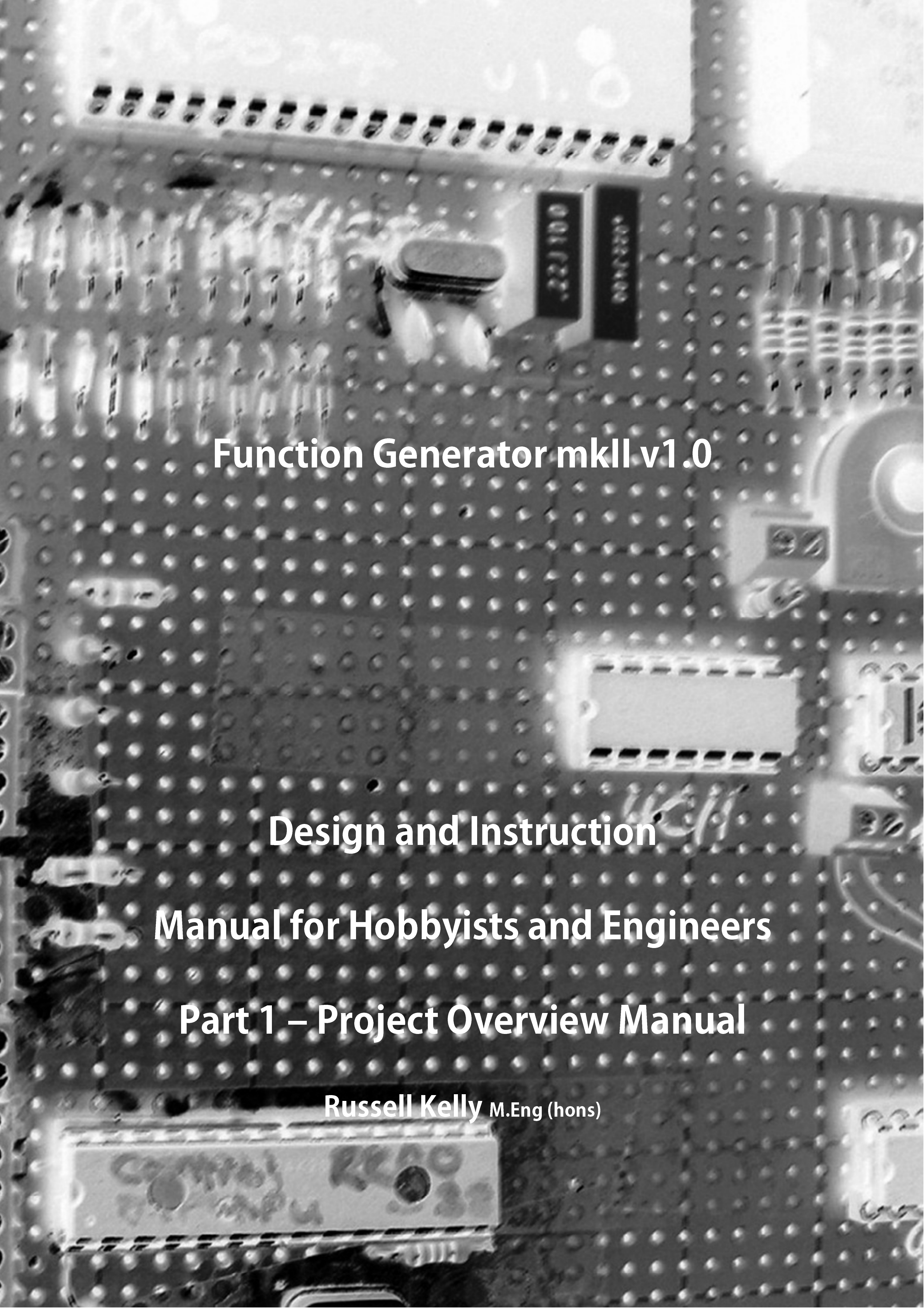


Function Generator mkII v1.0

Design and Instruction

Manual for Hobbyists and Engineers

Part 1 – Project Overview Manual

Russell Kelly M.Eng (hons)

Contents of Project

First I would like to thank you for your interest in this project and my work. It is my hope that you will find this project useful and maybe build this project for yourself or maybe just a good read. Should you have any comments I would welcome them gladly.

I would also like to at this time to thank my wife Dani, who has put up with my endless tinkering and messing up our spare bedroom.

I will also make note here credit to the following companies who through their kindness have provided sample components which made my project possible.

Microchip – PIC Microprocessors www.microchip.com

ST Electronics – NVRAM Chips www.st.com

Maxim – DAC Chips www.maxim-ic.com

OKW Enclosures - www.okw.co.uk/

Linear Technology – www.linear.com

Yours faithfully

Russell Kelly

russell.kelly@mail.com

This project is for the design of an 8 bit function generator. This project should have been provided as part as a project.zip folder which contains the following.

Primary Project

1. This project overview manual
2. PC software installer for Function Generator mkII v1.0 windows interface software
3. Software Instruction Manual
4. Mikrobasic Pro source code and Config files for the following
   a. PIC18f24k20 Control MPU
   b. PIC18f4550 USB MPU – with USB vendorID and productID values left blank (ie. USBdsc.asm not provided)
   c. PIC12f675 Power CPU
5. .hex files for the following MPUS
   a. PIC18f24k20
   b. PIC12f675

   Please note that PIC18f4550 .hex has not been provided see USB section

6. Schematic Diagrams

Table of Contents

1 Project Overview

This project manual details the design and development of a desktop function generator. The aim of this project was to produce a digital 8 bit function generator which could generate not only a range of standard waveforms, but allow the opportunity to create new user designed waveforms.

In order to achieve the latter an interface of some type is required ideally via a personal computer running Windows XP/Vista/7 (Sorry I have no experience with Apple Mac).

Typically PC to PIC microprocessor interfacing uses RS232 protocol. This works well and there has been a number of online designs which demonstrate RS232 ability that comes as standard on most PIC microchips. However the reality is RS232 is no longer popular on newer PCs, instead most manufacturers opting for USB 2.0. I wanted this design to utilise modern technology wherever possible to increase compatibility.

At a PC level the development of some kind of software would also be required to design the user interface. Free software development tools such as Microsoft Visual Studio is easy to obtain and develop USB data transfer software.

The function generator must also have the capability of storing not only factory pre-set waveform data but also the user waveform data. Here the use of NVRAM is explored as a viable way of storing small amounts of data.

One last consideration is the resolution of the waveform data. One of the key design concerns is that the higher the wave data resolution the higher the clock input frequency that is required to complete one wave form period. For example if my wave data had 128 data samples then in order to produce an output frequency (post digital to analogue conversion) of say 1,000 Hz the RAM access clock would need to be 128,000 Hz. The trade-off being a more accurate waveform reproduction.

For the purposes of this project the following conditions and processes were used to develop the project.

Total Number of Waveforms: 24

Factory/User Waveforms: 12/12

Waveform Resolution: 64 bytes per period

Desired function generator output frequency: 15 – 20,000 Hz

Data Storage: (2048 x 8 bit) NVRAM

PC to Function Generator Connection: USB 2.0 (using Microchip PIC 18F4550)

NVRAM Access Clock: 555 timer (limited to 300 kHz) + 4046 PLL (limited to 1.8 MHz at 5v)

Digital to Analogue Conversion: R/2R DAC Maxim MAX7523

PC Software Development: Microsoft Visual Studio – Visual Basic .net 2010. DotNet v4.0

Other features such as user controls, LCD displays, power supply and output stages also need to be considered. The user controls should consist of the following

Pre-set up/down

USB Mode activate

Power on/off

Frequency adjust (course)

Frequency adjust (fine)

Frequency range select

Power supply options – Adapter or battery

Output amplitude

Display interface is achieved using a standard 16x2 alpha numeric display. Ideally I wanted this display to show the current pre-set information but also display the output frequency.

In this particular design the power supply should be able to run off the local mains electrical power supply. The choice of transformer is generally up to the designer however here I have used a single phase 230v – 15 Vac around 15VA. Using a 15V AC secondary allows the use of multiple input voltages as low as 85 VAC (secondary voltage equalling 5.6v which is okay for LTC 1129-5), making the power supply section usable anywhere. (Please note for circuits using 7805 this increases the minimum inlet voltage to 115Vac.)

2 Circuit Modules

2.1 Building Blocks

In order to make the design and building of the project easier, each key component of the function generator is broken down into 6 main components

Power supply board with battery supply

RAM Clock Board

Output distribution board

Filter Board

LCD Display

Mother board with NVRAM

Each module is designed to perform a specific function. And building each module separately allowed for easier testing, you may find this to be the case when building this project yourself.

The following diagram explains the connections of each module and its dependencies;

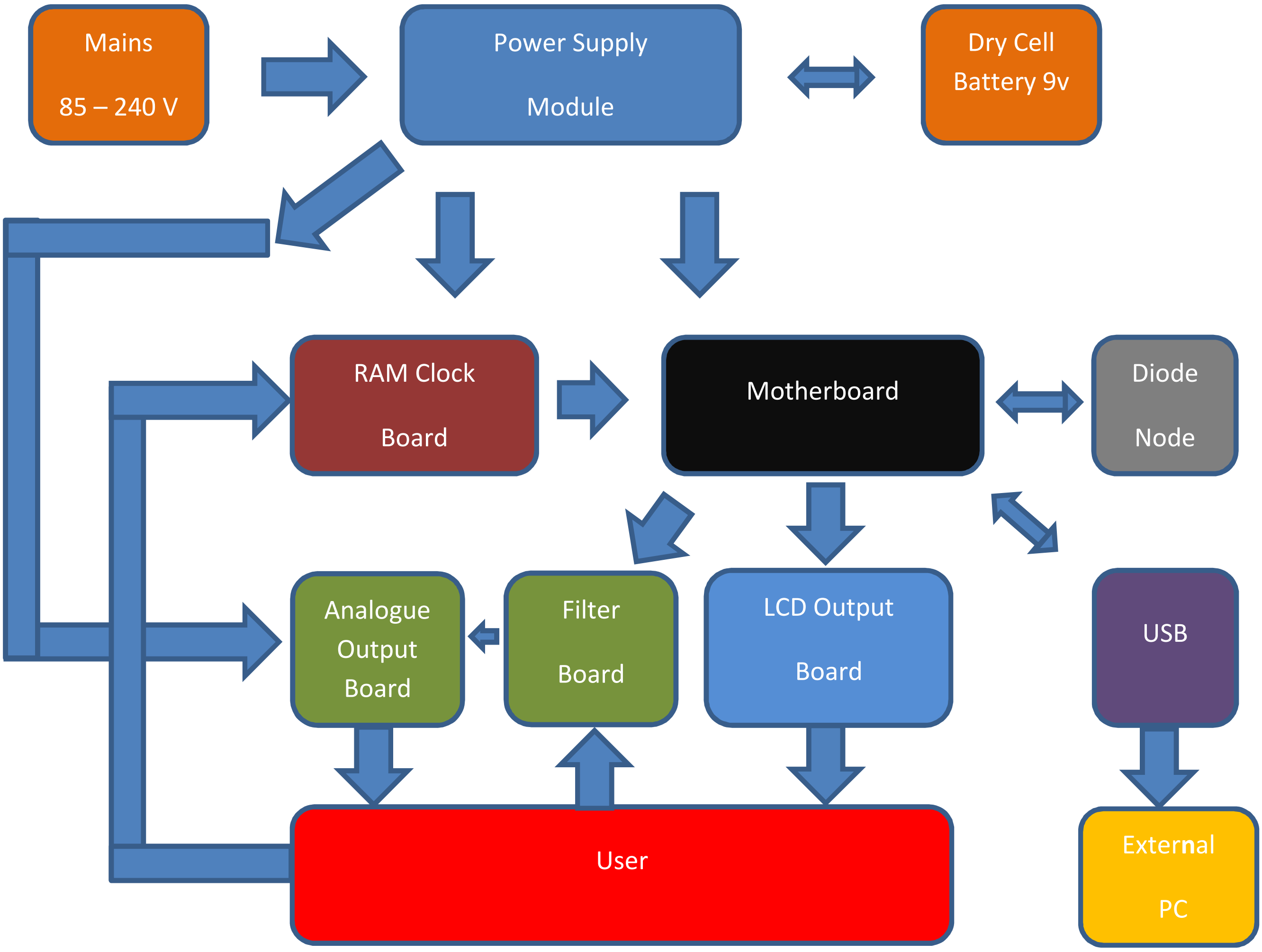


Figure 2.1.1: Circuit Board Arrangement

2.2 Power Supply Board

2.2.1 AC to DC Conversion

The power supply is perhaps the first board that needs to be constructed. It provides the following functions to the project

1. Provides a good stable low noise +5v DC power supply to each of the module boards
2. Allow for the connection to the mains home power supply
3. Logic control on/off function

There are a number of considerations which need to be addressed when designing a power supply.

It is important to provide a clean low noise power supply in this project. The function generator makes use of various integrated circuits and microprocessors; which can’t function properly or at all when using a power supply which is subject to various voltage variations, or noise from poorly rectified AC power sources. To achieve good rectification the use of a bridge rectifier, ballast capacitor and voltage regulators are required.

Below is a standard AC to DC conversion;

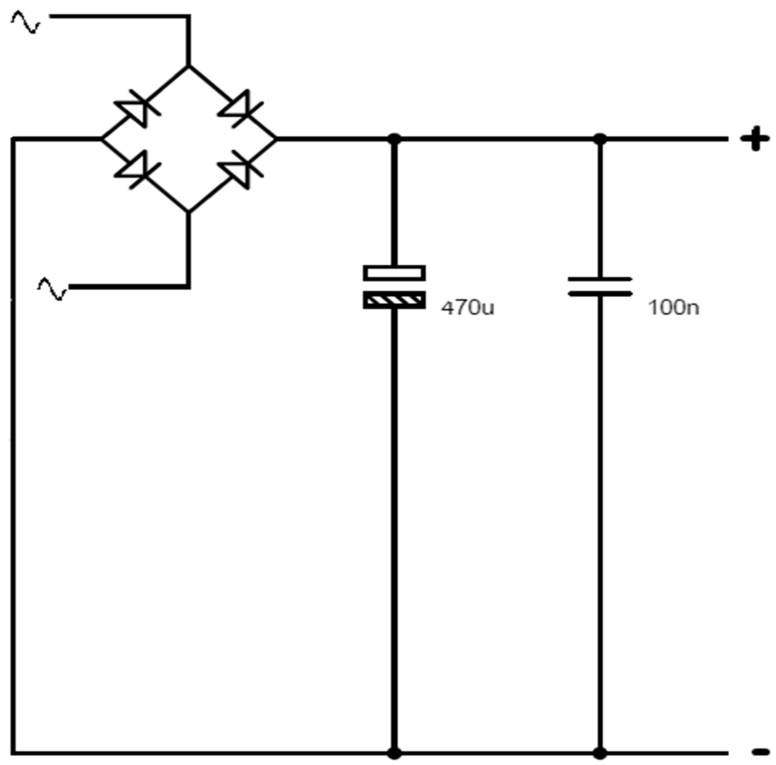


Figure 2.2.1.1 – Typical bridge rectifier with ballast capacitors AC to DC conversion circuit

Here the bridge diodes convert the AC to DC by reversing any negative voltages to become positive voltages. The sinusoidal motion of the AC waveform can’t be transformed alone by the use of rectifier diodes. Here only the negative voltages are converted to positive. The motion of voltage variation over time is still present. The voltage is still constantly changing from the peak maximum voltage from AC source to the AC minimum which is 0v.

The ballast capacitor is used to provide suppression of the periodic voltage variations, however a capacitor ballast is not perfect. The capacitor itself is drained during the low voltage phases, and results in a non-perfect DC source, where the output voltage still undergoes small variations in voltage due to incomplete conversion. This is often referred to as a DC ripple.

To remove the AC ripple a combination of both AC filters and voltage regulators are often used. Here the use of chokes and AC filters are not required. However the use of voltage regulator is required. Power regulators are useful for a number of purposes;

1. Maintain a constant voltage output regardless of the input voltage (within a certain specification)
2. Can compensate for DC ripple

The voltage regulator used here is the LTC 1129-5. This regulator provides a stable 5v DC supply for any power input between 5.4 – 24 volts. This means that a 6v battery or 4 x 1.5 AA cells can be used when running of a battery.

2.2.2 Logic Control

The use of logic control is a small addition to the power circuit. Essentially it removes the need for an on/off toggle switch and replaces this function with a momentary push switch. One push for on and another for off. This function is achieved using a small PIC microprocessor the 12F675.

2.3 Clock Circuit

The clock circuit is designed to provide a variable clock frequency for the motherboards 4040 binary counter IC. The 4040 counter IC provides the NVRAM address accessing required to generate the waveform data, such that a waveform of the desired frequency is achieved.

The clock itself must be adjustable and have a large frequency range. Given that the frequency range of the function generator is 15 – 20,000 Hz and there are 64 bytes per waveform, the required clock frequency required is 960 Hz – 1.28 MHz. It would also be unreasonable to expect this range to be achieved using a single potentiometer.

Many clock ICs have been developed to allow a wide range of frequencies. One of these being LTC6900. However most new ICs are designed for surface mount technology, which is not of use to us. Therefore in order to simplify this project and access to components the use of a 555 timer has been selected. The 555 timer is a long time available and understood timer IC amongst electronic enthusiasts for the past 30 years. There is however one problem. There are two types available TTL (555) and CMOS (7555) technologies, the later CMOS can achieve a clock frequency of 3 MHz, However the older TTL version is only capable of achieving a clock frequency of around 300 KHz.

300 KHz is not high enough however this may not be such a problem because the design does not want a single potentiometer sweep to achieve the whole frequency range. Here an introduction to a second component is required, the 4046.

The 4046 is an IC specialising in phase locked loop circuitry. One of the uses for the 4046 PPL is to increase the input frequency by an integer amount. For example say there is an input frequency of 300 KHz and the desired output frequency is 600 KHz; using the 4046 combined with a divide by 2 counter the input frequency can be multiplied by 2, by use of the 4046 internal VCO and phase comparator. The 4046 is a very useful device and can be obtained cheaply. Reading through the datasheet is very much recommended.

The clock board design here uses a 4046 combined with a 4040 counter IC. The use of a rotary switch is used to provide a divide by N function feedback to the 4046 IC. Therefore even though the maximum frequency of the 555 timer is 300 kHz the output frequency achievable is much higher.

The actual frequency range achieved by the clock board shown in this project is 550 Hz – 1.8 MHz.

2.4 Motherboard

The motherboard is the primary component to the entire function generator. The motherboard contains all the microprocessors, NVRAM and DAC. The motherboard is broken down into key components;

1. 18F4550 PIC Microprocessor. This MCU provides the interface between the PC and the NVRAM chip. This MCU has access to the entire data and address buses of the NVRAM chip. There is also a single bit connection between the MCLR pin of the 18F4550 to the RB7 (pin28) of the 18F24k20 control MCU. MCLR is low when in normal function generator mode, and high (MCU active) when in USB transfer mode. The interface MCU transfers data in both directions; to and from the PC. Factory presets are stored in the MCU flash and transferred to the NVRAM on a specific PC command

2. 18F24k20 PIC Microprocessor. The MCU provides the overall control of the function generator. It provides the data bus for the LCD alpha numeric screen, the upper 5 bit address of the NVRAM (preset sector selection), control pin for the interface MCU and responds to user input commands. The MCU also provides the user with an on-board frequency counter which is displayed on the LCD screen.

3. NVRAM. This type of RAM has one special function; the stored data is retained after power removal. This is made possible as the NVRAM chip has an internal Li-ion battery to keep the data stored. In all other areas the behaviour is the same as any other CMOS Static RAM. The size required is 2kB (2048 bytes). Each waveform preset requires 64 data samples and therefore the memory is divided into 64 byte sectors. There are 32 sectors in total. The first 12 are for the factory presets and 12 for the user presets. The other 8 are not currently used. The sectors are accessed using the 5 most significant bits A6 – A10. Preset waveform data is stored on the 6 least significant bits A0 – A5.

4. 4040 12 bit counter IC. This counter is used to access the first 6 bits of the NVRAM, A0 – A5. Depending on the sector selection of the control MCU; as the counter increments the waveform data is generated from the NVRAM. The clock for the 4040 counter is provided from the clock board.

5. MX7523 DAC. This 8 bit DAC converts the binary information on the data bus an converts to an analogue waveform. Reference voltage needs to be set so that DAC output is appropriate for the output board. Note post DAC filtration is required and this is provided by the filter board.

6. 4011 NAND Logic. Provides various logic controls as indicated on the schematic diagram.

7. Diode node. This is a small diode network which allows multiple devices access the same address line.

2.5 Filter Board

The filter board acts as a post DAC filter to remove any unwanted higher frequency harmonics. The use of a rotary selector switch is used to selected different low pass filter capacitors, and allows the filter to be used for the full range of frequencies.

2.6 Output Board

The output board is used downstream of the filter board. This board provides the final output of the function generator to the user. A gain of 4 is applied to the input to increase the waveform amplitude post of the low pass filter. Adjustment of the DAC reference voltage is paramount to insure no over clipping is generated from the amplifier board.

3 PIC Chip Development

3.1 PIC 18F4550

This PIC 18F4550 by Microchip belongs to a small family of microcontrollers which feature a EUSART which includes USB 2.0 Protocol. Normally PIC microcontrollers use RS232/485 SPI and I^2C, however in this case it is advantageous to utilise a controller which can communicate with USB 2.0 directly reducing on component count.

The USB is set up to receive and transmit packets of 64 bytes per transmission. Before transmission or reception of data commences a 64 byte instruction packet is sent from the PC to the PIC chip. Here the first number (matrix [0]) provides the instruction. Depending on the number determines what the PIC chip will do.

Below is a table of the instruction set;

Table 3.1.1 – PIC Chip Instruction Set

USB Transmission[0]	Command Source	Command	Comments
49	PC	Initiate PIC chip [Set up connection]	Handshake
50	PIC	Confirmation of Set up	
60	PC	Transmit user preset data	PIC sends data sectors 12-23
70	PC	Receive Preset Data	PIC stands by to receive sectors 12-23
200	PC	Install Factory Presets	PIC writes sectors 0-11
49	PC	Disconnect connection	Handshake
51	PIC	Disconnect connection acknowledged	

In order to start sending instructions, a handshake must first be initiated. This tells the PIC chip that a PC wishes to connect and begin sending instructions. After which one of three instructions can be sent.

The general principle of operation for transmission and receiving of data is periodic. Data is sent batch wise every second or so. For example when the PIC chip is sending the user data (sectors 12-23) it sends each sector as a single USB 64 byte matrix. A sector is sent or received every two seconds.

3.2 PIC 18F24k20

The PIC 18F24k20 provides the overall control for the function generator. It provides the user interface for scrolling through the presets. The USB MPU is activated by 18F24k20.

The control MPU (18F24k20) provides a frequency counting feature so that the user can determine the output frequency. User control is via a selection of push switches.

USB Activate – N/C push switch

Preset increment – N/O push switch

Preset decrement – N/O push switch

The frequency counter relies upon two 16 bit counters and one 16 bit (2 x 8 bit) overflow general purpose register. Timer 1 is incremented using the system clock and provides a once per second interrupt. During this interrupt the following equation is processed;

Total_count = tmr3_int + tmr3_interrupts

*Where tmr3_int is the 16 bit value of tmr3 and tmr3_interrupts = 65535 * overflows*

Timer 3 is incremented using an external clock input on RC0 pin. This pin in turn is connected to A5 or Q5 of the preset data address bus.

Timer 3 can overflow and interrupt. When it does the following calculation is performed;

Tmr3_interrupts = tmr3_interrupt + 65535

The frequency of the function generator therefore is equal to Total_count.

3.3 PIC 12F675

The PIC 12F675 provides the logic control for the power supply. Logic change from 0 to 1 on port gpio.2 will cause a logic inversion of gpio.5.

Power on – N/O push switch

4 USB Vendor ID and Product ID

When developing USB products the product needs to be assigned a vendor and product ID. The identification is designed to identify the equipment to the PC so that the appropriate drivers can be loaded.

However in order to use a vendor ID you must first officially request one (gain licence to use a specific vendor ID) from usb.org. The cost however is high. Unless you are intending on selling your product on mass market you would not request a specific number in your name. Other organisations such as Microchip for example up on request will allow you to use their vendor ID number if you are producing less than a specific number of units and you are using their microchip products. FTDI USART to USB converter chips also are available and carry their own vendor ID number which is already registered.

In principle any number can be used however driver clashes may occur if you choose a number which is already owned by another company, and you have that companies software installed.

The use of a vendor ID for personal and hobbyist use is a grey area; ultimately it is up to you which number you use.

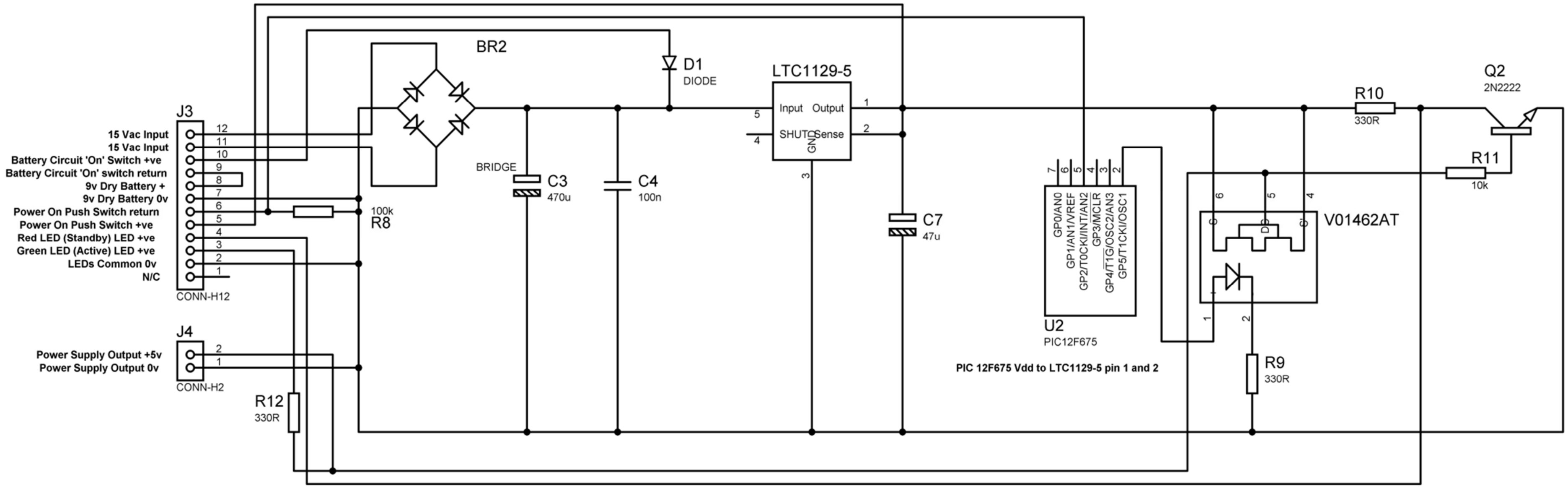
It is for this reason that the .hex file for the PIC 18F4550 has not been provided. You the end user will need to use the Mikrobasic HID tool to create your own vendor ID and product ID file (USBdsc.asm file).

The product ID is designed to identify the product separate from the vendor ID. Again the number you choose is up to you.

5 Schematic Diagrams

This next section provides the schematic diagrams for each modular section of the function generator.

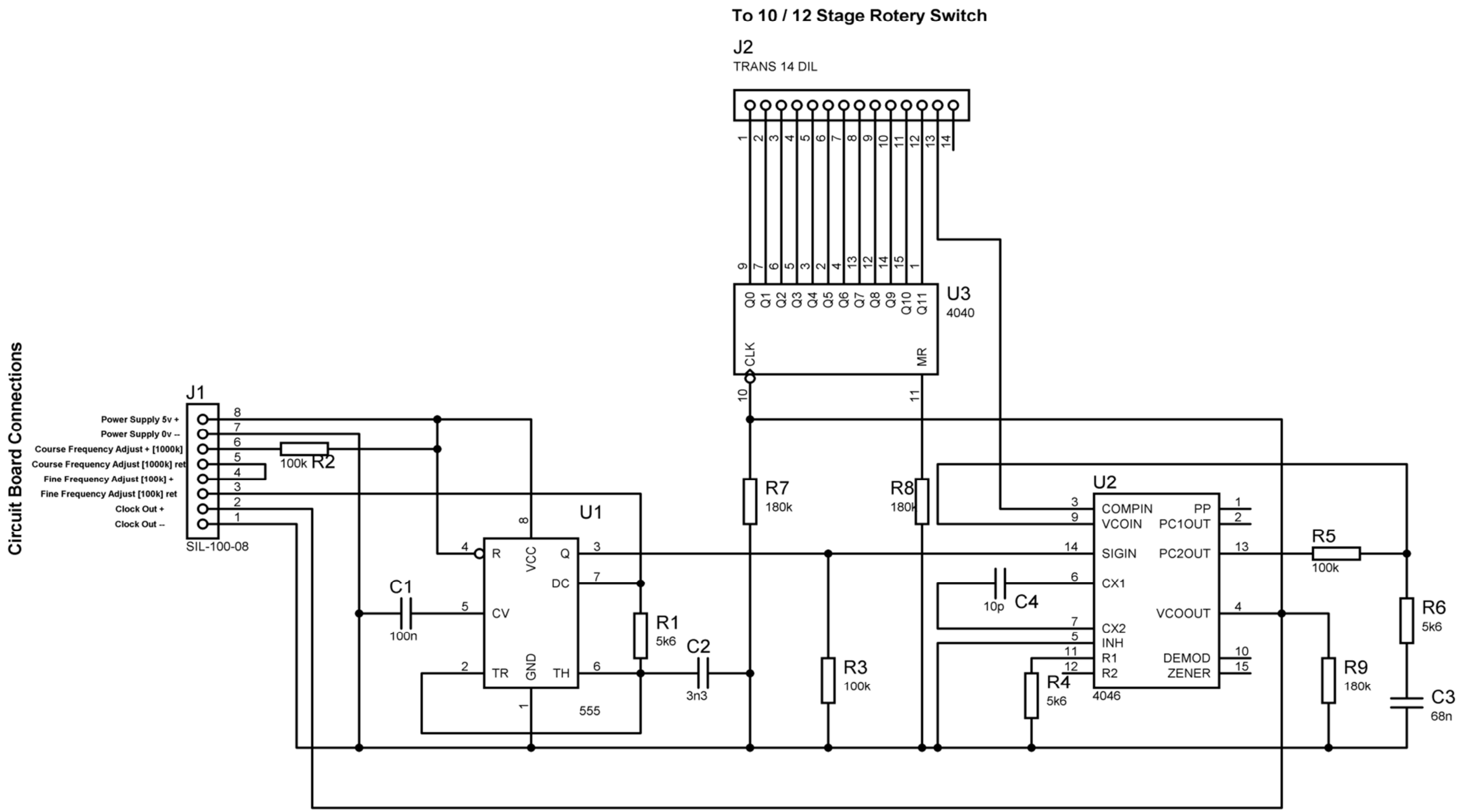
5.1 Power Supply



Function Generator mkII - Power Supply Board

14/09/2011

5.2 Clock Circuit



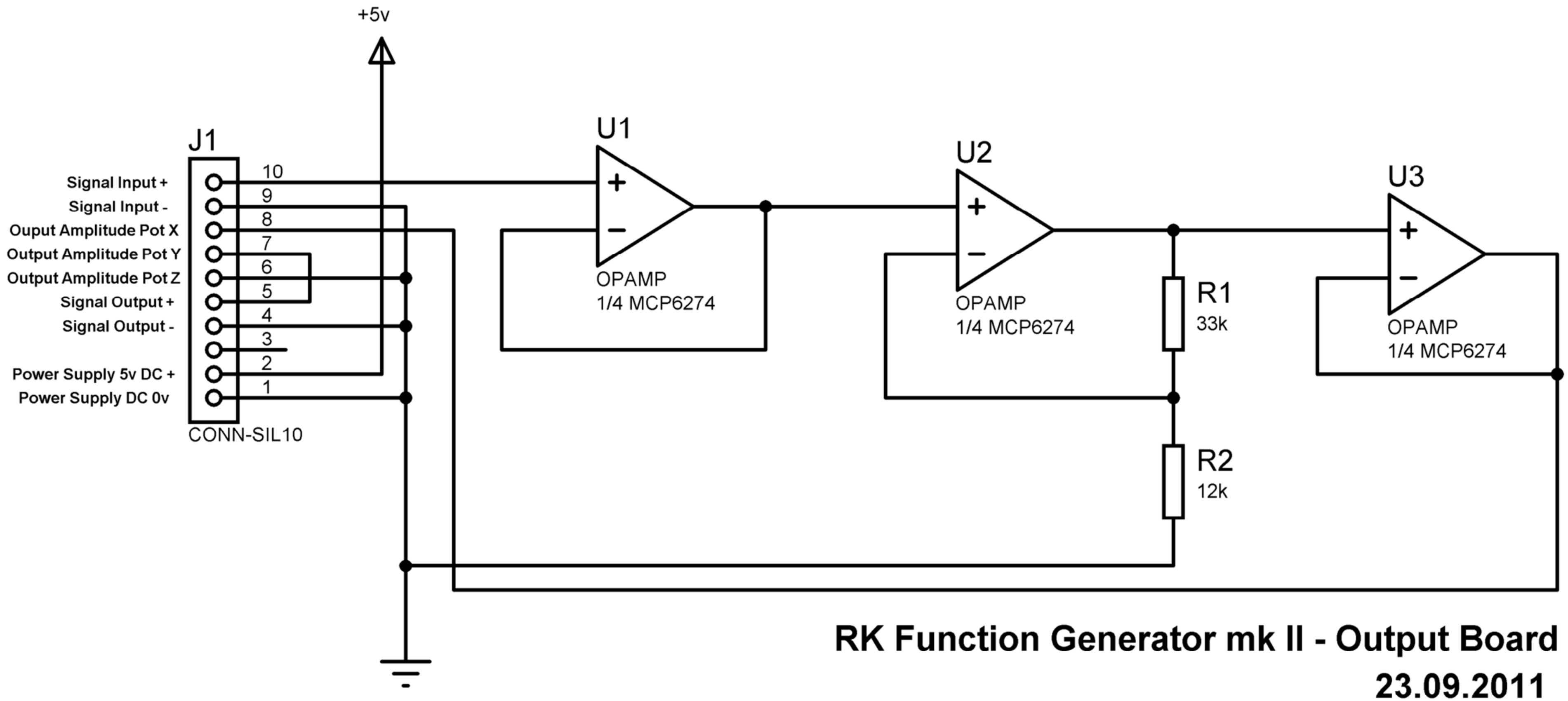
Tuning Resistor Values: Course Frequency = 1M

Fine Frequency = 100k

Function Generator mk II - Clock Board

15/09/2011

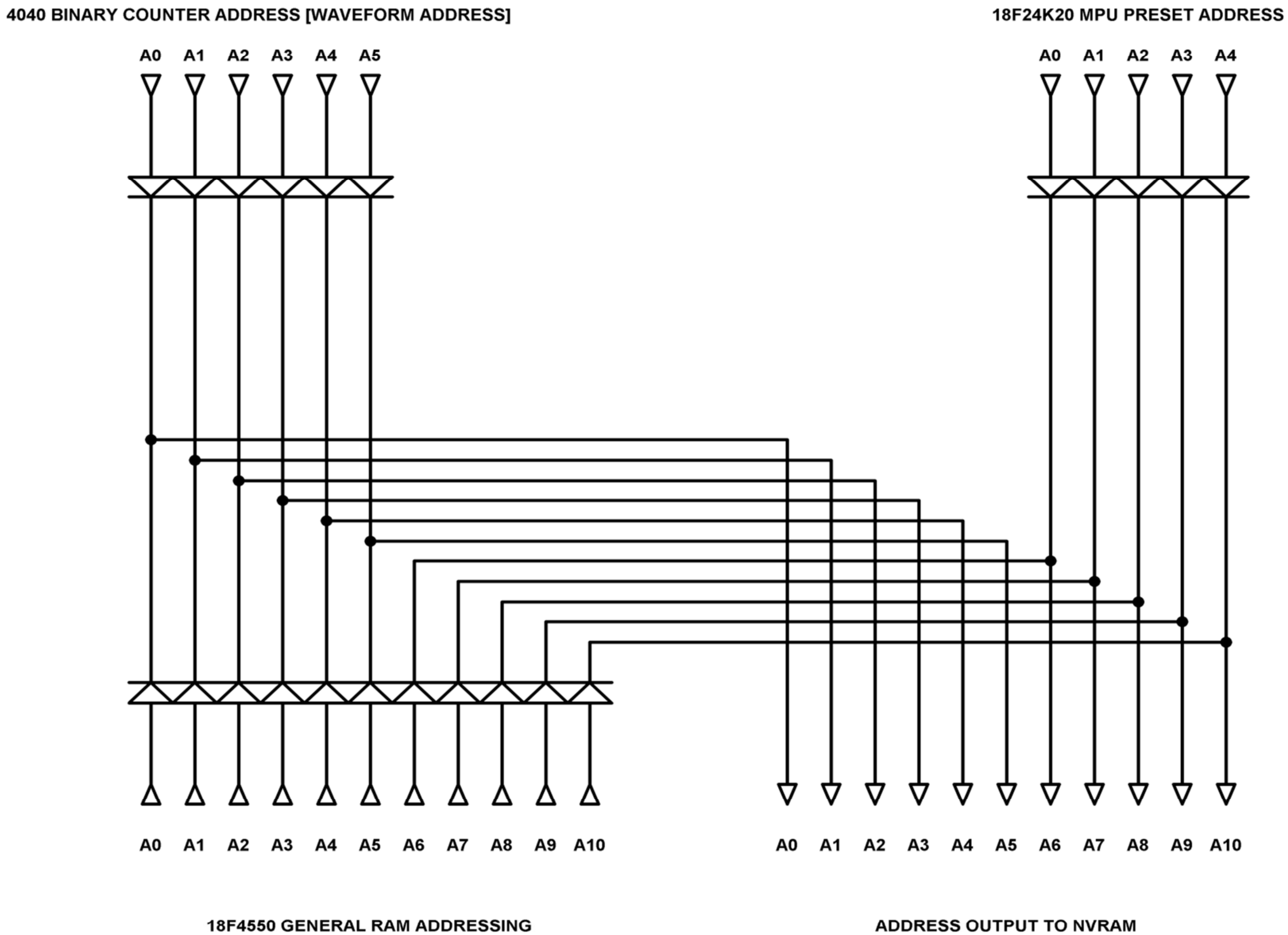
5.3 Output Board



RK Function Generator mk II - Output Board

23.09.2011

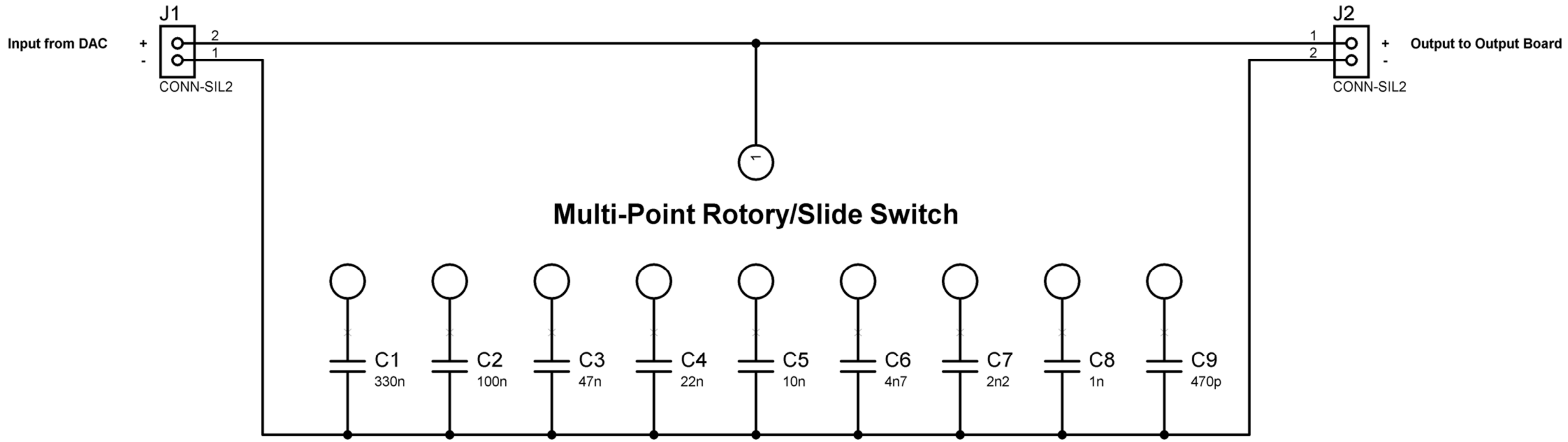
5.4 Diode Node



Function Generator mkII - Diode Node

09/10/2011

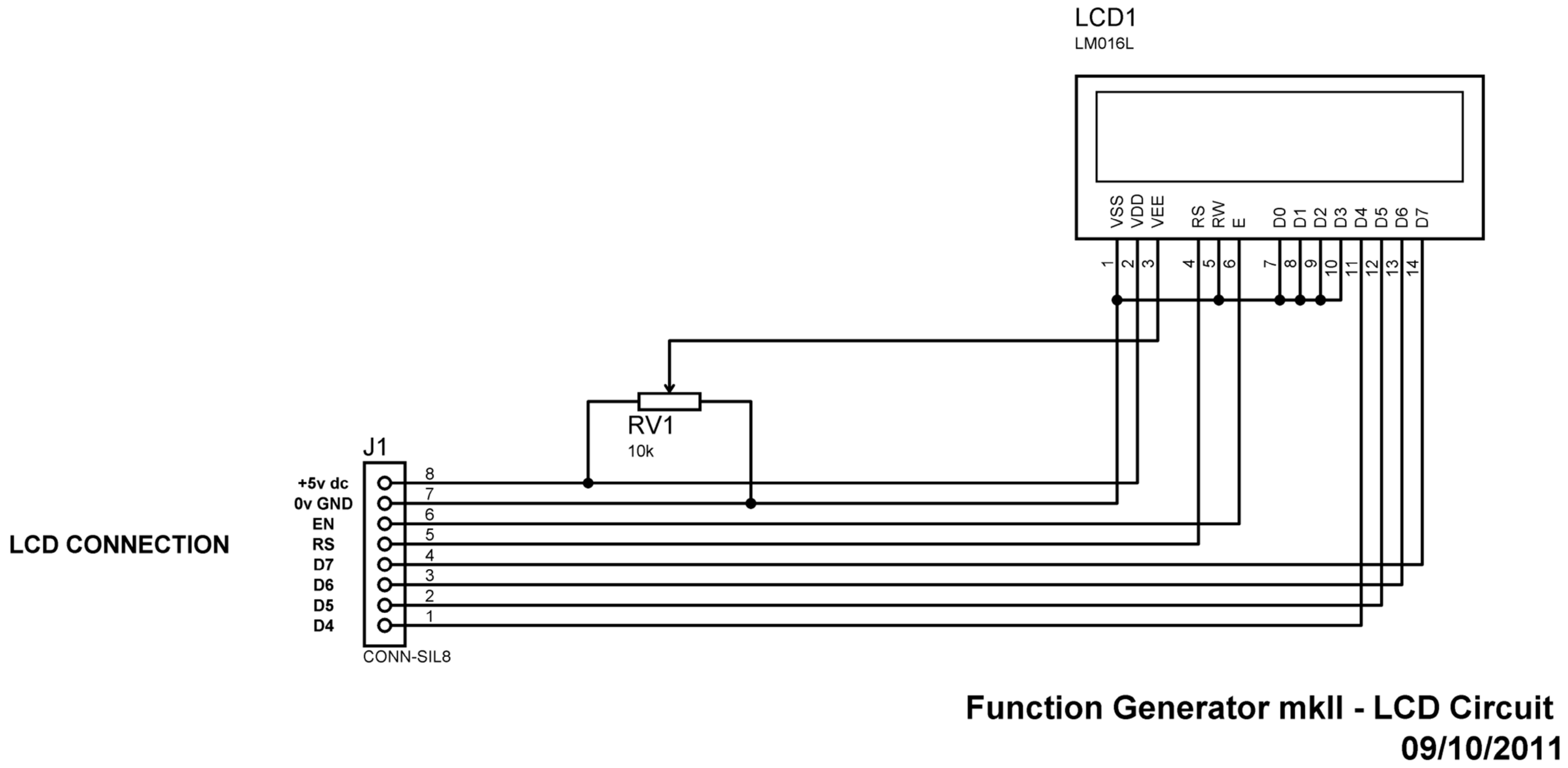
5.5 Filter Board



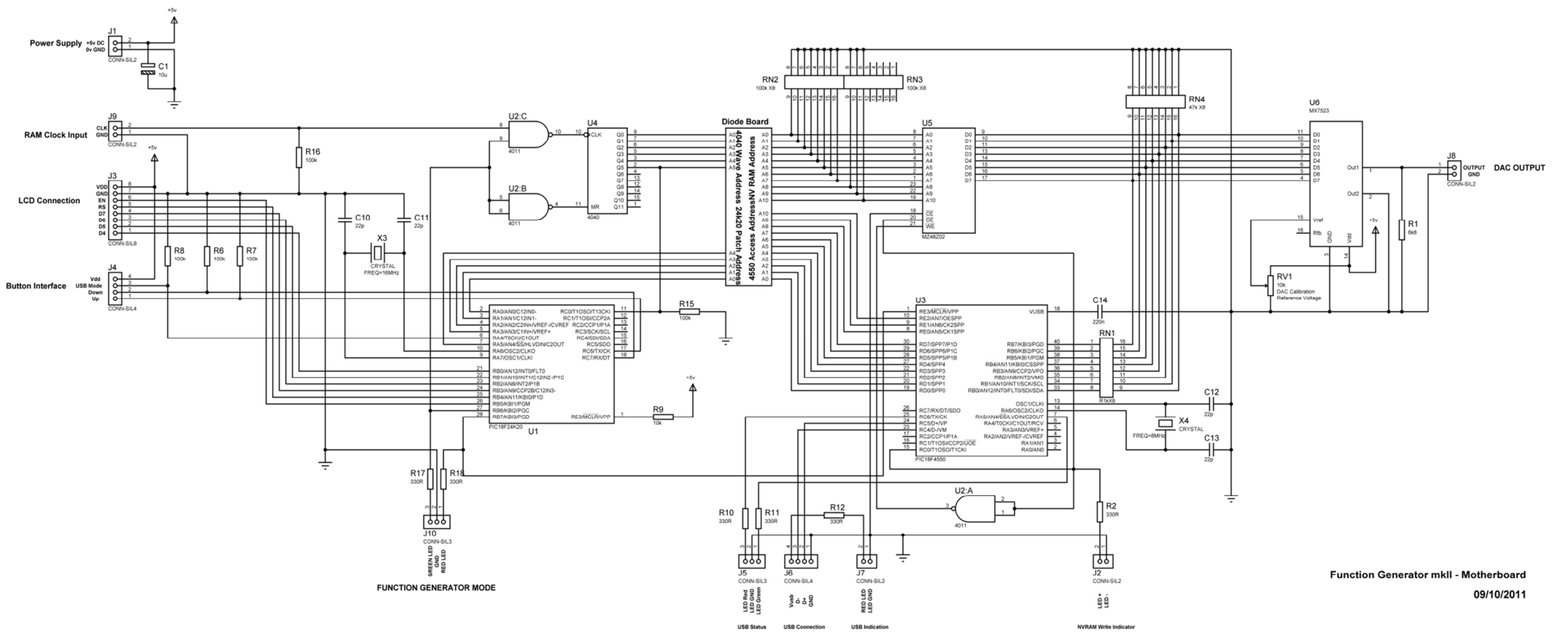
Function Generator mkII - Filter Board

31.10.2011

5.6 LCD Display



5.7 Motherboard



6 Bill of Materials

This provides a list of components that are required to build the function generator

6.1 Power Supply Board

Qty.	Component	Value	Farnell Order Code	Price	Price Suggest		
1	Resistor*	39k	9339604	0.50	0.50		
1	Resistor*	180k	9339264	0.50	0.50		
1	Resistor*	10k	9339060	0.50	0.50		
3	Resistor*	330r	9339418	0.50	0.50		
1	Power Diode		1700921	0.16	0.16		
1	Ceramic Capacitor	100n	1669198	0.64	0.64		
1	Electrolytic Capacitor*	220n	1871012	0.34	0.34		
1	Electrolytic Capacitor*	47µ	1236671	0.67	0.67		
1	Electrolytic Capacitor	470µ	8767440	0.26	0.53		
1	12 Way SIL Connector		2008011	1.68	1.68		
1	2 way SIL Connector		3089034	0.32	0.32		
1	Bridge Rectifier		1651041	0.33	0.33		
1	Linear Technology LTC1129-5 Power Regulator	5v	Available from Linear Only				
1	Microchip PIC 12F675		9759018	1.05	1.05		
1	NPN Transistor 2N2222*		1611371	1.32	1.32		
1	Vishay V01462AT Optio Isolator°		Available from Vishay Only				
1	PCB Dot Matrix Board 100x160		1172145	2.80	2.80		
	Replacement components for V01462AT:						
	Vishay IL4218		1469497	2.58			
	Vishay V04258M		1779739	1.50	1.50		
	Replacement components for LTC1129-5						
	ST L4941BV		9756051	1.52	1.52		
			Total		£14.86	$23.78	€ 18.12
			Tax (UK VAT @ 20%)		£2.97		
			Net Total		**£17.83**		
					UK	US	EU

* Components are subject to minimum quanties, price INCLUDES cost for multiple quanities

° OK to use suitable replacements as suggested below, please note that replacements are not pin compatable

Currency conversions are approximate only - £ = $1.6 and £ = € 1.15

Prices taken from www.farnell.co.uk on 21.10.2011

6.2 Clock Board

Qty.	Component	Value	Farnell Order Code	Price		
3	Resistor*	100k	9339078	0.50		
3	Resistor*	5k6	9339604	0.50		
3	Resistor*	180k	9339264	0.50		
1	Polymer Capacitor	100n	1669198	0.64		
1	Glass Capacitor	3n3	9520538	0.89		
1	Polymer Capacitor*	68n	1215514	0.49		
1	Mica Capacitor	10p	1264868	0.96		
1	8 way SIL Screwed Connector	8 SIL	2008009	1.12		
1	12 Way SIL or DIL Connector°	14 SIL/DIL	2008011	1.68		
1	555 Timer IC		9589953	0.54		
1	CMOS HC 4046		1106104	0.51		
1	CMOS HC 4040		1106103	0.47		
1	10 Way Switch [Rotary]²		1190388	10.47		
1	PCB Dot Matrix Board 100x160		1172145	2.80		
	Total exc. VAT			£22.07	$35.31	€ 25.38
	VAT (UK @ 20%)			£4.43		
	Net Total			**£26.49**		
				UK	US	EU

* This component is subject to minimum quanities. The price shown INCLUDES for the minimum purchase amount

° This component only needs to have 12 connections, Schematic shows 14, and 14 Can be used if CMOS 555 and HEF 4046 is used

² Can use a 12 way switch if CMOS 555 timer is used and HEF 4046 is used

Currency conversions are an estimate based on £ = $1.6 and £ = €1.15

Prices taken from www.farnell.co.uk on 21.10.2011

6.3 Output Board

Qty.	Component	Value	Farnell Order Code	Price		
1	Microchip MCP6274		1439453	1.17		
1	Resistor	33k	9341757	1.27		
1	Resistor	12k	9339132	0.50		
5	2 way SIL Screw Terminals		3089034	1.60		
			Total	**£4.54**	$7.26	€ 5.22
			Tax (UK@20% VAT)	**£0.91**		
			Net Total	**£5.45**		
				UK	US	EU

Prices taken from www.farnell.co.uk on 23.11.2011

6.4 Diode Node

Bill of Materials - Diode Node

Qty.	Component	Value	Farnell Order Code	Price		
22	Small Signal Diode		1467557	0.99		
1	PCB Connector [header]		1668589	4.28		
			Total	**£5.27**	$8.43	€ 6.06
			Tax (UK@20% VAT)	**£0.20**		
			Net Total	**£1.19**		
				UK	US	EU

Prices taken from www.farnell.co.uk on 23.11.2011

6.5 Filter Board – Capacitors not Included here

Qty.	Component	Value	Farnell Order Code	Price		
2	2 way SIL Screw Terminals		3089034	0.64		
1	10 position rotary switch		price estimate	10.00		
1						
1						
			Total	£10.64	$17.02	€ 12.24
			Tax (UK@20% VAT)	£2.13		
			Net Total	£12.77		
				UK	US	EU

Prices taken from www.farnell.co.uk on 23.11.2011

6.6 LCD Display

Qty.	Component	Value	Farnell Order Code	Price		
1	PCB Header 16 Way		1667444	4.95		
1	8 way SIL Screw Terminals		2008009	1.12		
1	10k variable resister [trimmer]	10k	1357152	0.40		
1	16x2 Alphanumeric Display		1671498	3.80		
			Total	£10.27	$16.43	€ 11.81
			Tax (UK@20% VAT)	£2.05		
			Net Total	£12.32		
				UK	US	EU

Prices taken from www.farnell.co.uk on 23.11.2011

6.7 Motherboard

Qty.	Component	Value	Farnell Order Code	Price		
24	Resistor*	100k	9339078	0.55		
5	Resistor*	330r	9339418	0.55		
1	Resistor*	22k	9339310	0.55		
2	Resistor*	6k8	9339663	0.55		
8	Resistor*	1k	9339051	0.55		
1	Resistor*	10k	9339060	0.55		
4	Ceramic Capcitor*	22p	1827810	1.08		
1	Electrolytic Capacitor*	10µ	9452486	0.27		
1	Quartz Crystal	8 MHz	1842269	0.41		
1	Quartz Crystal	16 MHz	1842217	0.41		
1	CMOS 4040		1106103	0.47		
1	CMOS 4011		1106098	0.45		
1	Microchip PIC 18F24k20		1439575	2.04		
1	Microchip PIC 18F4550		9321357	5.00		
1	Maxim 7523 8 Bit Additive DAC°		Available from Maxim			
1	2048 Byte NVRAM IC		1607930	9.44		
4	2 way SIL Screw Terminals		3089034	0.32		
1	8 way SIL Screw Terminals		2008009	1.12		
2	4 Way SIL Screw Terminals		2008006	0.67		
1	3 Way SIL Screw Terminals		2008005	0.50		
1	PCB Dot Matrix 100 x 160		1172145	2.80		
	Replacement for Maxim MX7523:					
	Analog Devices AD7524 (Pin Compatable)°		9605401	7.30		
			Total	**£35.58**	**$56.93**	**€ 40.92**
			Tax (UK @ 20% VAT)	**£7.12**		
			Net Total	**£42.70**		
				UK	US	EU

*These components are subject to minimum quanities, price shown INCLUDES cost for Minimum Quanties

° AD7524 is directly compatable with MX7523, MUST put pins 12 and 13 to GND for AD7524

° MX7523 does not require pins 12 and 13 to GND as they are not used. For the AD7524 they are used for

° chip select and write enable

7 About the Author

Name: Russell Kelly

Date of Birth: 15.04.1984

Location: Derby, United Kingdom

Profession: Chemical Engineer

Profession Skill Sets: M/E Balancing, Projects and Design

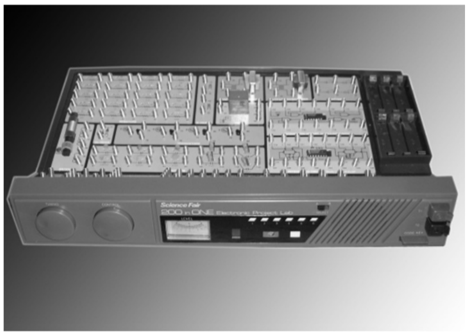
Special Skill Sets: Electronic Design and VB Programming

Education: Master of Chemical Engineering with Honours

University: University of Bath, England.

A Little about Me

Ever since I can remember I have always wanted to be an engineer following the footsteps of my Father and Grandfather who worked extensively in the automotive, quality assurance and lean manufacturing environment. For me I always wanted to pursue a career within Electronic Engineering, however after studying Chemistry at A-Level (16 – 18 years of age) I wanted to learn a profession that had almost no limit on its use or application. At 18 I decided to undertake my degree within the field of Chemical Engineering.



Electronics has always been a keen interest of mine ever since receiving my first Tandy 200-in-1 electronics design unit (picture to the right). It was here that I learned some of the basic electronic design principles before moving onto the 300-in-1 and finally breadboard circuit design; obtaining components from RadioShack, Maplin or out of an old radio or television set. Books including “Getting Started in Electronics” by Forest M. Mims III were indispensible (ISBN-10: 999133226X)

Since starting electronics as a hobby in 1991 I have continuously developed upon my design ability and project complexity, moving onto digital electronics and finally PIC Microprocessors. The latter of which can propel your circuit design enormously.

At a professional level I have worked for a number of different companies in variety of industries from Oil and Gas, Water Treatment and Nuclear.

I am currently married to Danielle whom I have been in a relationship with since 2006. We married in 2011. Between us we have two pets Alan and Steve our juvenile Tortoises (Alan pictured).