2007 Microchip 16bit Embedded Control Design Contest

dsPIC LCR Meter

Registration Number: MT1769

Eligible Part(s) Used:
dsPIC30F4012 28Pin *Motor Control MCU*
Bonus Part(s) Used:
MCP6022 10MHz *Dual Op-Amp*
Additional MICROCHIP Part(s) Used:
MCP23S08 *8Bit SPI GPIO*
MCP41010 *10K SPI Digital Pot*
MCP6S91 *SPI Binary PGA Op-Amp*
MCP1525 *2.5V Precision Voltage Reference*

Abstract:

The LCR meter is not a tool commonly found in the electronics hobbyist's workshop. Traditionally these tools have been limited to professional design labs and production line quality assurance activities. Despite this the increase in popularity of SMD components, including unmarked chip capacitors, and the prevalence of inductor based switching power regulator systems makes the LCR meter a useful tool.

The design presented utilizes up to date digital methods to analyze the analog performance of the *device under test* (DUT). The design uses *direct digital synthesis* (DDS) techniques to generate the test waveform and *digital signal processing* (DSP) methods to condition the resulting voltage and current signals. Three test frequencies are implemented (100Hz, 1kHz, 10kHz) and both parallel and series circuit models are evaluated; automatic selection of both frequency and circuit model is available. Basic accuracy is better than 1%.

The prototype system is built around Microchip's 16bit 28pin development board. Programming of flash memory was achieved using Microchip's USB *PICKITII* programmer. Firmware code was written in C and compiled using the competition version of *C30*, developed in MPLAB v7.50. Coefficients for DSP filtering were created using Momentum Data Systems *dsPIC FD Lite*. The analog anti aliasing filters were designed with Microchip's *Filter Lab* v2.0.

dsPIC LCR Meter Operating Specification	
Test Frequency	100Hz, 1kHz, 10kHz, (Auto)
Measurement Model	Series, Parallel, (Auto)
Drive Signal	1V pp via 1kΩ
Maximum Impedance	10MΩ
Minimum Impedance	100mΩ
Basic Accuracy	1% (± 0.1°)
Displayed Parameters	Z(Ω), R(Ω), X(Ω), C(F), L(H), Q, D, θ(°)
Supply Voltage	9V
Supply Current	180mA (385mA with LCD Back Light)

Fig 1 : Basic Operation Specifications

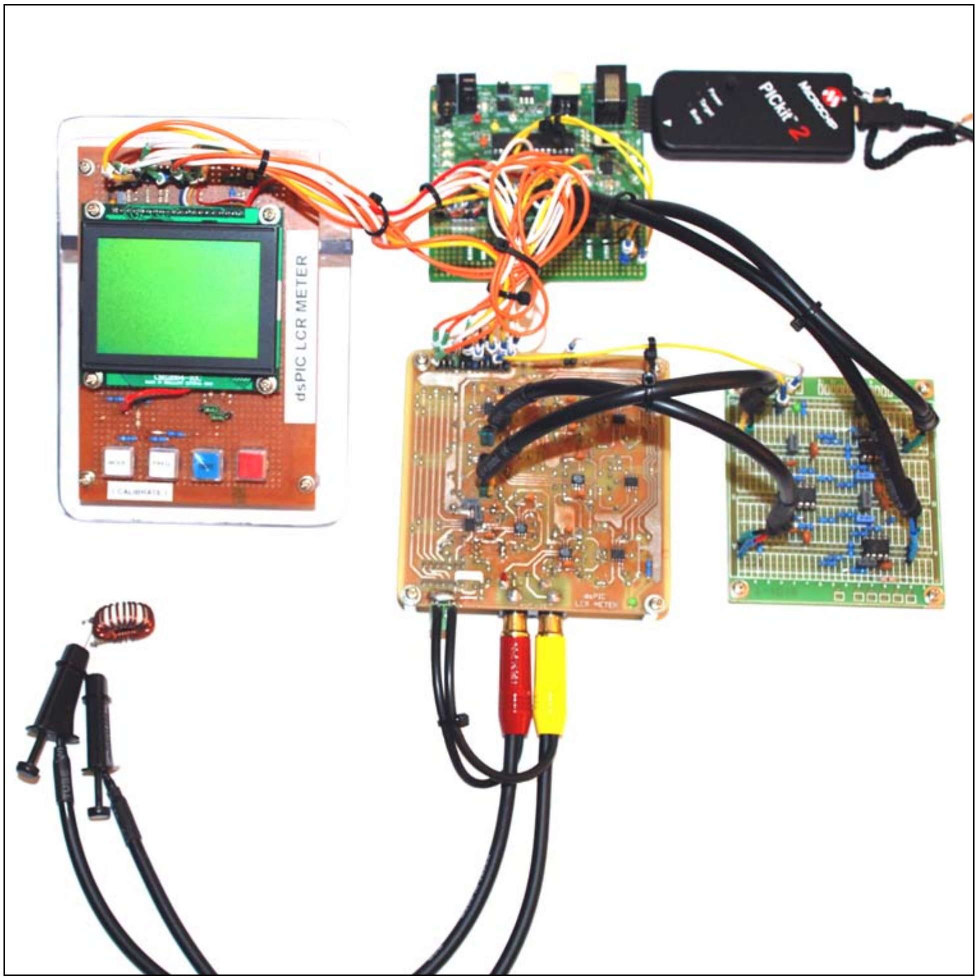


Fig 2 : Complete dsPIC LCR Meter Prototype System.

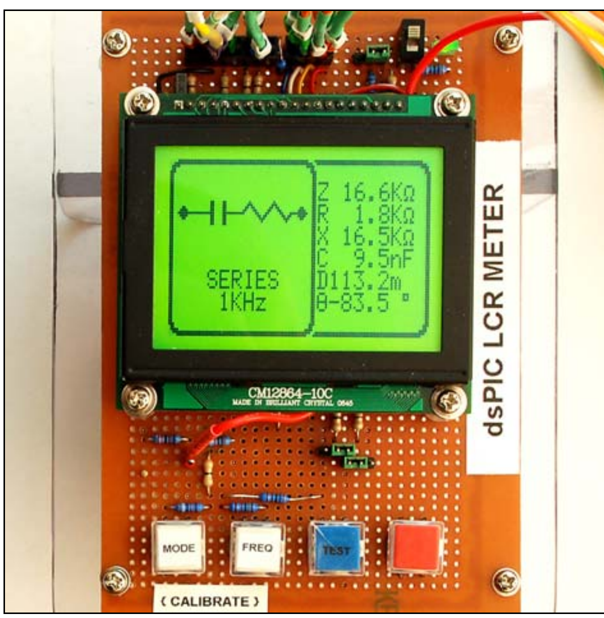


Fig 3 : User Interface Board.

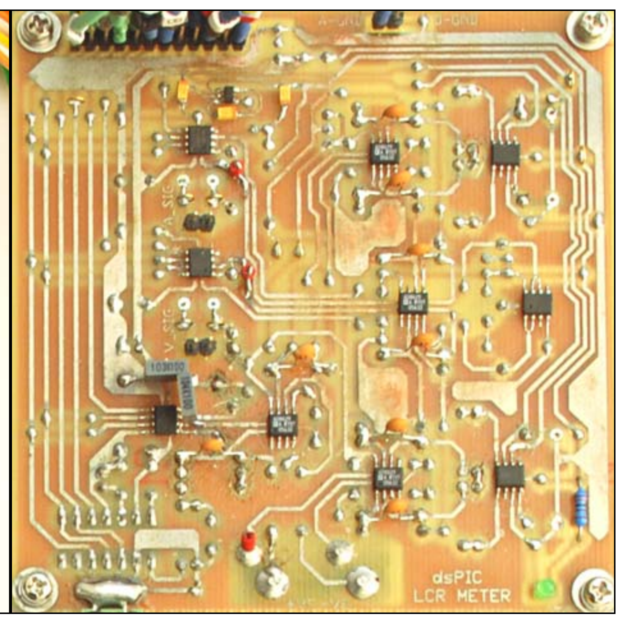


Fig 4 : Analog Stage Board - Top.

Theory of Operation:

The dsPIC LCR generates a sine wave of known frequency and applies this to the DUT via a source resistance. Signals representing the current through and voltage across the DUT are conditioned and amplified before being simultaneously acquired by the ADC module. The acquired signals are further conditioned by DSP filters to reduce the influence of numerous error sources. By accurately determining the zero crossings of the acquired waveforms the amplitude and phase can be calculated.

Once the amplitude and relative phase between the voltage and current waveforms is known all of the device paramaters can be evaluated using standard text book electrical fomulas. The exact formula to be used is determined by the nature of the component (i.e. leading or laging) and the type of circuit model to be used (i.e. series or parallel).

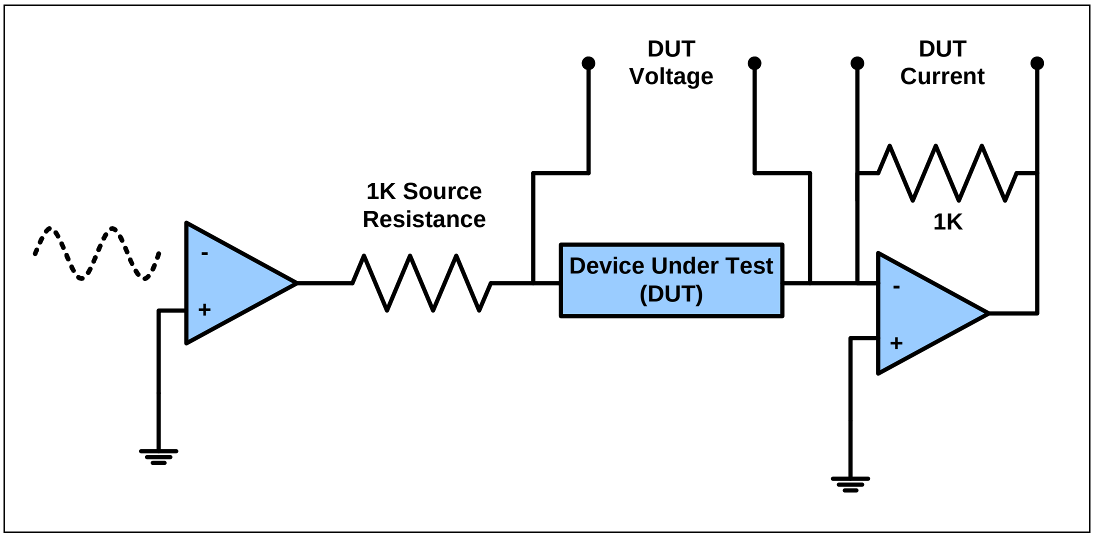


Fig 5 : Simplified Test Circuit.

DSP Implementation:

In order to effectively implement the mathematics used in this project the signals had to predominantly consist of the frequency under consideration. For this reason the signals were filtered to reduce any error sources becoming present in the data set. The analog stage includes an 6^{th} order Butterworth anti aliasing filter designed using Microchips *Filter Lab* v2.0. This was specified to ensure Nyquist requirements were met.

Further filtering was implemented using DSP functions. For test frequencies lower than 10kHz FIR low pass filtering was implemented in association with decimation to effectively down-sample the signal and reduce the data set size. The resulting data was band-pass filtered around the frequency of interest using an 8 tap IIR filter.

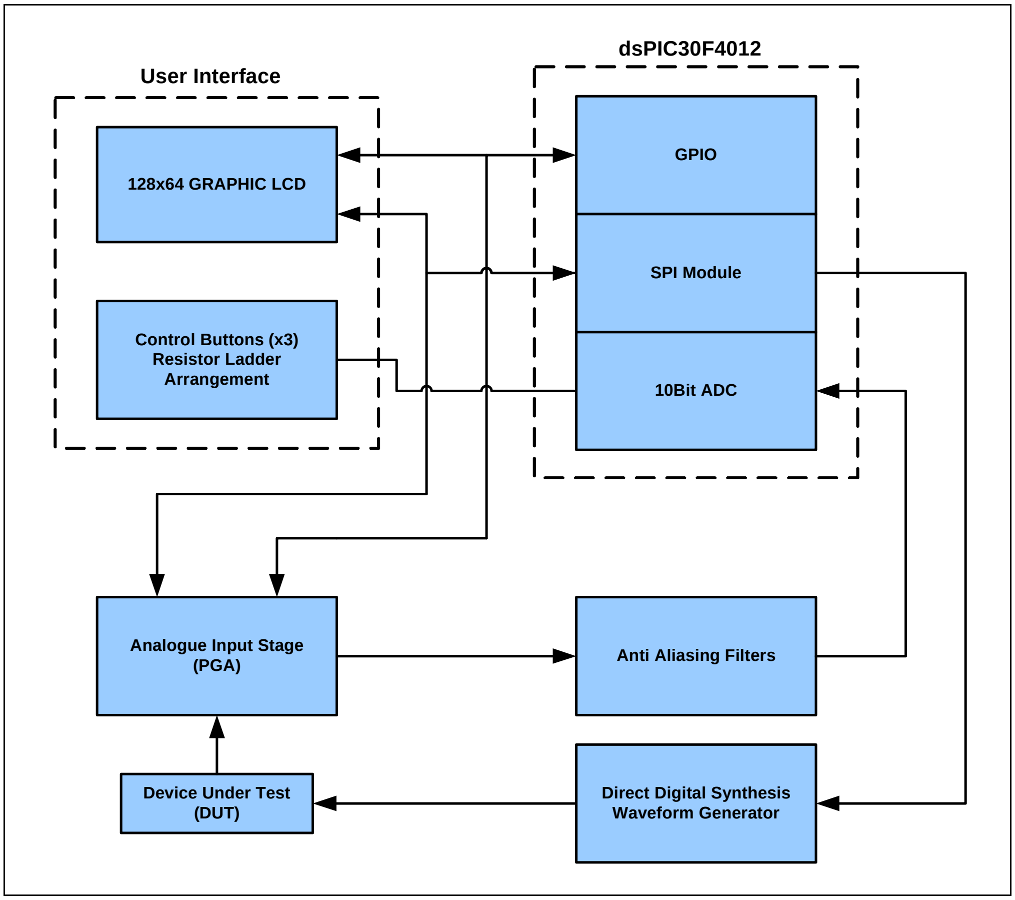


Fig 6 : System Block Diagram.

Hardware:

The prototype system was built around Microchips 16bit 28pin development board. In addition to this three other boards were manufactured. One board carries the user interface components, graphic LCD and control buttons. The SPI GPIO chip is mounted on this board, close to the LCD header. This board was manufactured on proto board and mounted on an acrylic stand to allow better viewing of the LCD

Another board supports the analog measurement components. Due to the low noise requirements and SMD components used, this double sided board was etched rather than using proto board. Whilst most component packages were able to be directly soldered to this board (SOIC etc) the AD9833 DDS signal generator is only available is an MSOP package that required a DIP adaptor board due to its fine pitch.

The final board constructed contains the anti aliasing filters. This was built using proto-board and reserves some space for future development of the battery power supply stage. Signal connections to and from this board are made with shielded cable to reduce additional noise pick-up.

The device under test is connected via a set of test leads to the analog board. In the prototype the connectors between the 4 wire test leads and PCB are two RCA plugs, the cable shielding is connected to the analog ground plane by a pair of screw terminals.

Firmware:

The code for this device was written in C, compiled with the contest version of C30 and MPLAB was used as the IDE. DSP filter coefficients were included as assembly files (*.s) generated by Momentum Data Systems *dsPIC FD Lite*. Code was compiled without any optimization levels in anticipation of the limited license period ending.

Code was developed as many small individual functions which could be tested in isolation. Developing the code in small manageable pieces was a necessary approach because the programming tool being used (PICKITII) did not support debugging of dsPIC devices.

The code submitted with the contest consumes 41,466 bytes of program space and 2,526 bytes of RAM. This result is with no code optimization; tests revealed that using optimization level five reduced the program code size to 32,775 bytes, although no extensive tests were made of functionality. Coefficients for DSP filter functions are stored in PSV Variable space to reduce RAM consumption. The fractional arrays holding the measured and filtered voltage and current data were the key users of RAM.

Performance:

The prototype system's performance is very pleasing. The user interface is easy to use, the push button operation has a positive feel and the Graphic LCD is clear and easy to read. Measurements appear to meet the required accuracy (<1%) and repeatability is excellent. The system is able to automatically choose the most suitable frequency and circuit type, making basic measurements very easy.

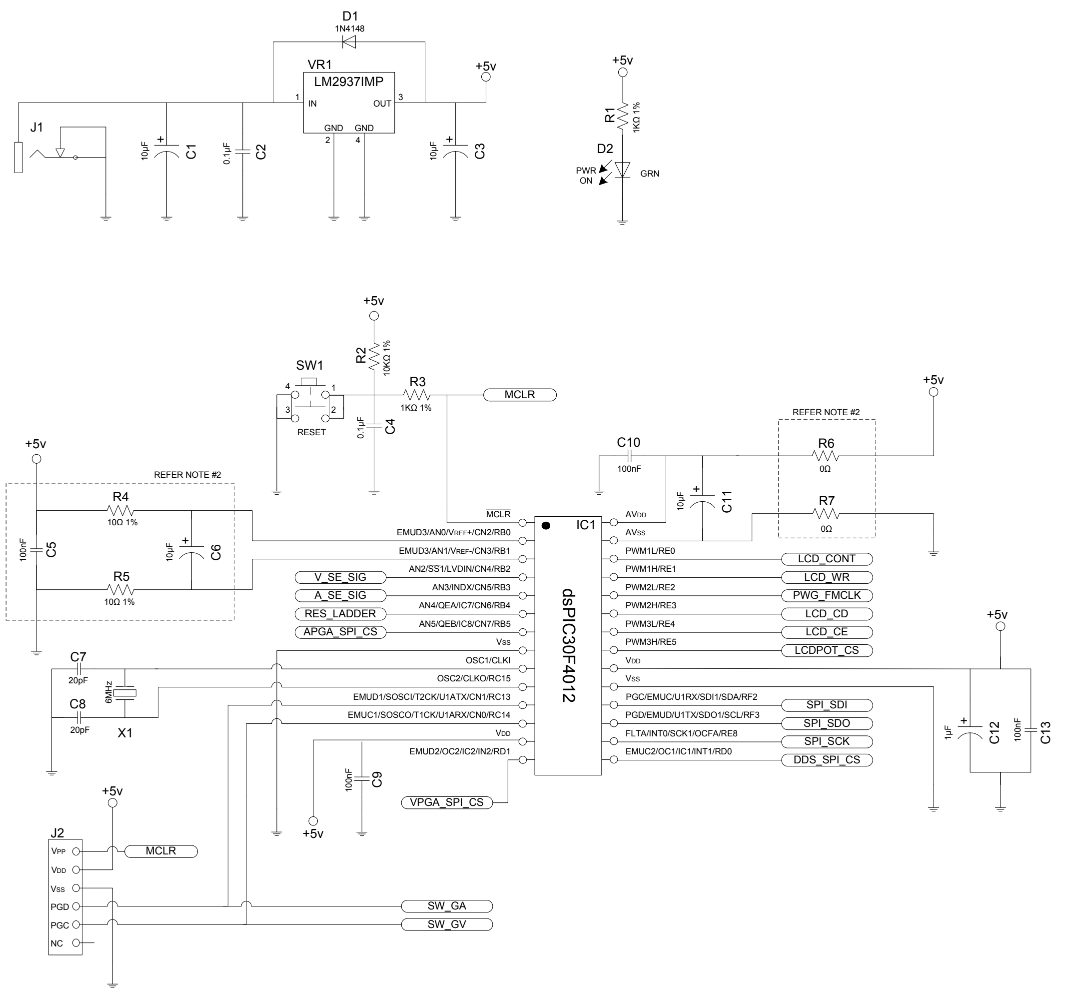
Currently the program implements a five cycle averaging function on the result to improve stability and accuracy. Whilst this is a useful function it has the disadvantage of increasing the overall test cycle time, a test on "automatic" will take up to five seconds to finish. A fast test feature is needed in the next iteration to allow quick sorting of parts at a lower accuracy.

Conclusion:

The development of the *dsPIC LCR Meter* has been an excellent introduction for the author to Microchip's 16bit DSP controllers. The tool chain and development tools supplied by Microchip make coding this type of controller quick and painless, especially important as I was moving on from years of coding 8bit PIC processors in assembly. The compiler was easy to use and all of the library files were well documented. Somewhat surprisingly, the DSP filter functions were the easiest part of the firmware to code, mostly due to the *dsPIC FD Lite* program and Microchip documentation.

The SPI communication protocol was a savior in terms of functionality to pin count ratio. This is especially true for the LCD which if not handled by the SPI GPIO would have consumed half of the microprocessors available pins.

Once some additional features are added, the *dsPIC LCR Meter* will make a welcome addition to tools on my desk. With some insight into the possibilities of these processors, I am already thinking of the next project.



NOTES:

1. UNLESS NOTED, ITEMS ON THIS PAGE ARE STANDARD SECTIONS OF THE 16-BIT 28-PIN MICROCHIP DEVELOPMENT BOARD.

2. ITEMS HIGHLIGHTED ARE NOT STANDARD PARTS OF THE DEVELOPMENT BOARD. MODIFICATIONS MADE FOR 1MSPS ADC OPERATION AS PER DATA SHEET.

3. THE FOLLOWING 0Ω RESISTORS WERE REMOVED FROM THE DEVELOPMENT BOARD: R14, R15, R16, R18

SYMBOL	DESCRIPTION
X1	6MHz Crystal
D2	LED Green
D1	1N4148
C13	0.1µF Ceramic
C12	1µF Tantalum
C11	10µF Tantalum
C10	0.1µF Ceramic
C9	0.1µF Ceramic
C8	20pF Ceramic
C7	20pF Ceramic
C6	1µF Tantalum
C5	0.1µF MKT
C4	0.1µF Ceramic
C3	1µF Tantalum
C2	0.1µF Ceramic
C1	1µF Tantalum
R7	0R 1% ¼W
R6	0R 1% ¼W
R5	10R 1% ¼W
R4	10R 1% ¼W
R3	1K 1% ¼W
R2	10K 1% ¼W
R1	1K 1% ¼W

J2	ICSP 6-Pin Single Inline RA Male
J1	2.5mm Female DC Jack
IC1	dsPIC30F4012
VR1	LM2937IMP 5V REG
SW1	SPST Mom Switch

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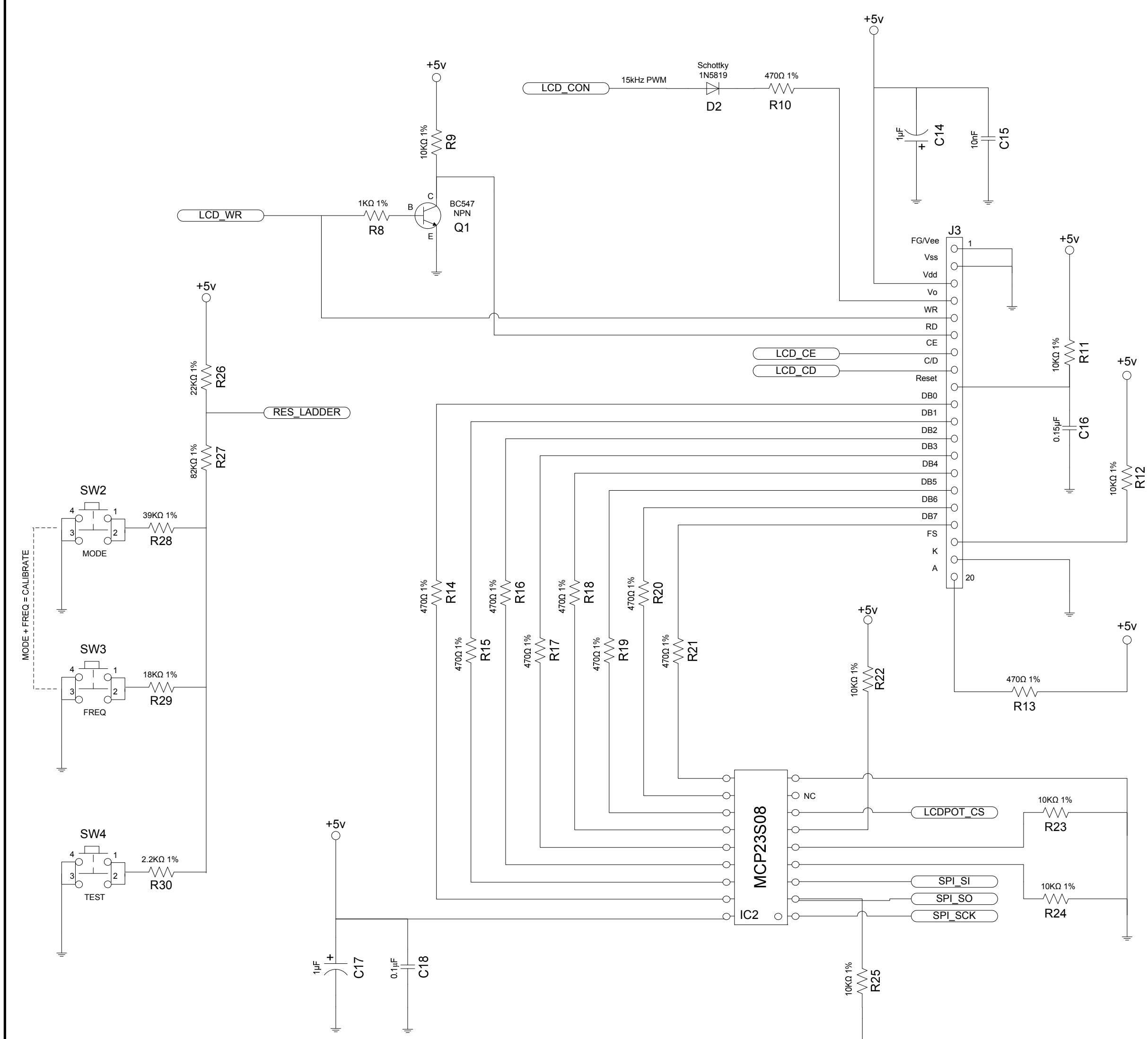
0	06/10/07	MICROPROCESSOR (28Pin Dev Board)	A4	1/5



SYMBOL	DESCRIPTION		
R30	2.2K 1% ¼W		
R29	18K 1% ¼W		
R28	39K 1% ¼W		
R27	82K 1% ¼W	J3	20-Pin Single Inline Female Socket
R26	22K 1% ¼W	IC2	MCP23S08 8-BIT SPI GPIO
R25	10K 1% ¼W	Q1	BC547 NPN
R24	10K 1% ¼W	SW4	SPST Mom Switch
R23	10K 1% ¼W	SW3	SPST Mom Switch
R22	10K 1% ¼W	SW2	SPST Mom Switch
R21	470R 1% ¼W	C9	1N5819 Schottky
R20	470R 1% ¼W	D3	0.1µF MKT
R19	470R 1% ¼W	C18	0.1µF MKT
R18	470R 1% ¼W	C17	1µF Tantalum
R17	470R 1% ¼W	C16	0.15µF MKT
R16	470R 1% ¼W	C15	0.1µF MKT
R15	470R 1% ¼W	C14	1µF Tantalum
R14	470R 1% ¼W		
R13	470R 1% ¼W		
R12	10K 1% ¼W		
R11	10K 1% ¼W		
R10	470R 1% ¼W		
R9	10K 1% ¼W		
R8	1K 1% ¼W		

NOTES:

1. INTERFACE FOR TOSHIBA T6963C LCD INTERFACE.

2. SCREEN RESOLUTION: 128 x 64.

3. FONT SELECT BIASED HIGH FOR 8x6 FONT SET.

4. MCP23S08 ADDRESS: A0 = 0, A1 = 0

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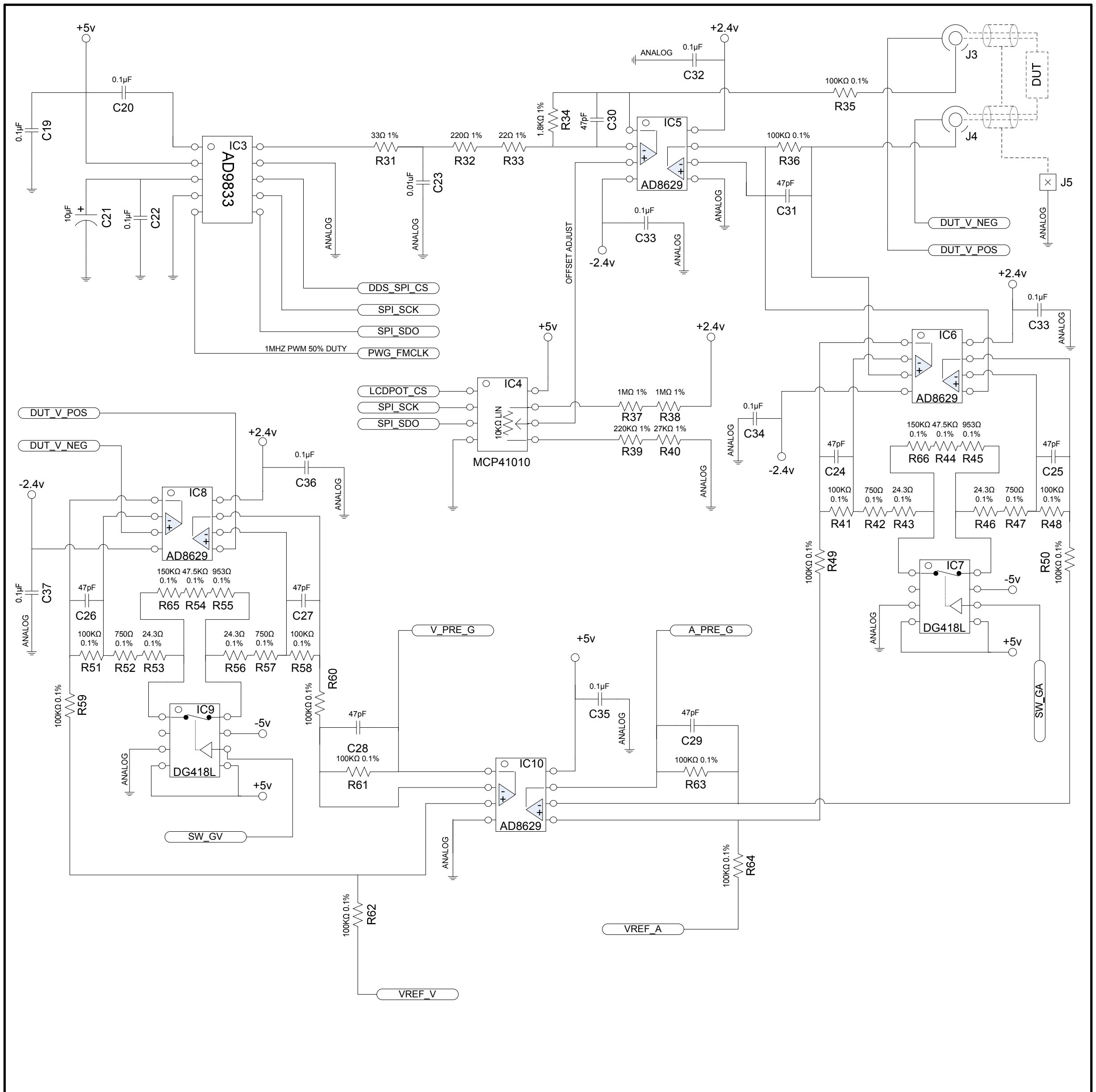

R56	24.3R 0.1% ¼W	C27	47pF Ceramic	J3	Gold RCA Socket		
R55	953R 0.1% ¼W	C26	47pF Ceramic	IC10	AD8629 Low Offset Op-Amp		
R54	47.5K 0.1% ¼W	C25	47pF Ceramic	IC9	DG418L Analog Switch		
R53	24.3R 0.1% ¼W	C24	47pF Ceramic	IC8	AD8629 Low Offset Op-Amp		
R52	750R 0.1% ¼W	C23	10nF MKT	IC7	DG418L Analog Switch		
R51	100K 0.1% ¼W	C22	0.1μF MKT	IC6	AD8629 Low Offset Op-Amp		
R50	100K 0.1% ¼W	C21	10μF Tantalum	IC5	AD8629 Low Offset Op-Amp		
R49	100K 0.1% ¼W	C20	0.1μF MKT	IC4	MCP41010 10K SPI Digital Pot		
R48	100K 0.1% ¼W	C19	0.1μF MKT	IC3	AD9833 DDS Signal Generator		
R47	750R 0.1% ¼W	R66	150K 0.1% ¼W	C37	0.1μF MKT		
R46	24.3R 0.1% ¼W	R65	150K 0.1% ¼W	C36	0.1μF MKT		
R45	953R 0.1% ¼W	R64	100K 0.1% ¼W	C35	0.1μF MKT		
R44	47.5K 0.1% ¼W	R63	100K 0.1% ¼W	C34	0.1μF MKT		
R43	24.3R 0.1% ¼W	R62	100K 0.1% ¼W	C33	0.1μF MKT		
R42	750R 0.1% ¼W	R61	100K 0.1% ¼W	C32	0.1μF MKT		
R41	100K 0.1% ¼W	R60	100K 0.1% ¼W	C31	47nF Ceramic		
R40	27K 1% ¼W	R59	100K 0.1% ¼W	C30	47nF Ceramic		
R39	220K 1% ¼W	R58	100K 0.1% ¼W	C29	47pF Ceramic	J5	Screw Terminal
R38	1M 1% ¼W	R57	750R 0.1% ¼W	C28	47nF Ceramic	J4	Gold RCA Socket
R37	1M 1% ¼W						
R36	100K 0.1% ¼W						
R35	100K 0.1% ¼W						
R34	1.8K 1% ¼W						
R33	22R 1% ¼W						
R32	220R 1% ¼W						
R31	33R 1% ¼W						
SYMBOL	DESCRIPTION						

NOTES:

1. GROUND CONNECTIONS MARKED "ANALOG" SHOULD BE PLACED ON A SEPARATE PLANE AND LINKED TO DIGITAL\GENERAL GROUND IN ONE POINT ONLY.

2. CHIP SELECT (CS) SIGNAL FOR DIGITAL POT (IC4) IS SHARED WITH 8 BIT SPI GPIO (IC2). INSTRUCTION MASKING ENSURES CORRECT INDEPENDENT OPERATION.

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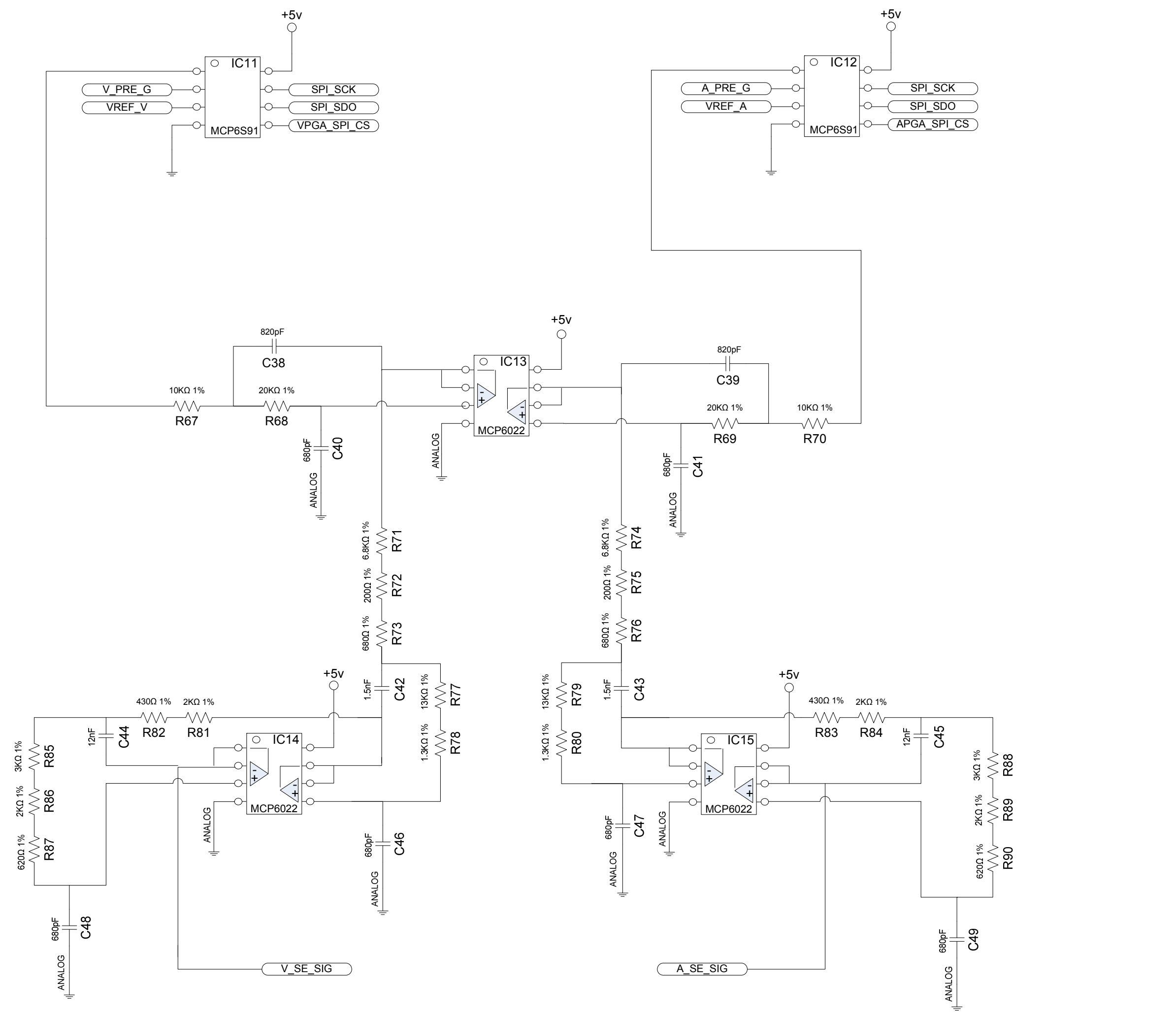

C39	820pF Ceramic		
C38	820pF Ceramic		
R90	620R 1% ¼W		
R89	2K 1% ¼W		
R88	3K 1% ¼W	IC14	MCP6022 Dual Op-Amp
R87	620R 1% ¼W	IC14	MCP6022 Dual Op-Amp
R86	2K 1% ¼W	IC13	MCP6022 Dual Op-Amp
R85	3K 1% ¼W	IC12	MCP6S91 SPI PGA
R84	430R 1% ¼W	IC11	MCP6S91 SPI PGA
R83	2K 1% ¼W	C49	680pF Ceramic
R82	430R 1% ¼W	C48	680pF Ceramic
R81	2K 1% ¼W	C47	680pF Ceramic
R80	1.3K 1% ¼W	C46	680pF Ceramic
R79	13K 1% ¼W	C45	12nF MKT
R78	1.3K 1% ¼W	C44	12nF MKT
R77	13K 1% ¼W	C43	1.5nF MKT
R76	680R 1% ¼W	C42	1.5nF MKT
R75	200R 1% ¼W	C41	680pF Ceramic
R74	6.8K 1% ¼W	C40	680pF Ceramic
R73	680R 1% ¼W		
R72	200R 1% ¼W		
R71	6.8K 1% ¼W		
R70	10K 1% ¼W		
R69	20K 1% ¼W		
R68	20K 1% ¼W		
R67	10K 1% ¼W		
SYMBOL	DESCRIPTION		

NOTES:

1. GROUND CONNECTIONS MARKED "ANALOG" SHOULD BE PLACED ON A SEPARATE PLANE AND LINKED TO DIGITAL\GENERAL GROUND IN ONE POINT ONLY.

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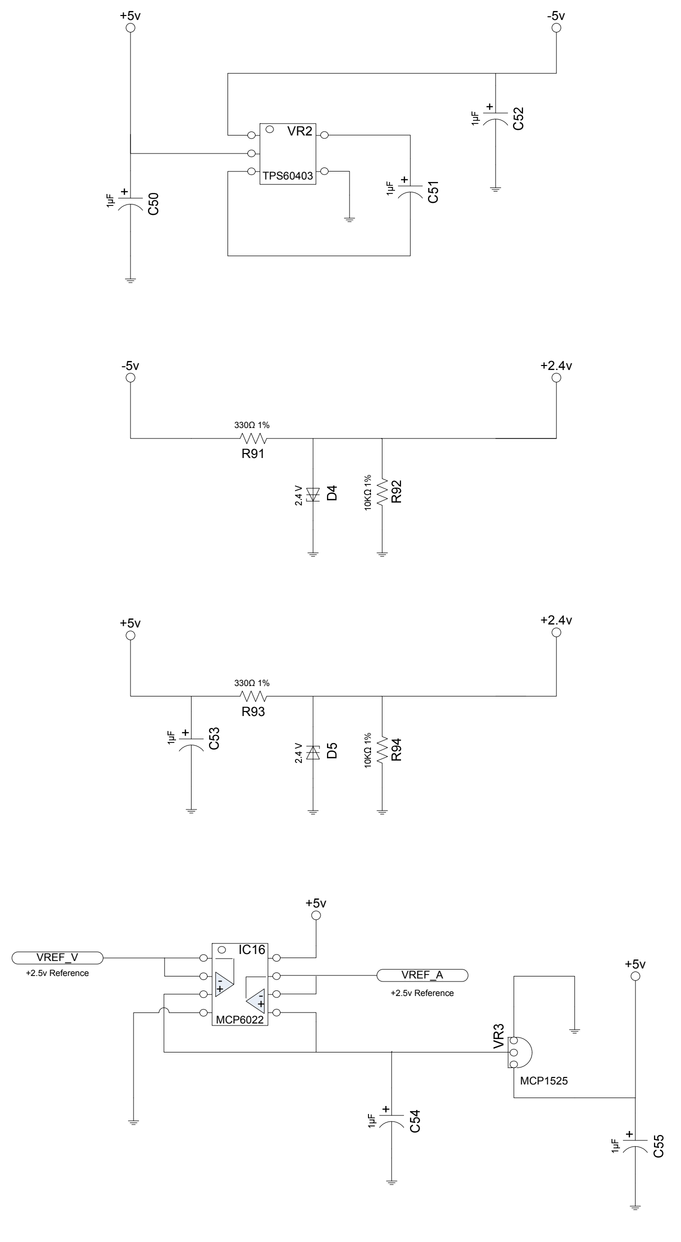

SYMBOL	DESCRIPTION
IC16	MCP6022 Dual Op-Amp
VR3	MCP1525 Precision 2.5V Reference
VR2	TPS60403 60mA -5V Charge Pump
D5	2.4V Zener
D4	2.4V Zener
C55	1µF Tantalum
C54	1µF Tantalum
C53	1µF Tantalum
C52	1µF Tantalum
C51	1µF Tantalum
C50	1µF Tantalum
R94	10K 1% ¼W
R93	330R 1% ¼W
R92	10K 1% ¼W
R91	330R 1% ¼W

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