RD-195 will continually check for arcing conditions; the yellow LED will indicate this by blinking approximately 1 time per second. When an arc is detected the red LED will turn on and the yellow LED will stop blinking.

As shipped, a detected Arc is automatically cleared after 4 seconds and the board will resume looking for arcs. This behavior can be changed by the user.

6 RS232 Interface Operation

The Evaluation Board can output its arc detection status via an RS232 interface located at connector J14. It will periodically issue a message stating “No Arc Detected” or “Arc Detected” as appropriate.

A custom interface cable is required for this functionality; refer to the table below for pinouts

Pin Number	Function
1	TX (out)
2	GND
3	RX (in)

7 RS232 Settings

Use of any terminal program will work. On Windows computer systems, HyperTerminal is an available program that can communicate with the Eval Board. In Windows XP, HyperTerminal can be found on the Start Menu under Start>Programs>Accessories>Communications. For Windows 7 Professional and Ultimate: Installation of Windows XP mode will provide Hyperterminal; or use another terminal program. Termite (http://www.compuphase.com/software_termite.htm) is free program available for personal and commercial use.

Once Hyperterminal starts, provide a name for the connection (e.g. “ArcDetectCon-nect”), and select the appropriate COM port. The port settings for the RS232 link must be set to 115200 baud (bits/sec), 8 Data Bits, No Parity, 1 Stop Bit and No Flow Control.

When connected and powered up, the Evaluation Board will send out a version information header, then will transmit either “Arc Searching” or “Arc Detected” on the console port.

8 RS232 Commands

The firmware provided on the unit provides the ability to modify the Evaluation board's operation through the RS232 interface. The following instructions assume that you are connected to the RS232 interface and are using HyperTerminal as described above.

Entering 'help' will provide a list of instructions. Note that with the default Hyper-terminal settings, your typing will not be visible. To see your typing, chose the File>Properties on the menu; then select the 'Settings' tab. Press the 'ASCII Setup...' button, then check the box to the left of 'Echo typed characters locally', and finish by pressing 'OK' twice.

There are 3 basic commands that can be issued through the RS232 interface -"help", "set", and "get" (do not include quotes). The "help" command returns a list of commands. "get" retrieves the current value of a parameter, and "set" command allows for changing a parameter. Some commands require one or two parameters, for example "set T 250", which would set the T parameter to 250. Parameters should be separated by a space. Care must be taken in changing the Arc Detect parameters (B, D, F, I, C, T) as the Arc Detect routine does not validate the settings, and these settings may not support proper operation. No indication is given if the RD-195 is configured with invalid settings.

9 Complete List of RS232 Commands

Command Parameter	Default	Name	Usage
B	30.0e3	Analysis Bandwidth	set/get Arc Detect Parameter 'B'. set requires a 2nd parameter which must be a number greater than 1.0 for proper operation. Note that the Arc Detection routine is re-initialized after a set command.
D	0.35	Bin Discard Factor: Controls how aggressive the filtering is and corrects for the arc signature shaping	set/get Arc Detect Parameter 'D'. set requires a 2nd parameter which must be a number be between [0.0, 1.0] for proper operation. Note that the Arc Detection routine is re-initialized after a set command.
F	4.00	Filter Weight: Controls how aggressive the filtering is and corrects for the arc signature shaping.	set/get Arc Detect Parameter 'F'. set requires a 2nd parameter which must be a number greater than 0.0 for proper operation. Note that the Arc Detection routine is re-initialized after a set command.
I	45.0e3	Min Frequency	set/get Arc Detect Parameter 'I'. set requires a 2nd parameter which must be a number greater than 1.0 for proper operation. Note that the Arc Detection routine is re-initialized after a set command.
C	55	Clipping Factor: Used to reduce the effect of quick transients causing false detects.	set/get Arc Detect Parameter 'C'. set requires a 2nd parameter which must be a number greater than 1.0 for proper operation.
T	250	Threshold for arc detection: Increasing this value reduces the likelihood of false detections. However, if it is too high, then there may be a risk of missing an arc.	Sets Arc Detect Parameter 'T' to provided number. set requires a 2nd parameter which must be a number greater than 1.0 for proper operation.
U	0.0	Unit Specific Gain Correction	set/get the unit specific gain correction. This value is in dB, and should nominally be 0.0. set requires a 2nd parameter which is the desired correction for customers.
A	NA	Arc Detected Status	"get A" returns the string "Arc Detected" or "No Arc Detected" based on current status. "set A" will clear an Arc if an Arc has been detected and the Arc Automatic clear is disabled.
N	1 (On)	Periodic RS232 Notifications Enable	"set N 1" will enable periodic RS232 notifications on Arc Detected Status (e.g. "No Arc Detected"). "set N 0" will disable periodic notifications on the arc detect status. "get N" will return the string "Notifications On" or "Notifications Off" based on the current setting. The default setting is notifications enabled.
R	1 (On)	Arc Detection Enable	"set R 1" will enable arc detection. "set R 0" will disable arc detection. "get R" will return the string "Arc Detect Running" or "Arc Detect not Running" based on the current setting. The default setting is arc detection enabled. Note when arc detection is disabled, the Green LED will turn off and the Yellow LED will rapidly blink.

Command Parameter	Default	Name	Usage
S	NA	EEPROM Settings	“set S 0" will save the current settings to the on-board EEPROM. “set S 1" will retrieve the settings from the EEPROM. “get S” is not a valid command.
V	NA	Firmware Version	“get V” will return the firmware version information. “set V” is not a valid command.
W	NA	Capture ADC Sample Data	“get W” will return <number> sequential raw ADC samples. If <number> exceeds 2048, then 2048 samples will be returned. Note that this is the only get command which accepts an additional parameter. The W command also returns the stored sample rate. “set W” is not a valid command.
X	1 (On)	Arc Detect Automatic Clearing	“set X 1" will enable the automatic clearing of detected arcs (a detected arc will be cleared approximately. 4sec after detection without any command issued). “set X 0" will disable the automatic clearing. When auto-clear is disabled, a “set A” is the only way to clear a detected arc. “get X” will return the string ‘Detected Arcs Auto-Cleared” or “Detected Arcs not Auto-Cleared” based on the current setting. The default setting is automatic clearing of detected arcs.
Z	0 (Off)	Self Test	“set Z 1” enables self test. ”set Z 0” disables this function. get Z” returns self test status “INACTIVE” or “ACTIVE”.

10 Raw Data Capture

For most efficient capturing of raw ADC codes, turn off the notifications and disable arc detection, by sending the following instructions:

set N 0

set R 0

Once these commands are issued, you should configure HyperTerminal to save the raw data to a file by selecting Transfer>Capture Text, and then set the filename to the conditions that are on the line (e.g. inverter_A_10panels_no_arc.txt), when click ‘Start’. You can then capture the data with:

get W 2000

Once the text transfer is complete (after approximately 2 seconds), close the HyperTerminal file by selecting Transfer>Capture Text>Stop. You can then repeat the file open, get W, and file close process until all desired conditions are saved in a text file.

11 Theory of Operation

Arcing present in a PV system creates random noise current in the cabling used for the PV string. The current noise of the arc itself has a Gaussian distribution with a spectrum extending to several MHz. Because of the geometry of the cabling in a typical PV system, the noise current density above 200 kHz varies significantly with frequency. The inverters used in PV systems usually use switch mode controllers to regulate the incoming DC voltage. These switching regulators usually operate in the kHz range, generally below 50kHz, and introduce an AC interfering signal on the PV string wiring at the switching frequency. For these reasons, noise in the band of frequencies between 40 kHz and 100 kHz was selected for arc detection. The point in the PV string in which the arc detection system is used may be at a potential of as high as 1000 VDC and the current in the system may have a DC component as high as 15 Amps DC. To isolate the high DC voltage and current from the arc monitoring circuit, an isolation transformer is used. A reasonably sized transformer meeting these requirements has relatively low magnetization inductance. Because of this, the noise signal at the secondary of the transformer is relatively low.

The 50 to 100 KHz spectrum is used by services such as maritime radio navigation, and standard time services. The large loop area of a standard PV cabling system may intercept these low frequency signals and create line current many times that of the noise signals caused by arcing. In addition, the switching noise from the inverter or other electronics present on the PV systems may also create noise sources at this frequency. An effective way to eliminate these signals is by digitally processing these signals after A/D conversion. However, in order to eliminate unwanted signals digitally, the signal chain including the A/D converter must have the dynamic range to process the high level CW signals while detecting the low level noise signal created by the arc. This drives the selection of a 16-bit ADC which has a dynamic range of 96dB. This enables the signal path to handle CW signals 93 dB greater than the noise that needs to be measured for arc detection purposes. Figure 2 shows the spectrum (10kHz-130kHz) in dB of the sensed current (after filtering and sampling) with arc and no arc condition. The arc is occurring in a PV string with a DC current of 12A.

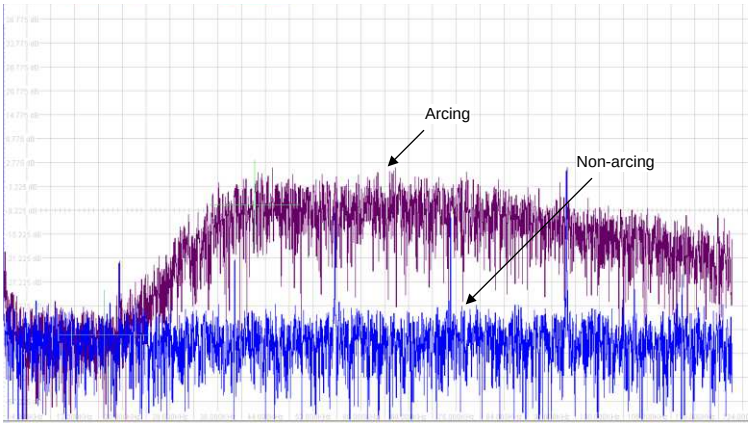

Figure 2. Spectrum of Digitized Current on SM73201

12 System Implementation

The arc detection board is comprised of a transformer, where the string current flows through the primary and that reacts to AC noise present on the string line. The signal appearing on the secondary is amplified and filtered to be fed to an A/D converter. The signal is then fed to a microcontroller for signal processing and arc detection. The board also includes a self test circuit which produces a signal that mimics an arcing event.

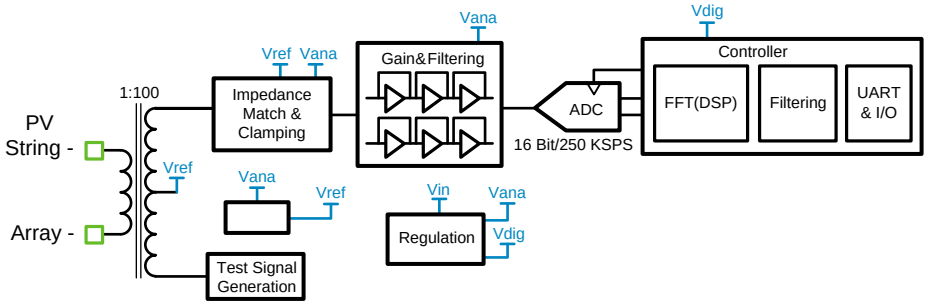

Figure 3. System Diagram

13 Installation

The board is designed to fit in a single string configuration as shown in Figure 4. While the RD-195 can be installed at any point in the string, recommended connection is on the negative side of the string for safety consideration. Arrays containing multiple PV strings can be serviced by connecting one arc detection board per string.

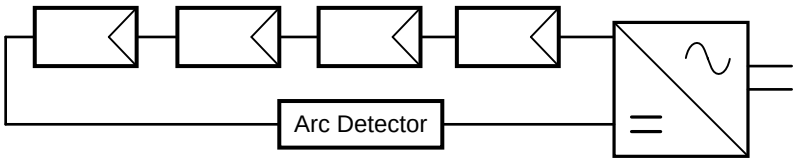

Figure 4. System Insertion

The board has a 1000V isolation capability. Therefore, the board could be connected at mid-string or on the positive side of the string if the voltage does not exceed 1000V. However, this is not recommended due to safety concerns regarding handling. The 6V power supply used to power the board is fed through J10 and J11. The current carrying the string current connects through J1 and J2. See Figure 5. A 9V battery can be used as a power supply for situations in which limited supplies are available. The 9V battery will provide several hours of operation. The RD-195 can be installed into a BUD Industries PN-1321-C Nema 4x enclosure for external evaluation. The enclosure will require appropriate modifications for string level and RD-195 power interfacing.

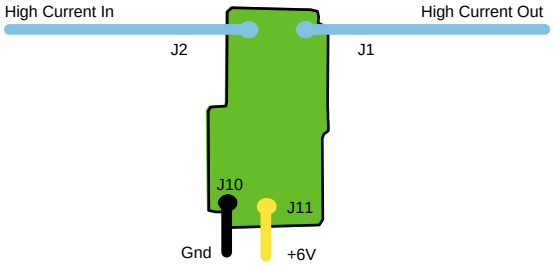

Figure 5. Board Connection

14 Design Description

The analog signal path is shown in Figure 6. The current is sensed through T3. U15A and U18A form a 4 pole Butterworth high pass filter, while U14B, U15B, and U18B form a 5 pole low pass filter. U18B and U14A add gain to the system with low noise floor operational amplifiers. The output of U18B is the input to the A/D conversion circuit. The filter has a cutoff frequency of 40kHz for the low limit and 100kHz for the high limit. This bandwidth is necessary for the proper operation of the software programmed in the microcontroller.

The op-amps are powered from a 5V rail provided by a linear regulator. The op-amps inputs are biased using a reference voltage derived from another op-amp circuit shown in Figure 7.

The board also supports a self test circuit which produces a signal that mimics an arcing event. See Figure 8. The self test circuit produces a noise signal that can be controlled manually with switch SW1, or with the CPU using the NOISE_EN input. For manual test (J9 open) press SW1 to generate a noise signal, simulating an arcing event. For CPU test (J9 open) set NOISE_EN signal (AIO10) high to generate a noise signal. In the RD-195 software this is done with “set Z 1” command. When an arc is detected, Z resets, and turns off the self test circuit. Should no arc be detected, Z continues to stay at 1, and the self test circuit remains enabled. Install J9 jumper to generate a continuous noise signal. +V should be between 8 and 12 volts for proper operation of the noise circuit.

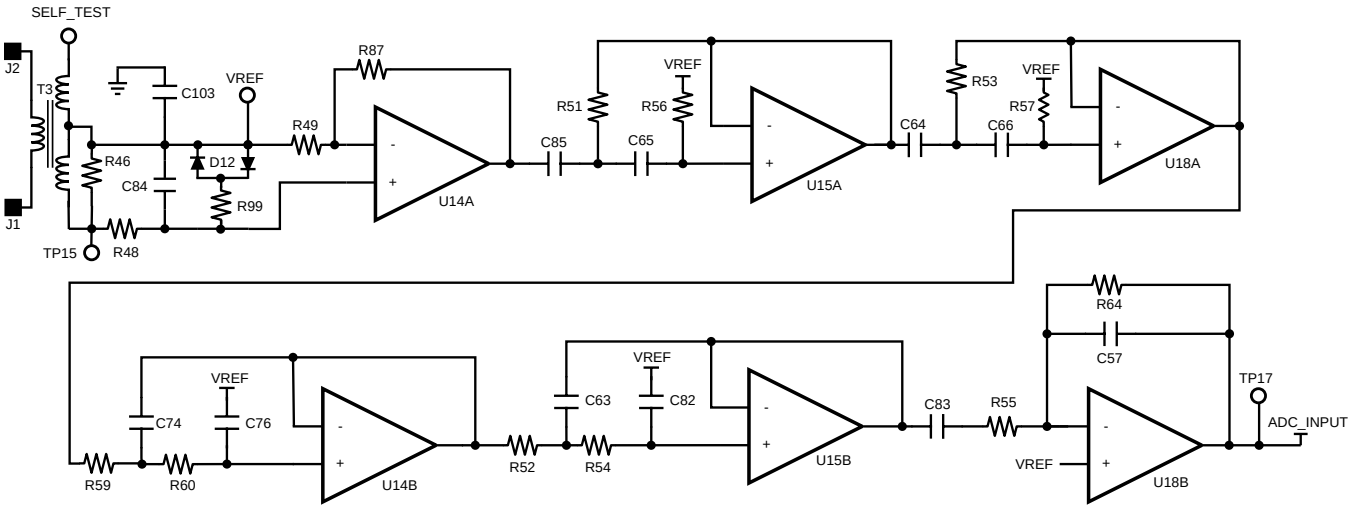

Figure 6. Analog Front End

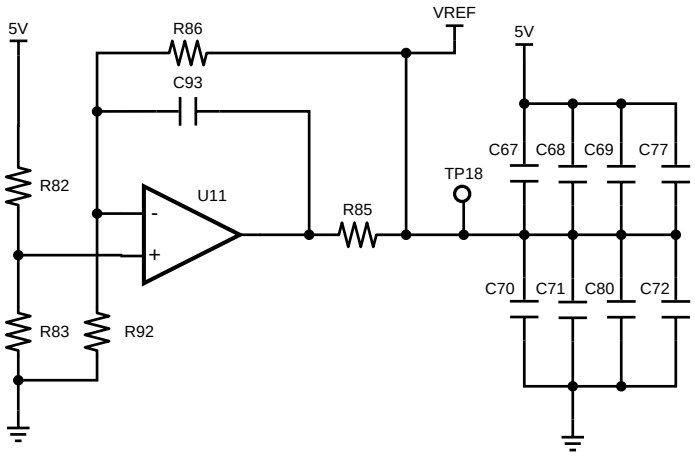

Figure 7. Reference voltage

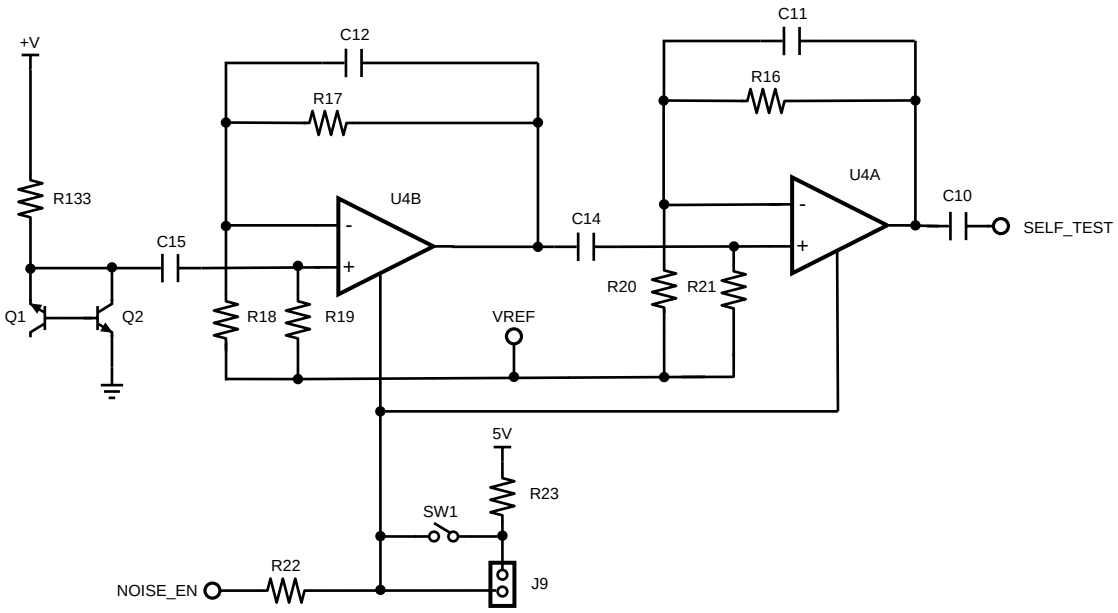

Figure 8. Self Test Circuit

The A/D converter is a 16bit converter operating at approximately 250kS/s. The high resolution translates to a high dynamic range for the sensed signal, thereby allowing the arc signature to be sensed properly without clipping due to the potentially higher amplitude of interference signals from the inverter. The converter sampling rate is controlled by the microcontroller. The connection is shown in Figure 9.

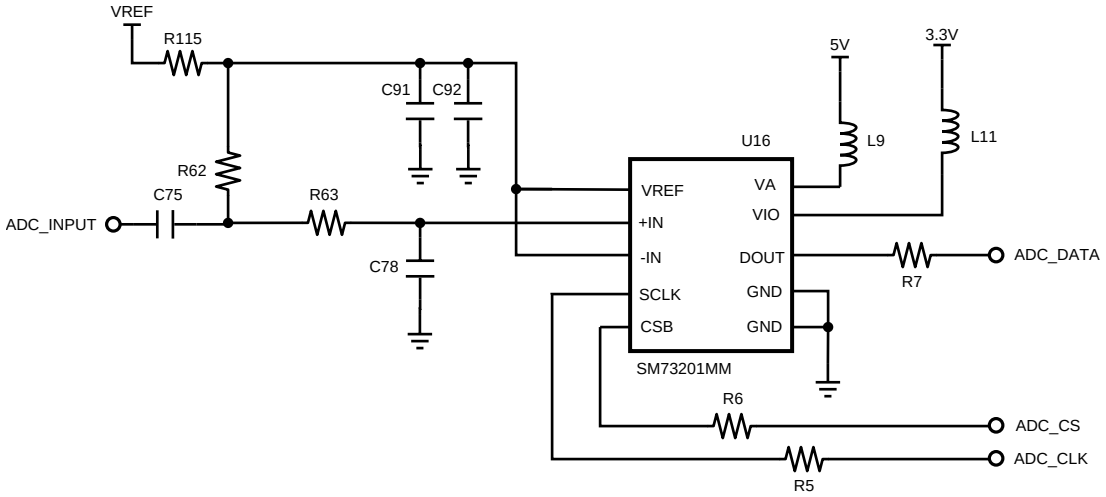

Figure 9. A/D Converter

15 Differentiation of Series and Parallel Arcing Events

There are two main types of electrical arcing events in PV systems: Series arcs and Parallel arcs. Series arcing events occur when the current path is opened and the breakdown voltage for the opening is exceeded. These are caused by any type of incomplete connection; examples include cold solder joints, conductor corrosion, and improperly mated connectors.

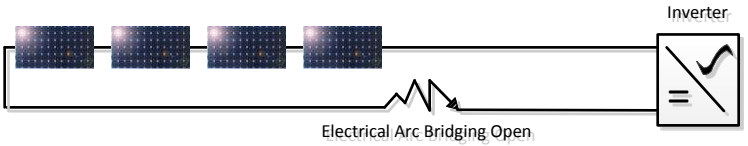

Figure 10. Series Arcing

A parallel arcing event occurs when an additional current path to a conductor outside of the designed current loop becomes available. The original current path of the system may not be interrupted; partial power may still be generated on the string. Parallel arcs can be caused by insulation damage or other damage to the system.

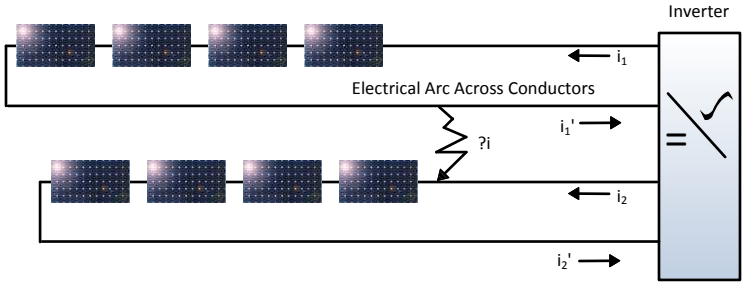

Figure 11. Parallel Arcing across strings

Detection of parallel arcing can be implemented with regular measurements of all the string currents and neutral lines; an arcing event is indicated when the individual string currents in and out of the inverter do not match. In Figure 11, the currents i1 and i1' should be equal in normal operation. Any significant current difference can be considered a dangerous condition. Parallel arcs can also be detected by the RD-195. Detection of a series arcing event is not as straightforward as checking for imbalanced currents; using an RD-195 is necessary. Use of current measurements in conjunction with an RD-195 provides a method to detect and differentiate both types of arcs.

The appropriate response to detection of an arc is system dependant. While a series arc can be extinguished be opening a relay in the path, which stops the current flow and therefore the arc, disconnection can actually exacerbate a parallel arcing condition by forcing more current though the arc. For many situations, shorting all positive and negative strings lines to ground will extinguish arcs. However this may not be possible for some systems. How to handle an arcing event should be considered during system design.

16 Safety

Caution must be used at all times while generating arcs. The high voltages present in a PV system pose a lethal hazard. Incandescent metal sparks and open flame can be present. Use all necessary safety gear, including Eye/Face protection, electrical gloves rated for the electrical conditions, and any other equipment appropriate for the conditions. Texas Instruments assumes no liability for any damage or injury that may occur.

17 Bench Evaluation Procedure

The RD-195 Photo-voltaic arc detection system is designed for reliable detection of electrical arcing events without producing nuisance false positive detections. Evaluating the RD-195 poses some difficulty, as the recommended setup requires a complete PV installation, including several PV modules and an inverter. Inclement weather can also restrict the time available for evaluation. Basic evaluation can be done using equipment available in a standard lab.

Required Equipment:

1. DC power supply with 200V/2Amps
2. DC power supply with 6v/150mA

- a. Used for RD-195 operation. A 9V battery can be used instead; this will provide several hours of operation.

3. Ballasting Resister (must be able to withstand >200W)
   - a. Incandescent light bulbs can be used as load.
4. Arc Generation unit (discussed further below)

The basic setup is shown in Figure 12 below.

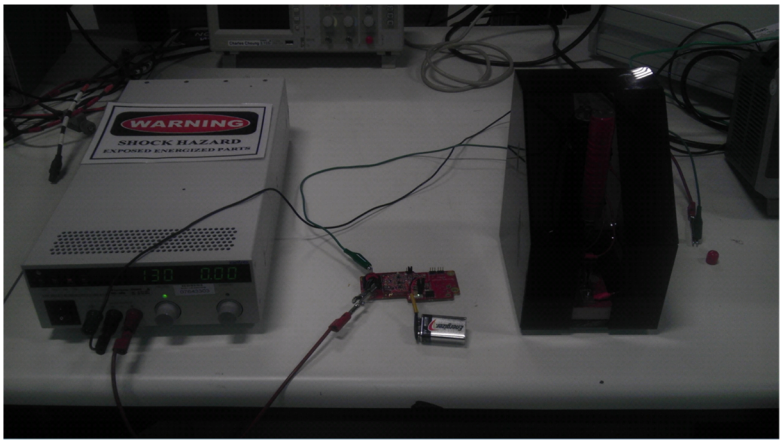

Figure 12. Basic Setup Photo

On the left is the DC power supply (item 1). The ballasting resistor and arc generation unit are combined into a single unit on the left. Once the system is connected up, slowly opening the knife switch on the Arc Generation unit will produce a controllable electrical arc. See Figure 13. The Arc Generation unit is not a commonly available piece of lab equipment. See Figure 14. They can be built using polycarbonate enclosure surrounding a knife switch (rating > 15A is required. A Filnor A-10S is acceptable). Polycarbonate is used as it provides protection against physical damage, is available in flame-resistant varieties, and also blocks the UV radiation an electrical arc produces. Below in Figure 15 is a picture of the knife switch. Notice the long handle. Be sure to use a non-conductive material for the handle which is flame-resistant.

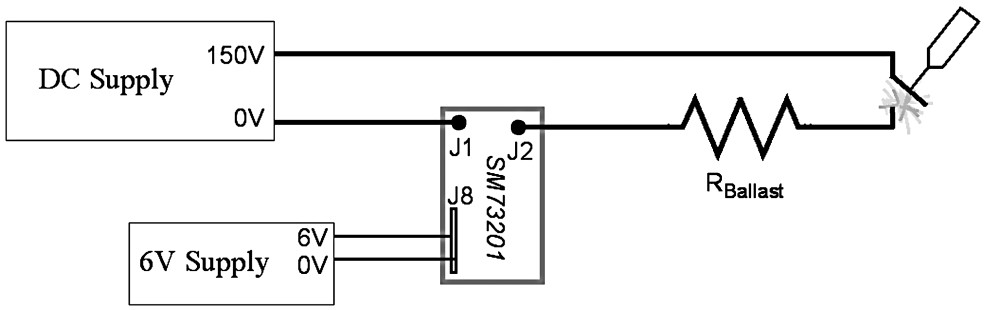

Figure 13. Basic Setup Schematic

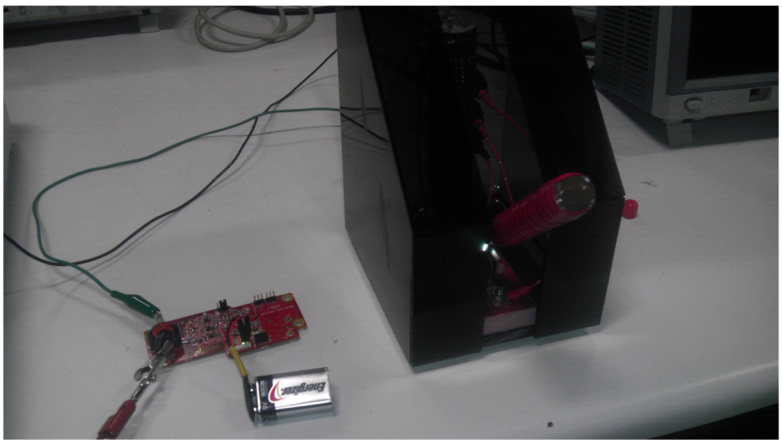

Figure 14. Arc Generation Unit

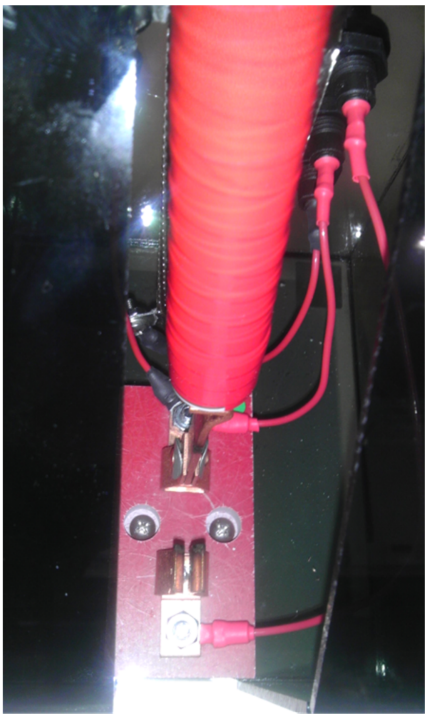

Figure 15. Knife Switch

Below in Figure 16 is a picture of the Arc Generation unit producing an arc. This arc was generated with the DC power supply set to 130V, with a maximum current of 2.0A.

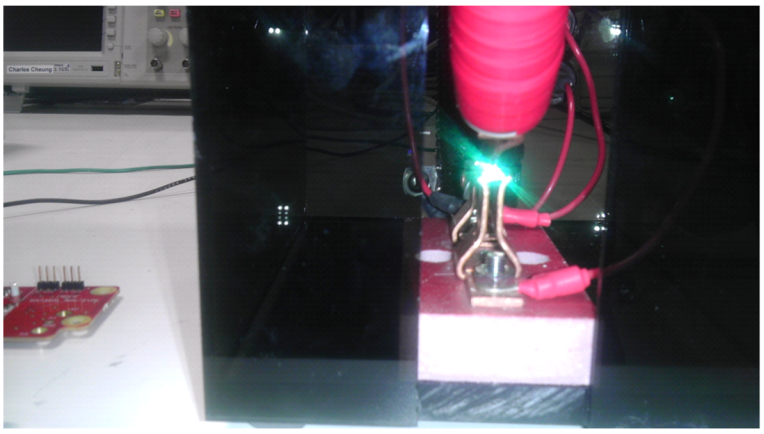

Figure 16. Arc Generation

Once the system is connected as described, an arc can be generated when desired. This can be used to evaluate the various annunciators of the RD-195. The default firmware provided with the RD-195 has the following annunciators :

1. Red LED D3 will turn on for ~4 seconds
2. An RS-232 115.2Kbaud connection on J14 will issue a message of status
3. J8 pin6 (Aux3) will be driven to 3.3v from 0v

18 Arc Detection Library Structure

Figure 17 shows the directory structure while the subsequent Table 1 provides a description for each folder.

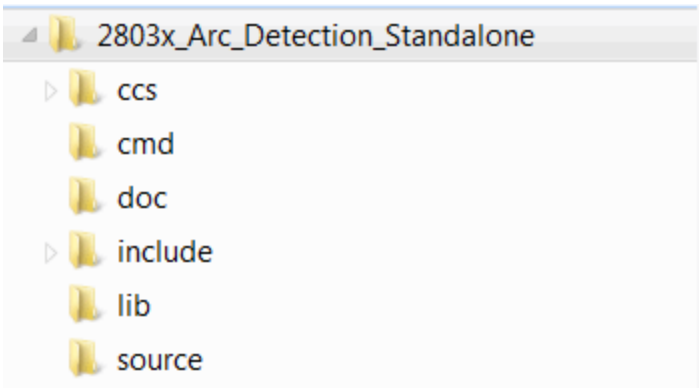

Figure 17. Directory Structure of the SM73201 Arc Evaluation Module

Table 1. SM73201 Arc Evaluation Module Directory Structure Description

Folder	Description
<base>	For the rest of this document <base> will be omitted from the directory names
<base>/ccs	CCS project for the Flash demo
<base>/cmd	Linker command files for the project
<base>/doc	Documentation for the current revision of the library including revision history
<base>/include	All device and library header files

Table 1. SM73201 Arc Evaluation Module Directory Structure Description (continued)

<base>/lib	FFT, Flash API, Arc Detection static libraries
<base>//source	Application source code

19 Using the Arc Detection Library

To begin integrating the Arc Detection library into your project you need to follow these easy steps

1. Go to the **Project Properties->C/C++ Build->C2000 Compiler->Include Options**(see Figure 18) and add the relative path,

INSTALLROOT_TO_ARCDETECT_VERSION/include

(VERSION is the current version of the library), to the list of search directories.

The Arc Detection library invokes the complex FFT routine from the Fixed Point Library. The path to this library must be included in your project i.e.

INSTALLROOT_TO_FIXEDPOINT_VERSION/include

Finally, if you plan on using the test vectors provided with the library to gauge the accuracy of the algorithm, you must include the path

INSTALLROOT_TO_ARCDETECT_VERSION/test

to the list of search directories.

These macros must be specified in a **macro.ini** file in your project. Each macro must reflect the path or location of each of the libraries relative to the folder in which your project was created.

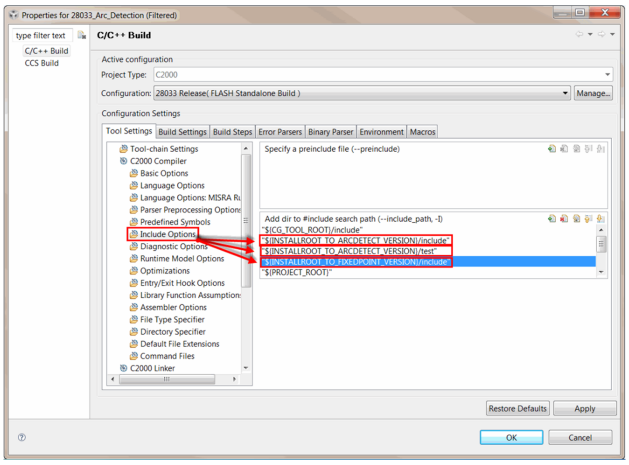

Figure 18. Adding the Include Search Path for the Library

2. Add the name of the libraries(Arc Detection and Fixed Point) and their locations to the **File Search Path** as shown in Figure 19.

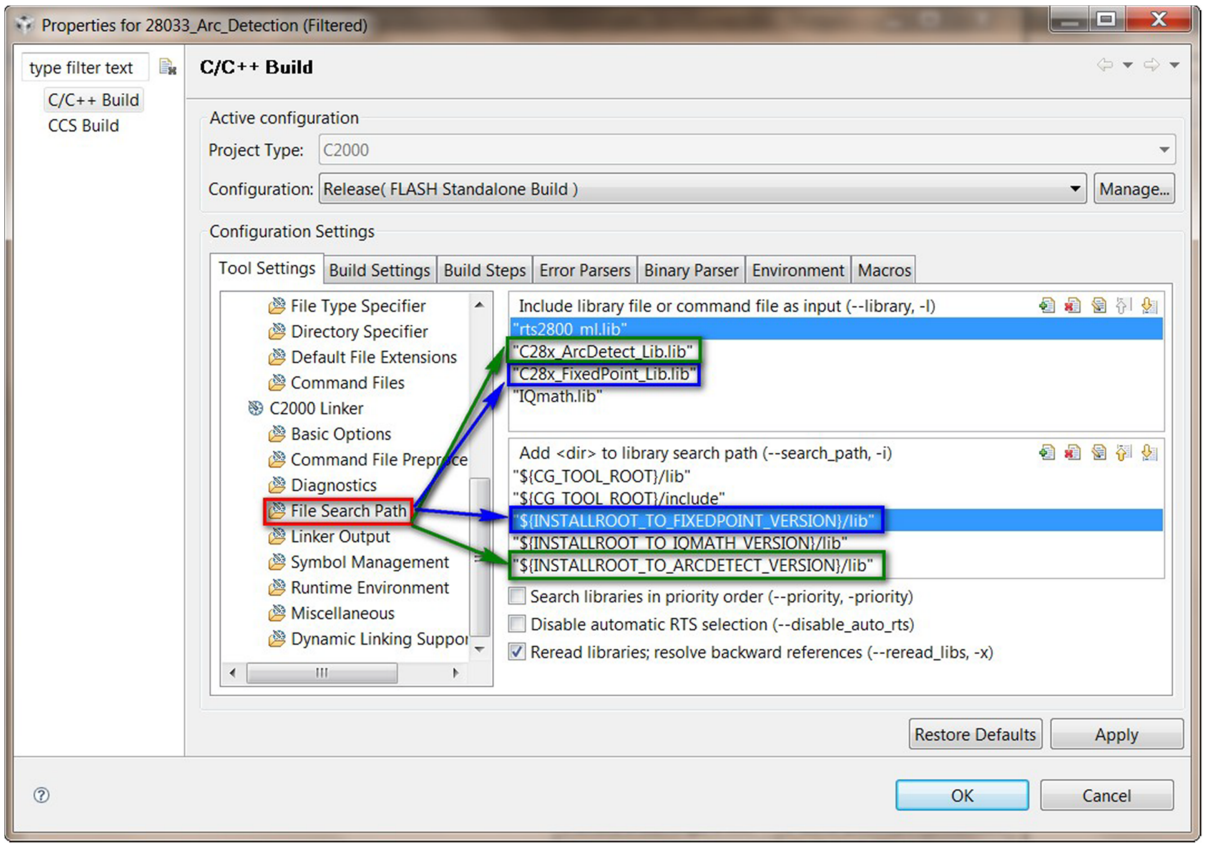

Figure 19. Adding the library and location to the file search path

20 Structure of the Code

The project view of the demo, once it is imported into CCSv4/v5, is shown below in Figure 20 and the description of the constituent files is given in the Table 2, Table 3, and Table 4

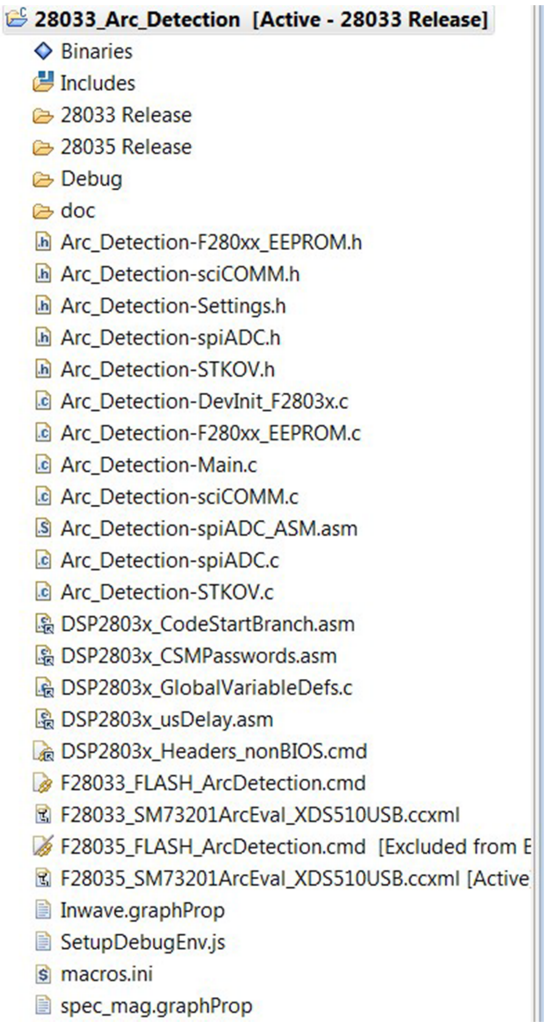

Figure 20. Project View in CCS

The project has three build configurations: **28033(default)**, **28305** and **Debug** as shown in Figure 21.

Table 2. Project Header File Description

Folder	Description
Arc_Detection-F280xx_EEPROM.h	Flash EEPROM Emulation Macros and Function Prototypes
Arc_Detection-sciCOMM.h	SCI-A Macros and Function Protoypes
Arc_Detection-Settings.h	Project setting, type defintions and incremental build options
Arc_Detection-spiADC.h	SPI-A Macros and Function Prototypes
Arc_Detection-STKOV.h	Stack Overflow Protection Macros and Function Protoypes

Table 3. Project Source File Description

Folder	Description
Arc_Detection-DevInit_F2803x.c	System and Peripheral Initialization Routines
Arc_Detection-F280xx_EEPROM.c	Flash EEPROM Emulation Routines
Arc_Detection-Main.c	Main body of the code
Arc_Detection-sciCOMM.c	SCI-A Function Definitions
Arc_Detection-spiADC_ASM.asm	SPI-A bit-banging routine

Table 3. Project Source File Description (continued)

Arc_Detection-spiADC.c	SPI-A Function Definitions
Arc_Detection-STKOV.c	Stack Overflow Protection Function Definitions

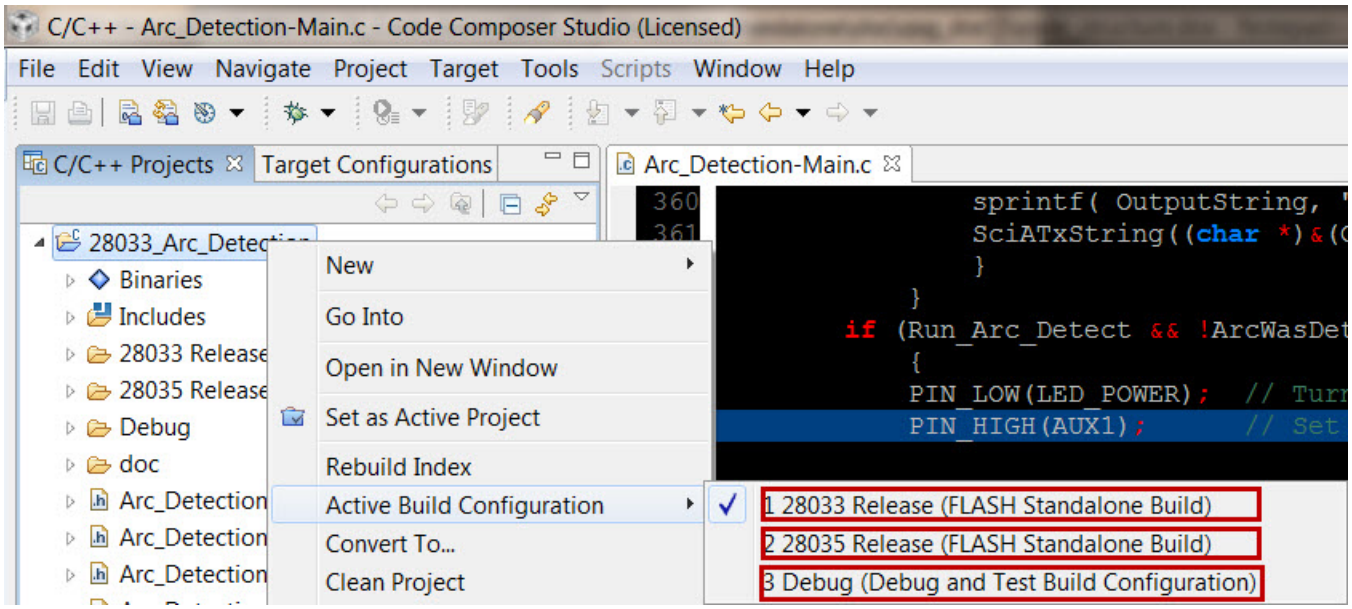

Figure 21. Build Configurations

The 28033 configuration is the default configuration for the project. The user must switch to the 28035 configuration if using it with the F28035 processor. The Debug configuration is used to test the functionality of several board components like the LED's, GPIO's and SCI communication and will work with either the F28033 or the F28035.

The Flash Linker Command File specifies the memory blocks and code sections for this example as shown in Figure 22. The following Table 5describes the main code sections.

NOTE: THE SECTIONS AND MEMORIES SHOWN IN THE IMAGES MAY NOT REFLECT THE ACTUAL VALUES USED IN THE CURRENT VERSION OF THE APPLICATION CODE.

Table 4. Miscellanous File Description

Folder	Description
F28033_FLASH_ArcDetection.cmd	Flash linker command file for F28033
F28035_FLASH_ArcDetection.cmd	Flash linker command file for F28035
SetupDebugEnv.js	Script to setup the watch window and graphs in the debug perspective of CCS

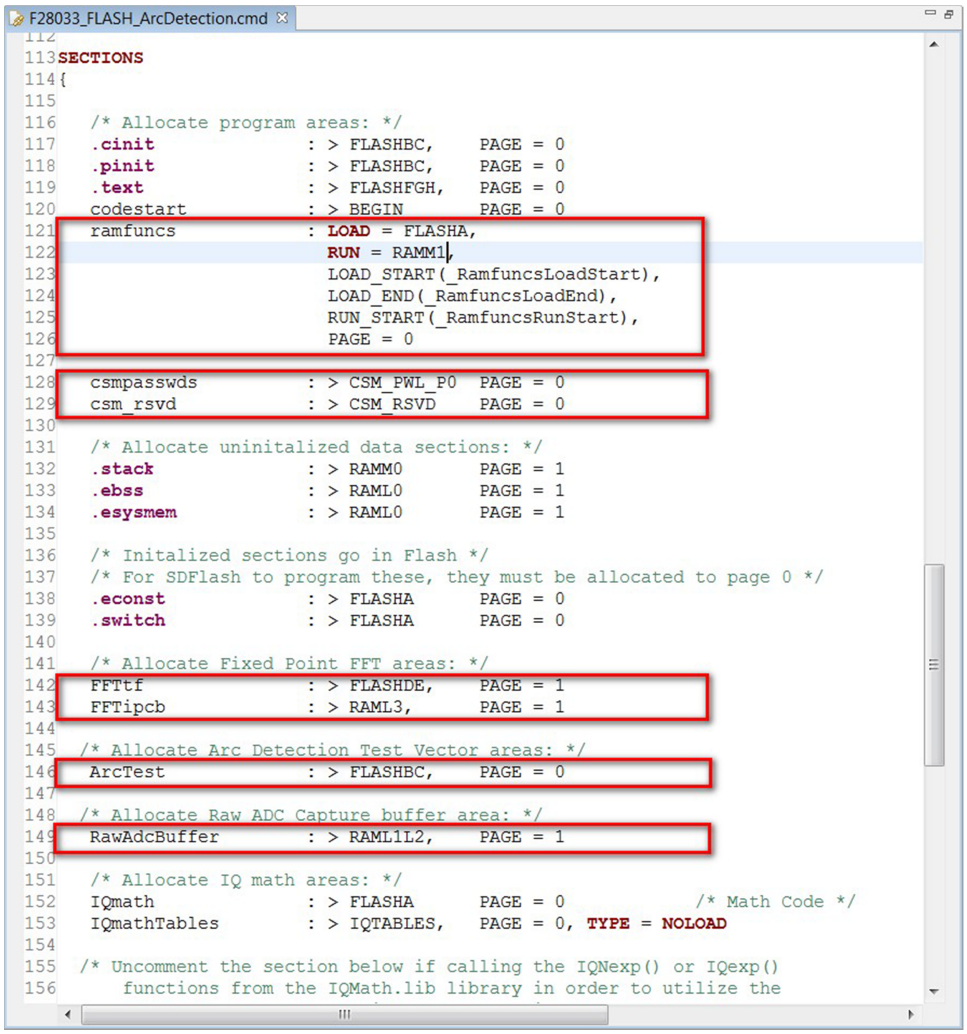

Figure 22. Flash Linker Command File

Table 5. Linker Command File Description

Folder	Description
ramfuncs	Time critical code is placed here. It is copied from FLASH to RAM after the device is brought out of reset
csmpasswds	The CSM(128-bit) password is written to this location
csm_rsvd	The section of FLASH(120 words) prior to the password locations are reserved locations and must not be written to
FFTtf	Section for the FFT Twiddle Factors
FFTipcb	Section for the complex FFT input buffer. The default size is 4096 words (1024 inputs * 2 complex * 2 32-bits wide). This buffer must be aligned to 4*N word space. In this case, since the buffer is allocated to the start of a RAM block, alignment is not required.
ArcTest	The test vectors are allocated to this section
RawAdcBuffer	The raw ADC capture buffer is allocated to this section

21 Benchmarks

The benchmarks were obtained with the following compiler settings for the application firmware and the library.

The Application Firmware:

-v28 -mt -ml -g -O1 -ms --keep_unneeded_statics

The Library:

-v28 -mt -ml --symdebug:none -O1

Table 6. Benchmark for the various routines

Function	Cycles	Time(ms) SYSCLK = 60MHz
DoArcDetect	997375	16.6229
– Data acquisition	435179	7.2529
– Time Domain Processing	98311	1.6385
– Frequency Domain Processing	233115	3.8852
—- Bit Reversal(1024 complex)	30224	0.5037
—- FFT(1024 complex)	202887	3.3814
– Data Analysis	230614	3.8435
SelfCheck	432589	7.2098

The user should note that the algorithm makes a determination of whether an arc has occurred or not over 10 iterations of the DoArcDetect routine, therefore, the time per iteration of the algorithm, on average, should be considered to be 10 times the cycle count for the DoArcDetect routine.

22 Other Resources

The Arc-Detection Evaluation module makes use of the Piccolo line of C2000 devices which you can check out at the TI Piccolo page: http://www.ti.com/piccolo

And don’t forget the TI community website: http://e2e.ti.com

Building the Arc Detection library requires **Codegen Tools v6.0.1 or later**

23 Layout

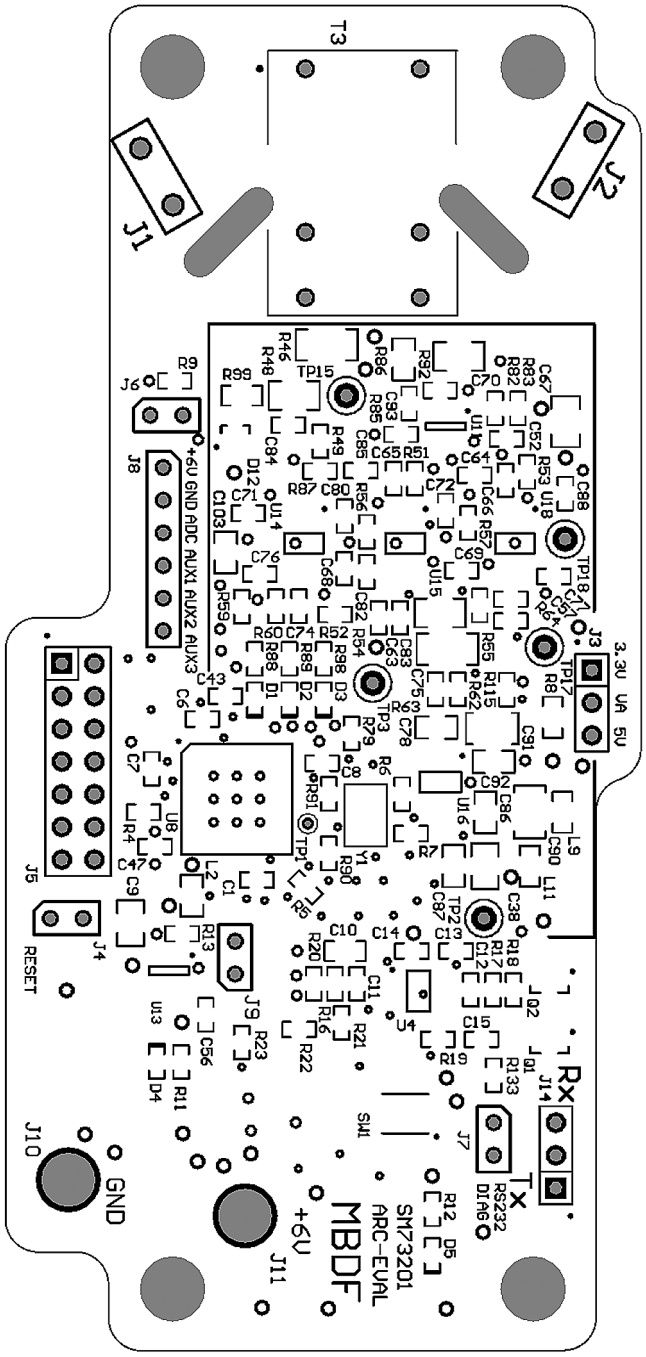

Figure 23. Board Assembly TOP

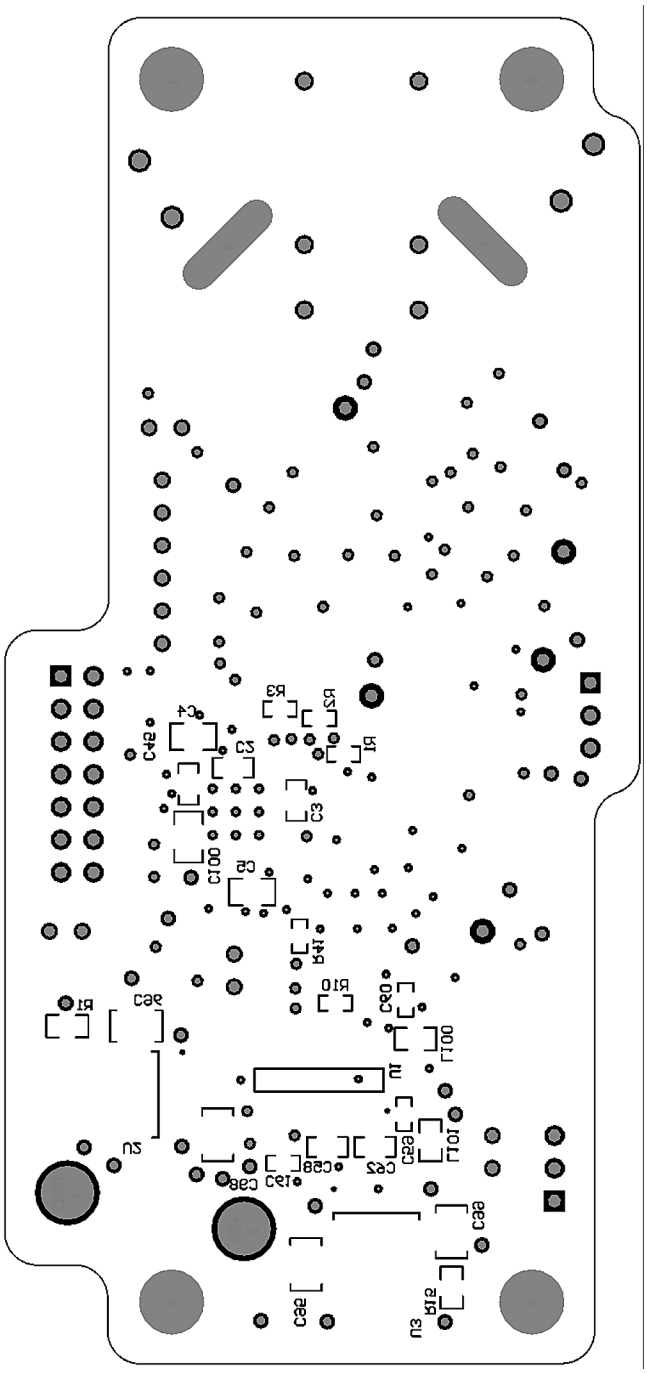

Figure 24. Board Assembly BOTTOM

24 Bill of Materials

Designator	Description	Manufacturer	LibRef	Quantity
C1, C6, C7, C8, C13, C43, C47, C52, C56, C59, C60, C61, C68, C69, C71, C72, C77, C80, C88	CAP CER .10UF 16V X7R AUTO 0402	TDK	CGA2B1X7R1C104K	18

Designator	Description	Manufacturer	LibRef	Quantity
C2, C3, C45	CAP, CERM, 1.5uF, 6.3V, +/-10%, X5R, 0603	Kemet	C0603C155K9PACTU	3
C4, C5, C38, C90, C91, C95, C98	CAP, CERM, 1uF, 16V, +/-10%, X7R, 0805	Taiyo Yuden	EMK212B7105KG-T	7
C9, C96, C99	CAP, CERM, 2.2uF, 16V, +/-10%, X7R, 0805	Taiyo Yuden	EMK212B7225KG-T	3
C10	CAP, CERM, 0.022uF, 50V, +/-10%, X7R, 0603	Murata	GRM188R71H223KA01D	1
C11, C12, C93	CAP CER 10PF 50V C0G 0402	Murata	GCM1555C1H100JZ13D	3
C14, C15, C84	CAP CER 2200PF 25V 5% C0G 0402	Kemet	C0402C222J3GACTU	3
C57, C63, C64, C65, C66, C76, C85	CAP CER 1000PF 50V 5% C0G 0402	Murata	GRM1555C1H102JA01D	7
C58, C62, C86, C87, C92	CAP, CERM, 0.1uF, 25V, +/-10%, X7R, 0603	Murata	GRM188R71E104KA01D	5
C67, C70	CAP, CERM, 4.7uF, 10V, +/-10%, X5R, 0805	Murata	GRM219R61A475KE34	2
C74	CAP CER 1500PF 25V 5% C0G 0402	Kemet	C0402C152K3GACTU	1
C75	CAP CER 47000PF 50V 5% C0G 1206	Murata	GRM31M5C1H473JA01L	1
C78	CAP, CERM, 4700pF, 100V, +/-10%, X8R, 0603	TDK	C1608X8R2A472K	1
C82	CAP CER 91PF 50V 5% C0G 0402	TDK	C1005C0G1H910J	1
C83	CAP, CERM, 0.033uF, 25V, +/-5%, C0G/NP0, 0805	TDK	C2012C0G1E333J	1
C100	CAP, CERM, 2.2uF, 10V, +/-10%, X5R, 0805	AVX	0805ZD225KAT2A	1
C103	CAP, CERM, 2200pF, 50V, +/-5%, C0G/NP0, 0603	TDK	C1608C0G1H222J	1
D1, D4, D5	LED 0402 GREEN 54MW 20MA SMD	Rohm	SML-P11MTT86	3
D2	LED 0402 YELLOW 52MW 20MA SMD	Rohm	SML-P11YTT86	1
D3	LED 0402 RED 50MW 20MA SMD	Rohm	SML-P11UTT86	1
D12	DIODE SW DUAL 75V 200MW SC70-3	Diodes	BAV99W-7-F	1
J1, J2	TERM QF .032DIA .250" STURDY MT"	Keystone	1289-ST	2
J3, J14	Header, TH, 100mil, 3x1, Gold plated, 230 mil above insulator	Samtec	TSW-103-07-G-S	2
J4, J6, J9	CONN HEADER 2POS .100 T/H GOLD"	Samtec	TSW-102-07-L-S	3
J5	Header, TH, 100mil, 7x2, Gold plated, 230 mil above insulator	Samtec	TSW-107-07-G-D	1
J8	CONN HEADER 6POS VERT .100 GOLD	TE Connectivity	644884-6	1
L2, L9, L11, L100, L101	FERRITE CHIP 330 OHM 1200MA 0603	Murata	BLM18PG331SN1D	5
Q1, Q2	Transistor, NPN, 40V, 0.2A, SOT-23	Diodes Inc.	MMBT3904-7-F	2
R1, R2, R3, R10, R13, R41, R62, R79, R82, R83	RES, 10.0k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW040210K0FKED	10
R4, R90	RES, 2.21k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04022K21FKED	2
R5	RES, 64.9 ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW040264R9FKED	1
R6, R7, R3, R49, R55	RES, 1.00k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04021K00FKED	5
R8	RES, 0 ohm, 5%, 0.1W, 0603	Vishay-Dale	CRCW06030000Z0EA	1
R9, R22	RES, 20.0k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW040220K0FKED	2
R11, R88, R89, R98	RES, 330 ohm, 5%, 0.063W, 0402	Vishay-Dale	CRCW0402330RJNED	4
R12	RES, 787 ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW0402787RFKED	1
R14, R15	RES, 0.22 ohm, 1%, 0.1W, 0603	Panasonic	ERJ-3RQFR22V	2
R16, R17, R19, R21	RES, 121k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW0402121KFKED	4
R18, R20, R133	RES, 4.75k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04024K75FKED	3
R52, R54	RES, 5.11k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04025K11FKED	2

Designator	Description	Manufacturer	LibRef	Quantity
R46	RES, 200 ohm, 1%, 0.25W, 1206	Vishay-Dale	CRCW1206200RFKEA	1
R48	RES, 100 ohm, 1%, 0.125W, 0805	Vishay-Dale	CRCW0805100RFKEA	1
R51	RES, 2.61k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04022K61FKED	1
R53	RES, 1.78k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04021K78FKED	1
R56	RES, 3.92k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04023K92FKED	1
R57	RES, 10.5k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW040210K5FKED	1
R59, R60	RES, 1.27k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04021K27FKED	2
R63	RES, 49.9 ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW040249R9FKED	1
R64	RES, 1.65k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04021K65FKED	1
R85, R115	RES, 1.00 ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04021R00FKED	2
R86	RES, 0.33 ohm, 1%, 0.1W, 0603	Panasonic	ERJ-3RQFR33V	1
R87	RES, 9.09k ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04029K09FKED	1
R91, R92	RES, 1.00Meg ohm, 1%, 0.063W, 0402	Vishay-Dale	CRCW04021M00FKED	2
R99	RES, 49.9 ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW060349R9FKEA	1
SW1	SWITCH TACTILE SPST-NO 0.02A 15V	Panasonic	EVP-AA202K	1
T3	XFRMR CURR SENSE 76MH 200:200:1 TH	PULSE	PA3655NL	1
TP1, TP2, TP3, TP15, TP17, TP18	Test Point, TH, Miniature, White	Keystone	5002	6
U1	TXRX DUAL 5V TIA/EIA-232 16-SOIC	TI	LMS202ECMX	1
U2	IC REG LDO 500MA 3.3V TO252	TI	LP38691DT-3.3	1
U3	IC REG VOLT MICROPWR 5V TO-252	TI	SM72238TD-5.0	1
U4	1.8V Dual Low Noise CMOS Input Op Amp with Shutdown	Ti	LMV792MM	1
U8	IC MCU	TI	TMS320F28033RSHT	1
U11	IC OPAMP LOW OFFSET RRO SC70-5	TI	SM73308MG	1
U13	5-Pin Microprocessor Reset Circuit 3.08V	TI	SM72240MF-3.08	1
U14, U15, U18	1.8V Precison, Dual Low Noise CMOS Input Op Amp	TI	SM73307MM	3
U16	IC ADC 16BIT 50/250KSPS 10-MSOP	TI	SM73201IMM	1
Y1	CER RESONATOR 6.00MHZ SMD	Murata	CSTCR6M00G53–R0	1

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   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

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   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for any defects that are caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

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      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

      3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

      CAUTION

      This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

      Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

      FCC Interference Statement for Class A EVM devices

      NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

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4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

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