A PIC-Based Handheld Multi-Channel Analyzer (MCA)

PRELIMINARY DESCRIPTION

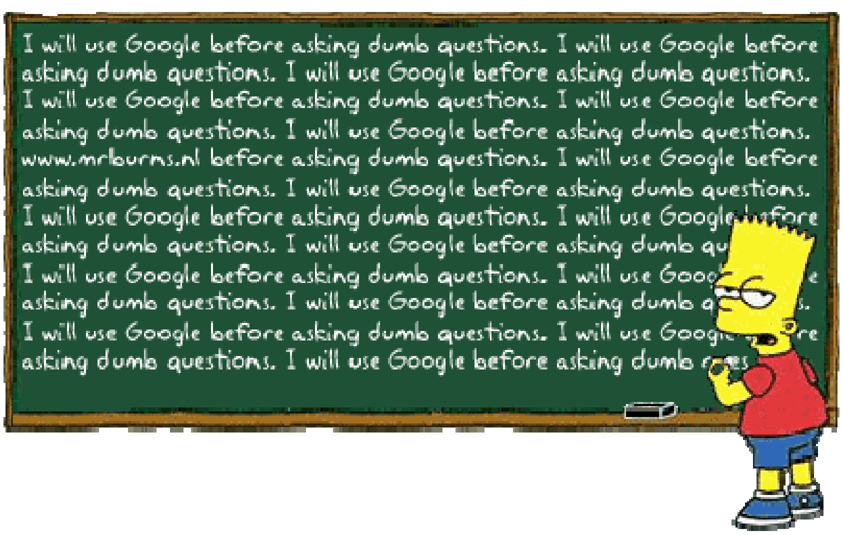
© David Prutchi, Ph.D., 2007

BEFORE YOU CONTACT ME WITH QUESTIONS, PLEASE READ:

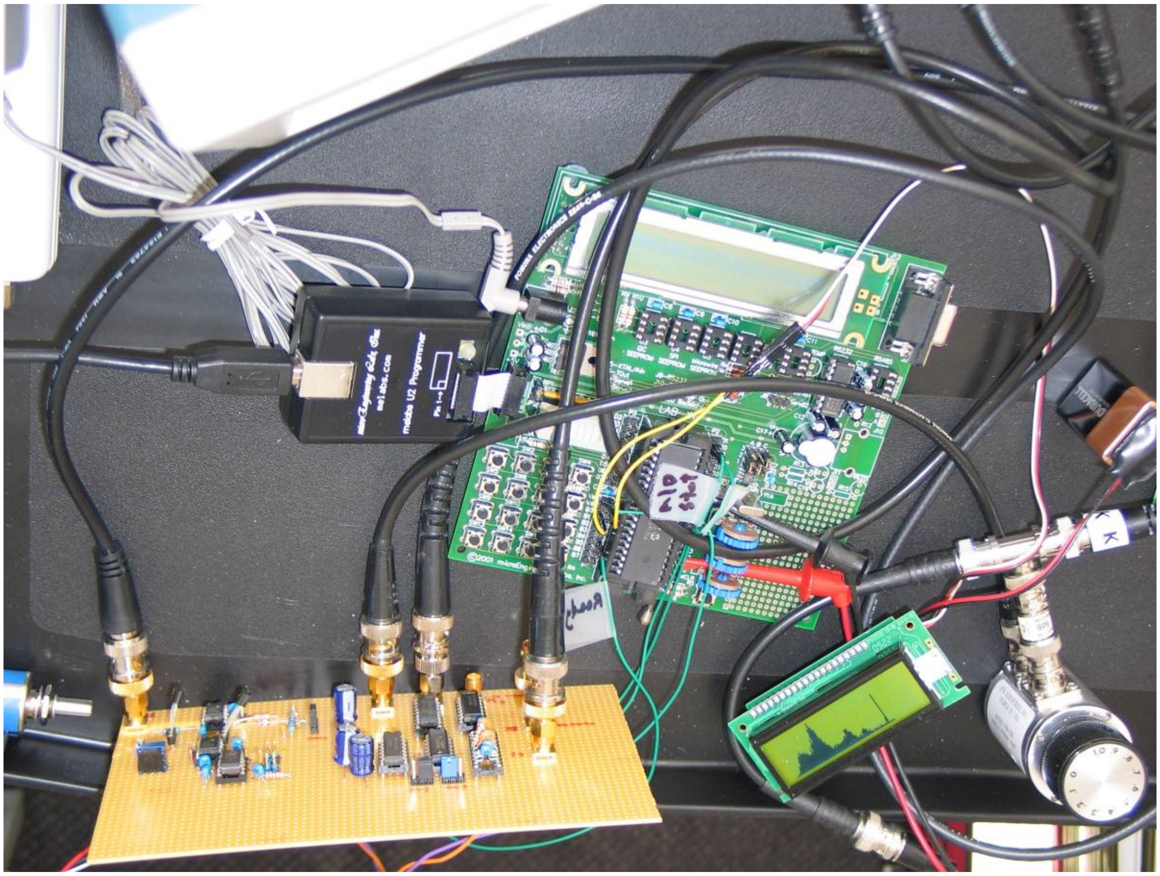
This document is a **preliminary** description for a very early prototype of the instrument. It is not intended to serve as a how-to guide to building a MCA. Instead, it is meant to help anyone else who is versed in the development of electronic instruments as a very first step towards open-source collaboration on the development of a handheld MCA for amateur use.

This is a personal hobby project. I am not interested in turning into a commercial instrument. Please note that my time is limited and I will not address every question that I receive regarding this matter (especially if the answer to the question is readily available by searching on Google).

Lastly, I am a law-abiding, peace-loving citizen. I will not help you with any application for this device that is illegal, immoral or unethical. I reserve the right to report all such requests to the authorities.



I am now developing a new medical instrument which requires histogramming, which got me in the mood to retake my own PIC MCA project (http://home.comcast.net/~prutchi/index_files/scint.htm). I have the prototype working under a most basic operational mode (just histogramming). I am using just the variable RAM in the microcontroller (16F877), so I limited the number of channels to 95 and let the histogram run until some channel reaches 240 counts (the highest 8-bit number that yields an integer when divided by 8). The firmware then displays the spectrum as a bar with a maximum height of 30 pixels for each one of the 95 channels. The following picture shows the development prototype in its current state:

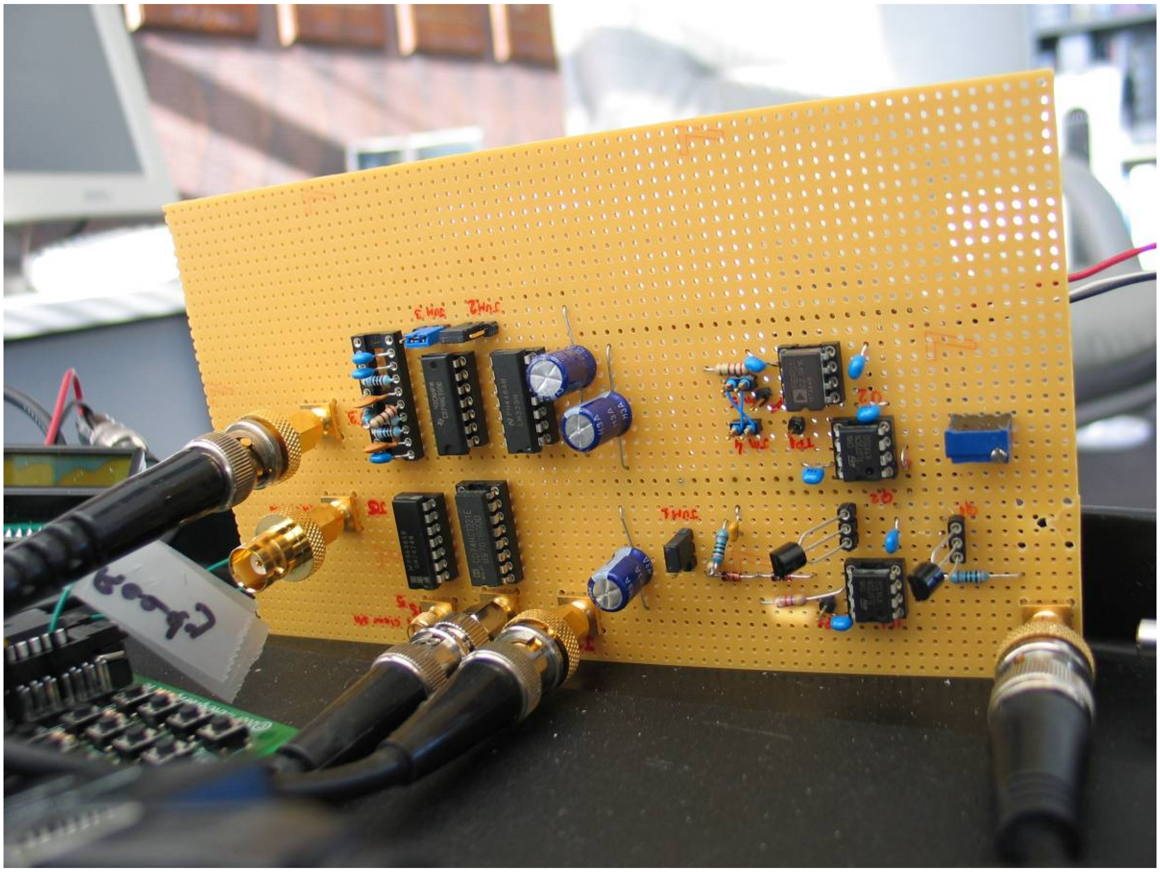


The MCA hardware portion of the instrument is a peak detector and track/hold that feeds the PIC's A/D. The design is heavily based on:

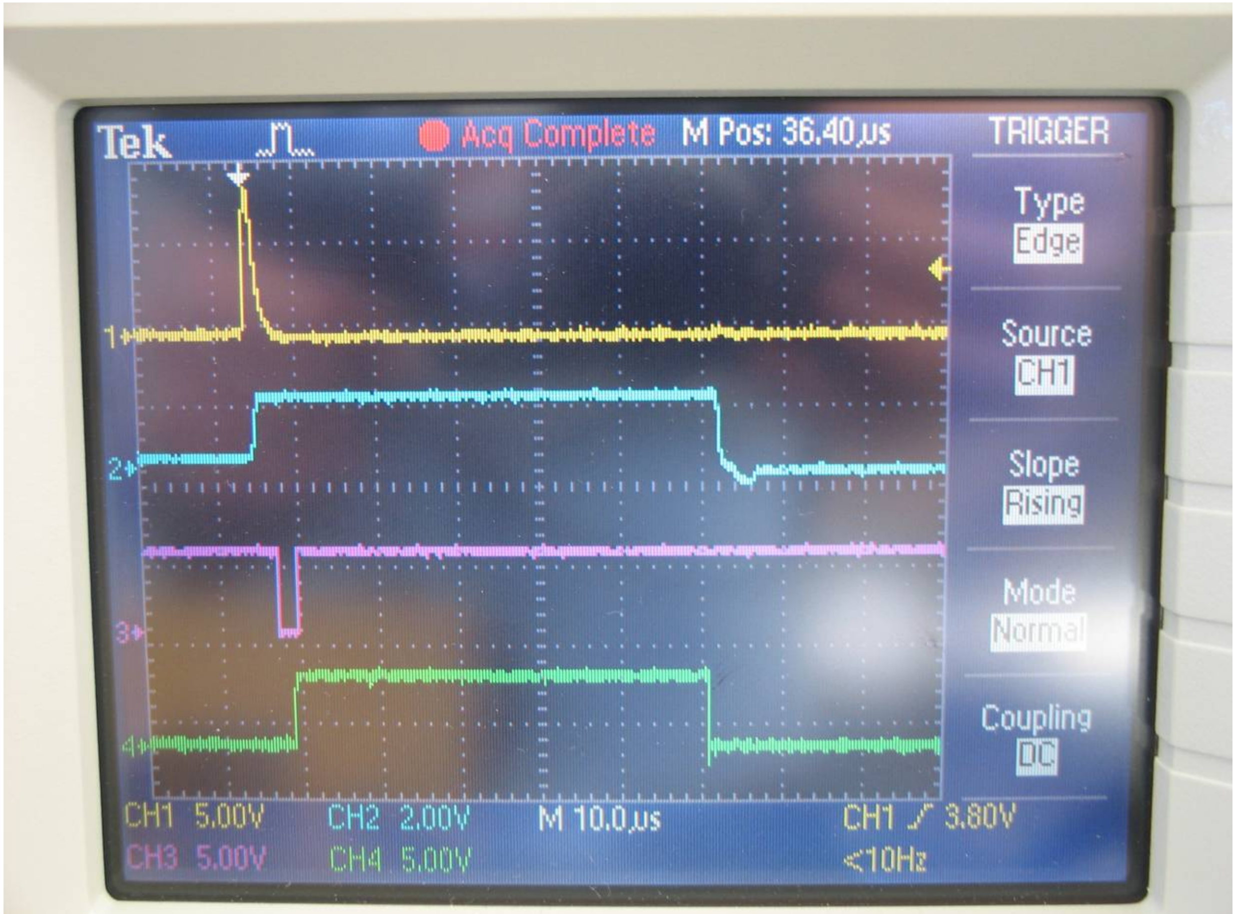
> P.-H. Lefebvre, M. Clar, H.-P. Garnir, "DESIGN OF A NETWORKED MULTICHANNEL ANALYZER (nMCA)", *International Conference on Accelerator and Large Experimental Physics Control Systems*, 1999, Trieste, Italy

available at: http://www.elettra.trieste.it/icalepcs99/proceedings/papers/mc1p65.pdf

Please read the paper by Lefebvre et al. since it describes the operation of the circuit, its timing considerations and overall performance. The following picture shows the peak detector and track/hold circuit board:



The peak detector takes care of capturing the peak level of each event detected by the PMT (after amplification and Gaussian shaping). The logic of the peak detector tells the PIC that it has a new sample ready, and the PIC then leisurely samples the voltage held by the S/H. The PIC then resets the peak detector and waits for the next event. I poll a PIC digital port line for the peak detector's signal that a new sample is ready (vs. using an interrupt), and processing a sample with my program written in PIC Basic Pro (http://www.melabs.com/products/pbp.htm) and the PIC running at 20MHz takes about 60µs. **I haven't done any optimization whatsoever - this was just proof of principle whipped up in a few hours.** I plan to move to a 18Fxx PIC to expand the number of channels and then zoom to a region of interest for display on the LCD. The following oscilloscope screen shot shows the main timing of events:



- Channel 1 is the output of the PMT amplifier/shaper (before attenuation)
- Channel 2 is the signal at U1B pin 7, the output of the S/H (input to the PIC A/D)
- Channel 3 is the "Sample Ready" signal at U6A pin 3
- Channel 4 is the A/D status signal generated by the PIC and delivered to U5B pin 9

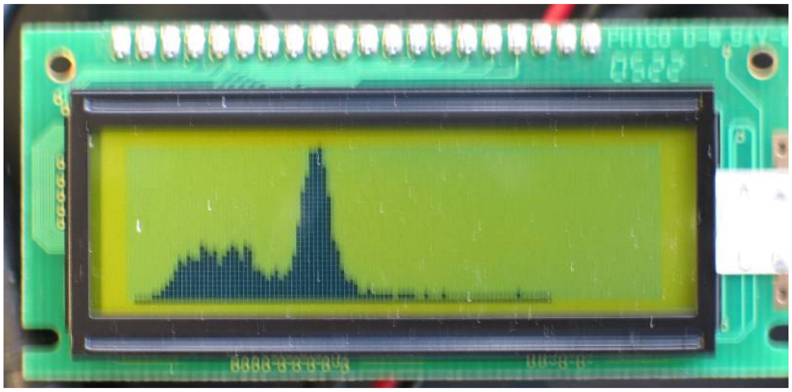
Connections between the MCA interface board and the PIC are as follows:

- U6A pin 3 ("Sample Ready") to PIC B4
- U7A pin 1 ("Clear S/H") to PIC D0
- U5B pin 9 ("A/D Status") to PIC D1
- U1B pin 7 (S/H analog output) to PIC A2 (attenuated to max of 5V!!)

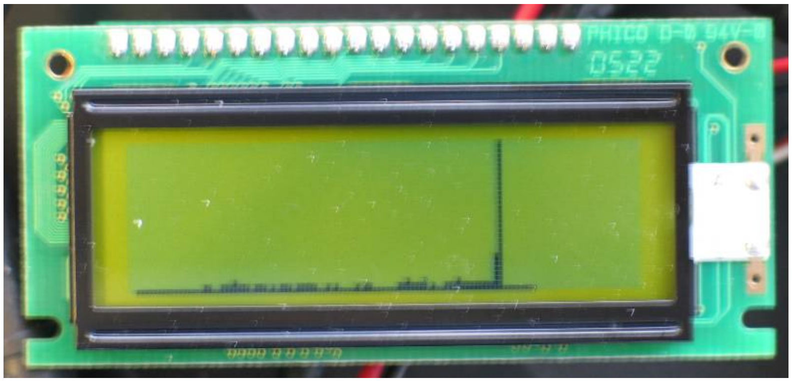
The selection of control ports may seem strange to you at first, but it's based on the lines available in the LabX1 PIC experimenter's platform by MicroEngineering Labs (http://www.melabs.com/products/labx1.htm). I am not using any of the platform-specific portions of the LabX1, so a PIC with a 20MHz crystal oscillator and a 5V power supply are all that is needed for the microcontroller portion. The display is a SGX-120L Serial Graphics LCD by Scott Edwards Electronics (http://www.seetron.com/sgx120_1.htm). The LCD serial data line is connected to the PIC's line B0.

The following pictures (sorry about the quality, took them without a tripod) show spectra displayed by my prototype for Cs-137, Co-60, Ba-133 and Eu-152. My MCA peak detector is set to truncate low-energy events (noise), and I set the top end to catch the tallest events generated by my Co-60 source. The detector is a NaI(Tl)/PMT probe operating at 1.6kV and feeding my prototype amplifier/shaper. Even with this simple setup you can tell pure check sources apart.

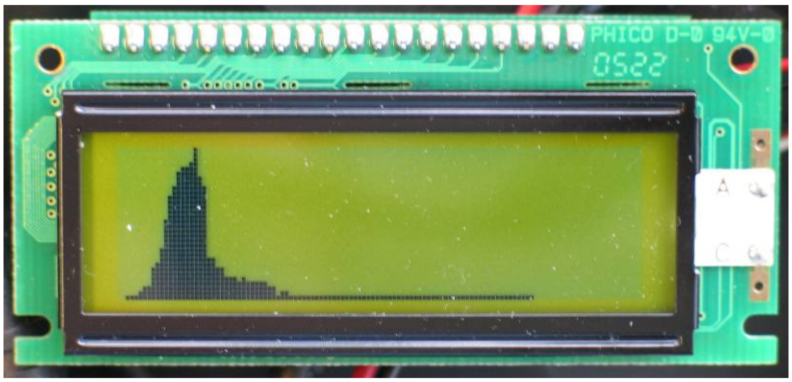
Cs-137:



Co-60:



Ba-133:

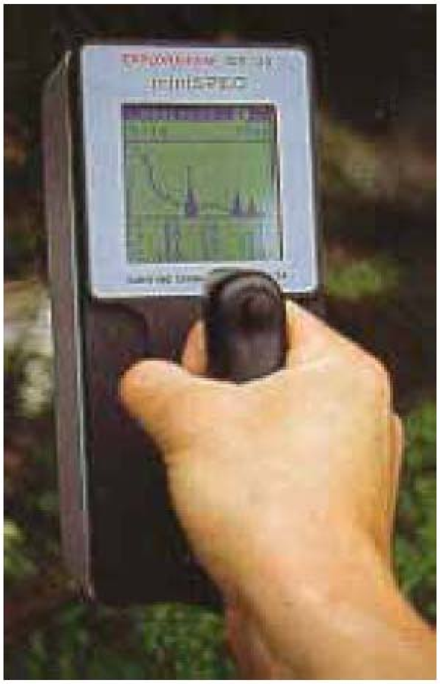


Eu-152:

I envision developing it into a simple and cheap handheld scintillator/MCA to allow amateur-level work to identify radioactive materials in field surveys (especially urban prospecting for old/forgotten sources). Similar commercial products to what I envision are:

http://www.nucsafe.com/Products/identispec.htm

http://www.terraplus.ca/html/GR-135G1.pdf



I think that I could store some templates in EEPROM to display them as an overlay (without trying automatic identification by template matching) so a user could scroll through the various templates and try eyeball matching to identify the source. I guess that this method will be confusing when looking at a mixed sample (e.g. radon with all of its daughters), but given that this is just an amateur project with low personal priority, I think that the limit of where I will take it.

I hope that you find this simple MCA platform interesting and feel motivated to vastly improve its processing and display capabilities.

Resources

Manuals for student/research grade instruments by Spectrum Techniques are available at: http://www.spectrumtechniques.com/manuals/ . These contain full circuit schematic diagrams for their instrumentation! A complete amplifier/shaper (Spectech ST400 Scintillation Processor) is shown in: http://www.spectrumtechniques.com/manuals/ST400manual.pdf . Other relevant schematics for this project are related to Spectech's single-channel analyzer: http://www.spectrumtechniques.com/manuals/ST450manual.pdf and their "Universal Computer Spectrometer": http://www.spectrumtechniques.com/manuals/UCS20manual.pdf

A simple PIC-based MCA is described by staff from the Instrumentation Center of the Physics Department, University of Coimbra, Portugal: J. M. Cardoso, V. Amorim, R. Bastos, R. Madeira, J. B. Simoes, and C. M. B. A. Correia, "A very low-cost portable multichannel analyzer", *IEEE Nuclear Science Symposium 2000*, Lyon, France, 2000. available at http://lei.fis.uc.pt/pdfs/Com002.pdf

The same group has worked on DSP-based implementations of a MCA: http://lei.fis.uc.pt/pdfs/Com006.pdf, http://lei.fis.uc.pt/pdfs/Com005.pdf, http://lei.fis.uc.pt/pdfs/Thesis001.pdf

Other papers from the same group worth exploring are at http://lei.fis.uc.pt/pdfs/

Source code, documentation and executables for a MCA server and display program using the nMCAs described by P.-H. Lefebvre, M. Clar, H.-P. Garnir, " DESIGN OF A NETWORKED MULTICHANNEL ANALYZER (nMCA)", *International Conference on Accelerator and Large Experimental Physics Control Systems*, 1999, Trieste, Italy (http://www.elettra.trieste.it/icalepcs99/proceedings/papers/mc1p65.pdf) are available at: http://www.ipnas.ulg.ac.be/garnir/javaspectre/

An undergraduate laboratory project that combines microprocessor programming, interfacing, and system design to produce a multichannel analyzer is described in: B.L. Munger and R.E. Zammit, "Microprocessor Multichannel Analyzer Laboratory Project", *Am. J. Phys.*, Vol. 48, No. 8, August 1980 Pages 623 – 625. You can access it on-line if you are a subscriber of the American Journal of Physics: http://link.aip.org/link/?AJPIAS/48/623/1. Otherwise, you can look for it at your local university library. This paper shows flowcharts for the MCA implemented on a 1980s vintage microprocessor.

I legally purchase my check sources from Spectrum Techniques. Last time I purchased, 1µCi Ba-133 1" disc solid source was $45, 1µCi Co-60 1" disc solid source was $45, 1µCi Eu-152 1" disc solid source was $85 and 0.1uCi Sr-90 1" disc solid source $45. http://www.spectrumtechniques.com/

Program Listing (PIC Basic Pro v. 2.47)

```
'****************************************************************
'*  Name    : MCA1.BAS                                         *
'*  Author  : David Prutchi, Ph.D.                             *
'*  Notice  : Copyright (c) 2007                               *
'*          : All Rights Reserved                              *
'*  Date    : 2/22/2007                                        *
'*  Version : 1.0                                              *
'*  Notes   : First prototype of multichannel analyzer         *
'*          :                                                  *
'****************************************************************
'
' Hardware configuration:
' LabX1 PIC Experimenter's board, clock set to 20MHz,
' loaded with 16F877-20
'
' Connections between MCA  interface board and LabX1:
'   U6A pin 3 ("Sample Ready") to PIC B4
```

```
'     U7A pin 1 ("Clear S/H") to PIC D0
'     U5B pin 9 ("A/D Status") to PIC D1
'   U1B pin 7 (S/H analog output) to PIC A2
'
' Connection between SEETRON SGX-120L LCD and LabX1:
'   SGX-120L Data line to PIC B0
'

Define  OSC     20   ' Oscillator at 20 MHz

' ==GRAPHIC LCD CONTROL CONSTANTS========================
N9600  CON  $4054    ' baudmode constant, 9600 bps.
S_PIN  var  PORTB.0  ' Serout pin to SEETRON LCD
CLRLCD  CON  12      ' ASCII form feed = clear screen.
CTL_P  CON  16       ' Control-P (position cursor).
CTL_B  CON  2        ' Start inverse-video print.
CTL_C  CON  3        ' End   "              "
CUT0  CON  64        ' 1-byte shortcut for 0.
ESC  CON  27         ' Escape (begins graphics instruction).

' ==LCD CHART CONSTANTS==================================
' You can change HEIGHT, WIDTH, and PCOLOR to modify the
' plot display. Try changing PCOLOR to WHITE for an
' inverse-video look.
BLACK  CON  1        ' Black pixel-ink.
WHITE  CON  0        ' White (background color) pixel-ink.
HEIGHT  CON  31      ' Max Y val of plotting area.
WIDTH  CON  120      ' Width of the plotting area.
PCOLOR  CON  BLACK   ' Color of the plot.
ECOLOR  CON  PCOLOR ^ 1  ' Erase color (opposite of PCOLOR).

' ==PROGRAM VARIABLES==================================
i VAR Byte              ' Iteration variable
x VAR Byte(95)          ' Array x(95)is for spectrum
adval var   byte        ' A/D result

' ==ADCIN PARAMETERS==================================
Define      ADC_BITS    6     ' Set number of bits in result
Define      ADC_CLOCK   3     ' Set clock source (3=rc)
Define      ADC_SAMPLEUS      10    ' Set sampling time in uS

' ==MCA PEAK DETECTOR CONNECTIONS=====================
ClearSH VAR PORTD.0     ' Alias PORTD.0 to Clear S/H:
                        '   1=clear
                        '   0=track
ADStat  VAR PORTD.1     ' Alias PORTD.1 to A/D Status:
                        '   1=conversion in progress
                        '   0=conversion complete
LED     VAR PORTD.3     ' Alias PORTD.3 to LED

' ==LINE SETTINGS=====================================
' Peak detector control line initial setting
Low ADStat
low ClearSH
LOW LED
```

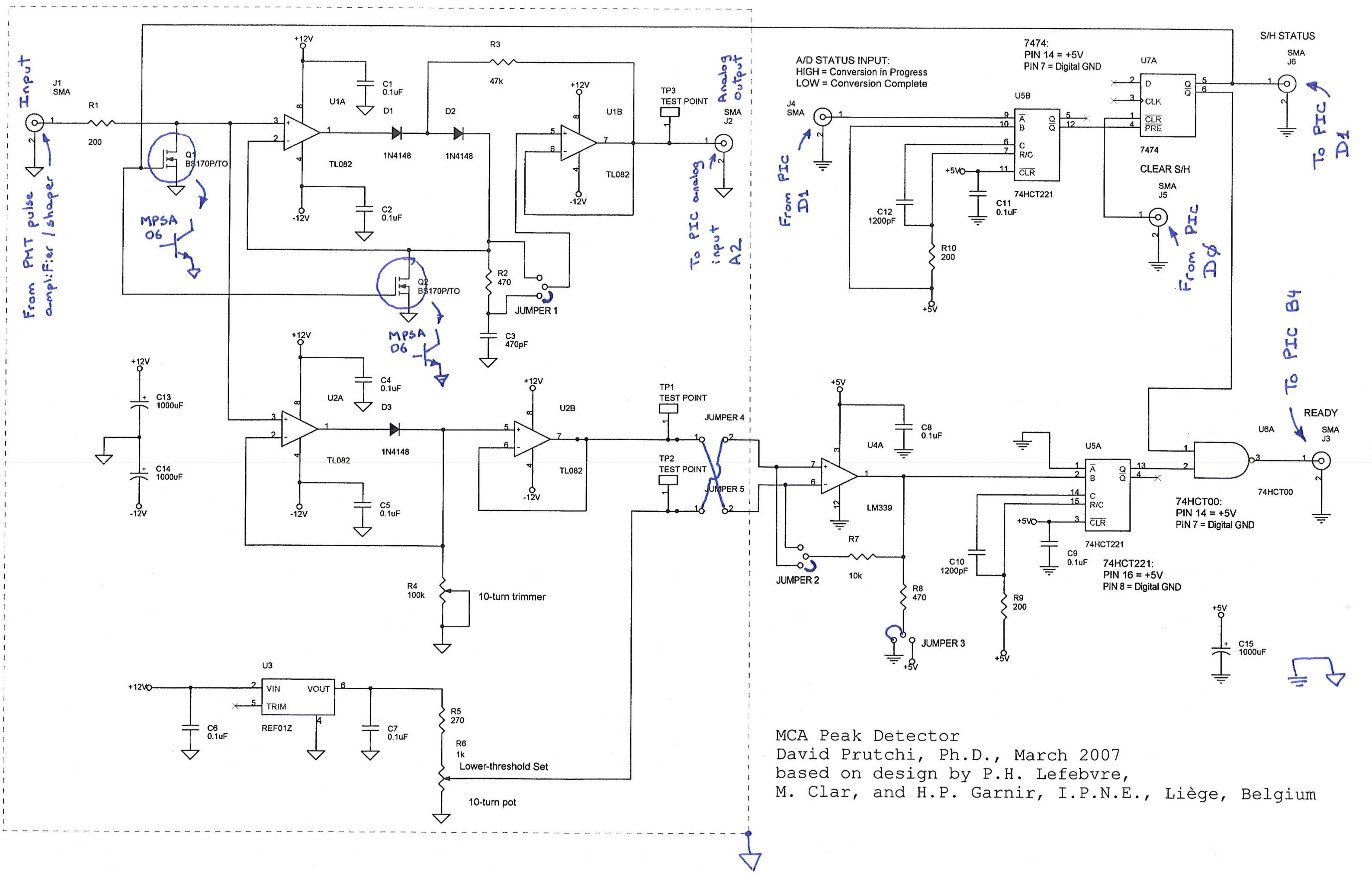
```
'A/D port settings
TRISA = %11111111 ' Set PORTA to all input
ADCON1 = %00000010      ' Set PORTA analog

' ==INITIALIZE=========================================
' Initialize histogram array, zero all values
for i=1 to 95
    x(i)=0
next
'  Initialize LCD display
PAUSE 1000  ' Wait for LCD to initialize.
'Send some dummy data to finish pending instructions
sEROUT2 S_PIN,N9600,[CUT0,CUT0,CUT0,CUT0,CLRLCD]

' ==MAIN PROGRAM=======================================
loop:
        PORTB = 0       ' PORTB lines low to read S/H status
        TRISB = $f0     ' Enable all button lines
        If PORTB.4 = 0 Then     ' If Ready line is low then A/D
                HIGH led        ' Turn LED on
                high  ADStat       '  Signal  peak  detector  that  A/D  is
converting
                ADCIN 2, adval      ' Read channel 0 to adval
                low  ADStat          '  Signal  peak  detector  that  A/D
conversion is done
                pauseus 5       ' Pause for 5us
                high ClearSH     ' Clear the S/H by strobing clear line
high
                pauseus 5       ' Pause 5us
                low ClearSH     ' Return S/H to low
                low LED         ' Turn LED off
                x(adval)=x(adval)+1    ' Increase histogram bin by 1
                if x(adval)=248 then goto disp    'integrate until one
channel
                                                  'reaches 240 counts
        Endif
 GoTo loop

' Display histogram once one channel reaches a count of 240
disp:
PAUSE 1000  ' Wait for LCD to initialize.
' Send some dummy data to finish pending instructions
SEROUT2 S_PIN,N9600,[CUT0,CUT0,CUT0,CUT0,CLRLCD]
SEROUT2 S_PIN,N9600,[ESC,"I",(CUT0+PCOLOR)]
' Display each element of x() as a bar with a maximum height of 30
pixels
FOR i = 1 TO 95
  SEROUT2         S_PIN,N9600,[ESC,"L",(i+CUT0),(31+CUT0),(i+CUT0),(31-
(x(i)/8)+CUT0)]
NEXT

End
```



MCA Peak Detector
David Prutchi, Ph.D., March 2007
based on design by P.H. Lefebvre,
M. Clar, and H.P. Garnir, I.P.N.E., Liège, Belgium