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FIFTH COLLEGE ON MICROPROCESSORS: TECHNOLOGY AND APPLICATIONS IN PHYSICS

2 - 27 October 1989

Multichannel Analysers

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Multichannel analysers (MCA'S) are in general the most probable data acquisition equipment you can see inside a physics research laboratory.

Frequently they are also the most expensive and sophisticated piece of electronic equipment used by the research group.

Modern MCA'S are build around one or more microprocessors and also around DSP'S ,some are stand alone units and others are plug in boards.

By now you are suposed to be able to understand in full their architeture and hopefully, able to design simple MCA'S systems.

Let's have a look on the history of MCA's

A look on this is also a look on the evolution of electronics.

We can report this story to fifty years ago when physicists were dealing with hard functions like this one

$$Y=f(X)$$

where :

Y-intensity,number of events, etc

X-energy,wave lenth, etc

What did they do ?

They divide X into a large number o equal pieces and made tedious data acquisition runs for every piece of X.

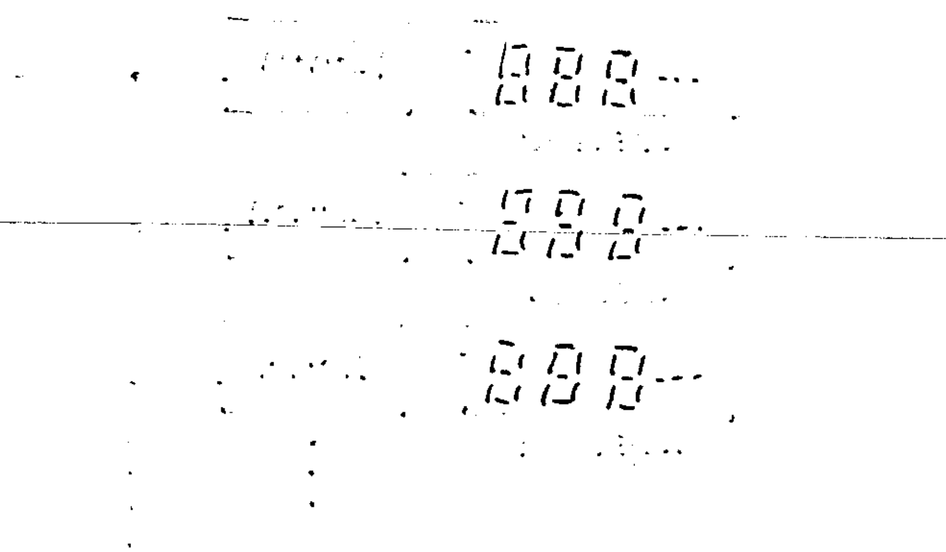
A typical example of this is the following (gama-spectroscopy)

Problems:

- Time consuming
- Boring
- Limited number of channels
- Difficult and expensive to automate
- Wastes the majority of the events

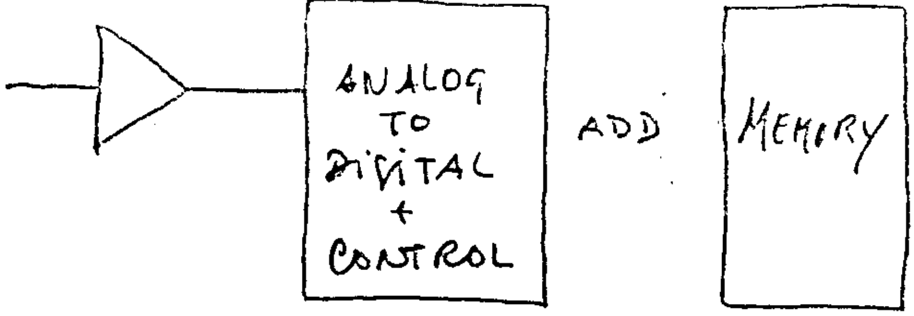
And because of the last one, it was impossible to do spectroscopy of short_lived radionuclides (mS).

To overcome this problem they used this solution:

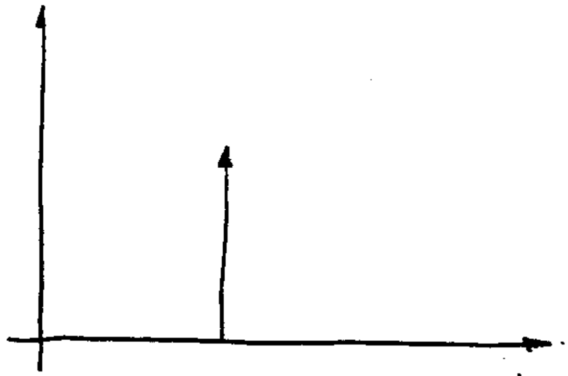


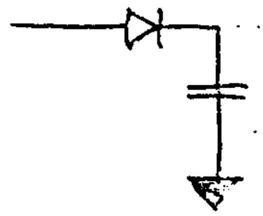
In's and out's:

- Cleary a very expensive solution, BUT
- You don't waste time and loose events
- BUT still unsatisfactory, because it was impossible to profit in full the high resolution of the semi-conductors detectors Ge(Li) and Si(Li) intro-duced by then.

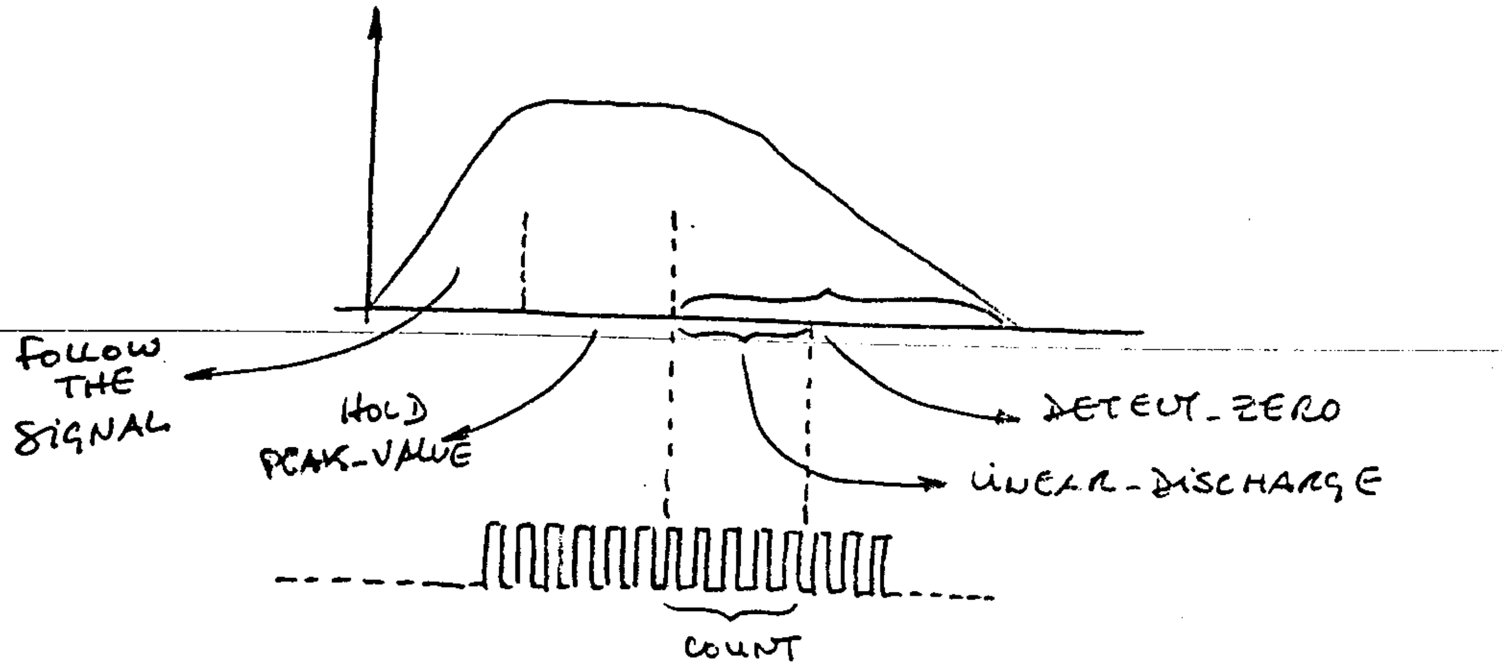


And here comes Prof. Wilkinson with a brilliant idea.





To start with we need a analog memory.



Typical frequencies: 50, 100, 450 MHz

At the and of the conversion the content of the counter is an address,so we have:

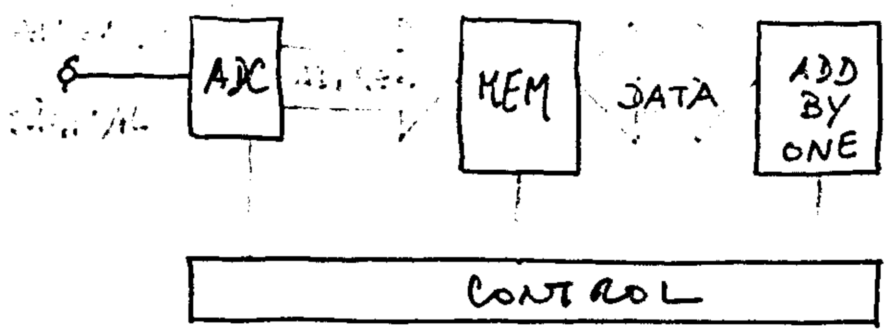
read the content of that addres
increment content by one
store this value in address

In fact Wikinson ADC's are not very fast and the time for one convertion is a function of the amplitude of the signal you are converting.

Maximum nu. of channels*clock period
Tipically 8192 * 10 nS =80 uS, plus some constant =5 to 10 uS

In general they are free of integral and differencial non linearity and by that, adequate for precise and high resolution spectroscopy.

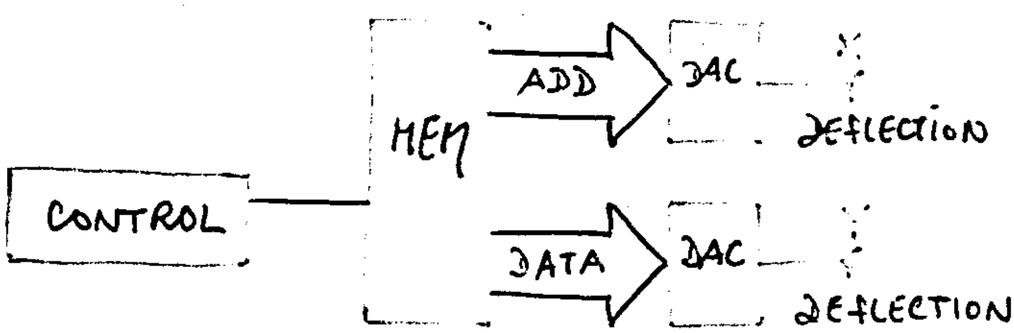
We are now at the point.



In general memory is organised in 24 bits words

- 20 bits for counting till 10
- 4 bits reserved for flags

By this time all MCA's normally provide live displays.



The live display of histograms is also an extra source of dead time to the system.

Modern MCA's use not the "oscilloscope type "display ,but the video (raster) display, here the coils are rotated 90 degrees; instead the plug in boards use the display part of the computer.

The architecture of MCA's is quit similar to the architecture of a computer.

So, why don't we use a minicomputer or a microcomputer ?

In fact it as been used with minicomputers (PDP's 8, MULTI 8, MULTI 20, HP's). But there is always a problem and the problem with minis was that the CPU could not be used during acquisition.

- Takes to long to read -increment -store 24bits words
- Difficult to have live display

The second solution adopted was to use DMA.

Brillant conclusion:

- Minicomputers based MCA's were to expensive

So, fixed _programmed (hardwired) systems were prefered.

The Microprocessors changed all this.

In fact they are cheap, easy to use, it's why they are inside MCA's.

Now a days we have a very large choise of models.

Stand alone MCA's are allways uP (one or two) based, but still dedicated add-one circuits for the control in general and of the display must be used because of time constraints, as a consequence the price is still high

8000 US$ to 50000 US$

Question?

Is it possible to build an MCA arround a personal computer?

The answer is yes and we can find some boards that can be added as plug_in boards to popular computers,that will be configurated as MCA's.

With this solution the cost effective is about a half or a third of the price of the other ones.

According with our experience they have the same perfomance of the others.

We still think that it is possible to design a MCA around a low cost computer, perfoming the same tasks.

If we have a look we see that, to start with, the computer solves a lot of problems:

- Graphs display
- Input/output
- Mass storage
- High level languages
- Programmable

But in general they have no DMA possibilities.
With our experience on MCA's it was not very difficult to implement a plug_in board the following slides try to give you the idea.

- Purpose
- General purpose interface
- Multichannel analyser

- MCA (block diagram)
- Schematics

Software:

- Windows
- or a compiled program written in Pascal

The MCA hardware is divided into two boards:

- The Main board
- Control board.

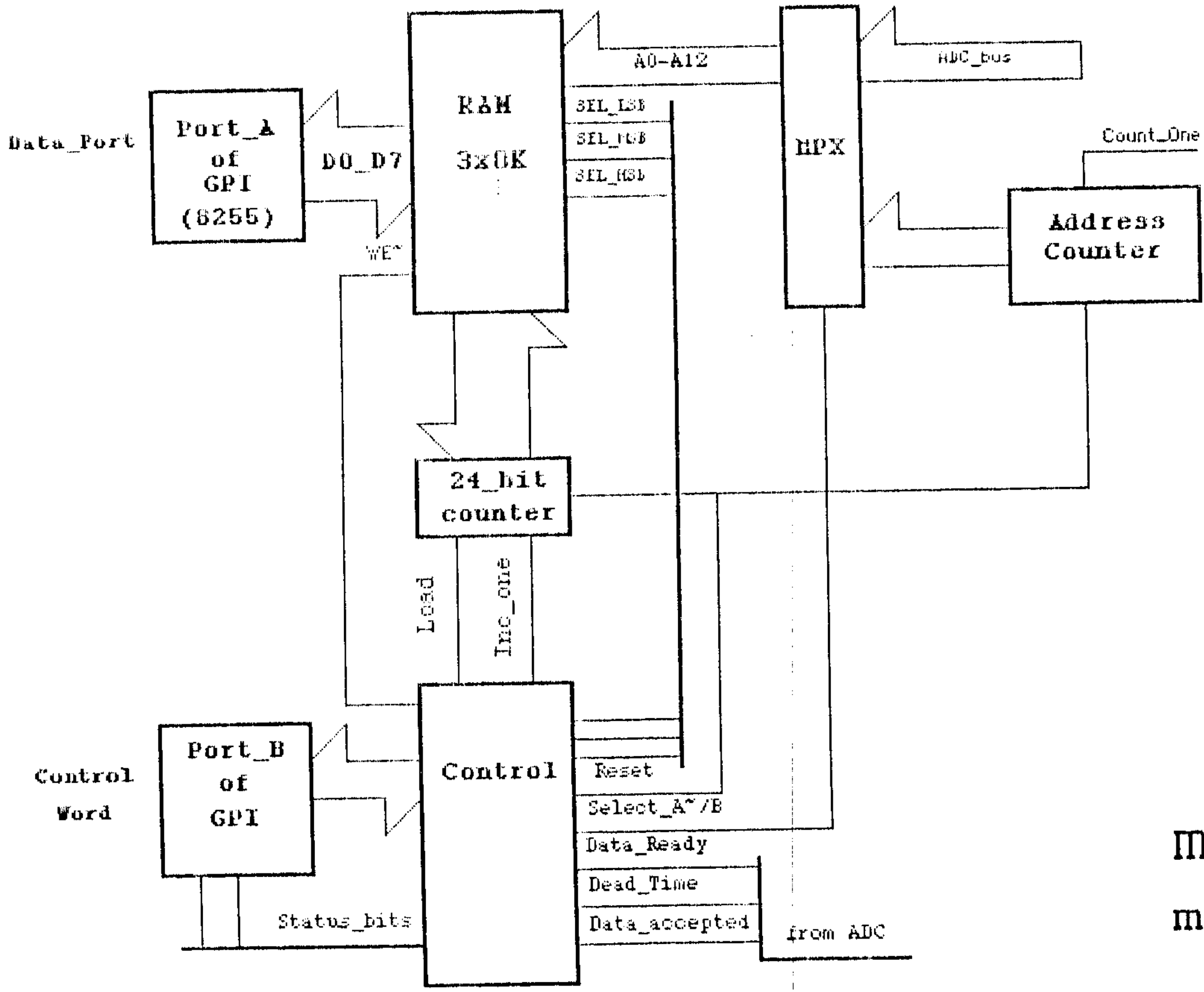
The first is a PC_XT size board witch contains memory,buffers,time counters and connectors (ADC and GPI).

The second is a piggy back board of the former and supports the logic control implemented with standard TTL family.devices.

With the piggy back option is possible to improve the control with different solutions and other logic devices.

The Main board is designed in such a way that can support also the General Purpose Interface,so it can be plugged inside the PC.

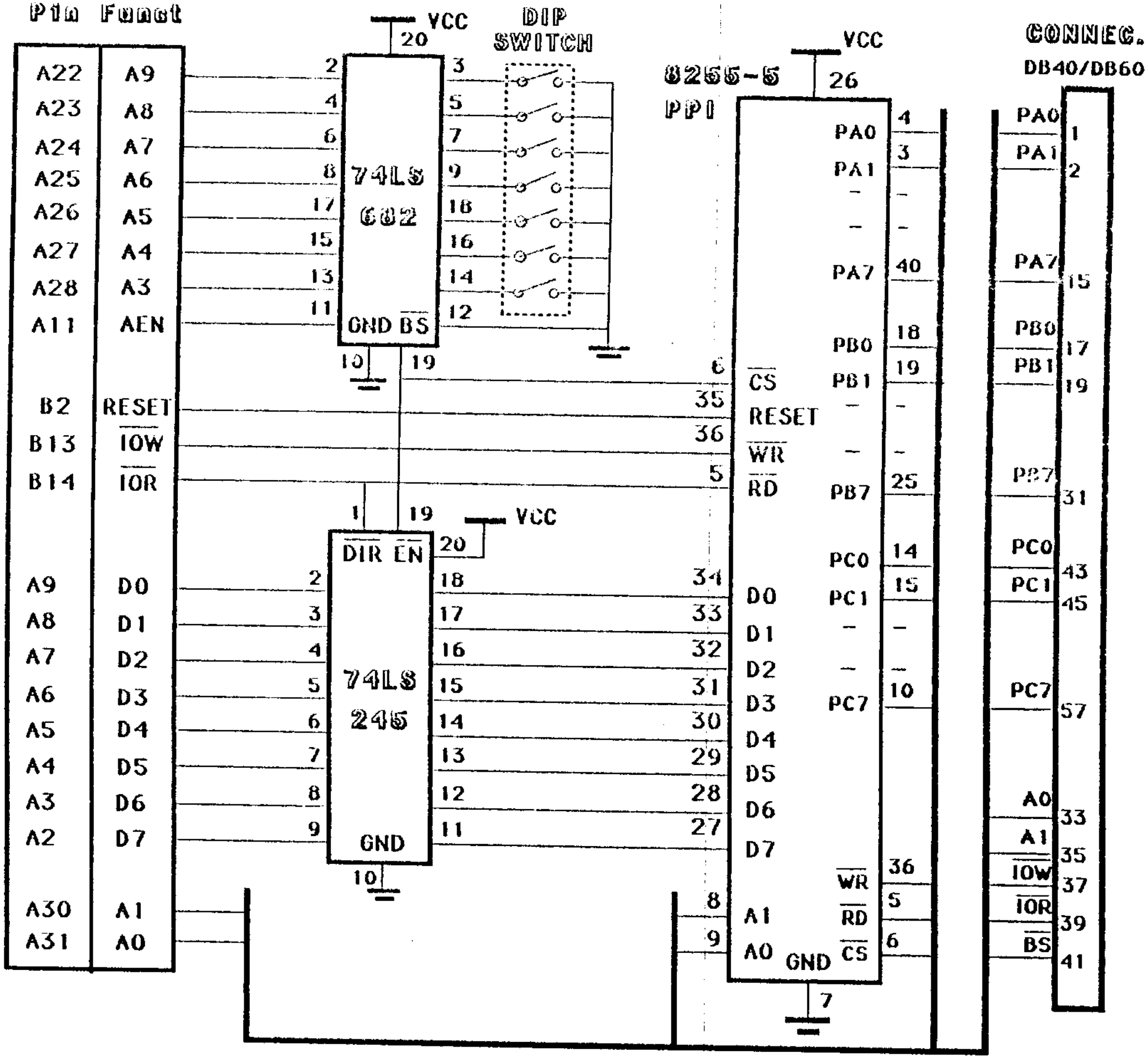
At this moment the General Purpose Interface is ready and the pcb's of the MCA are arriving to be debugged.

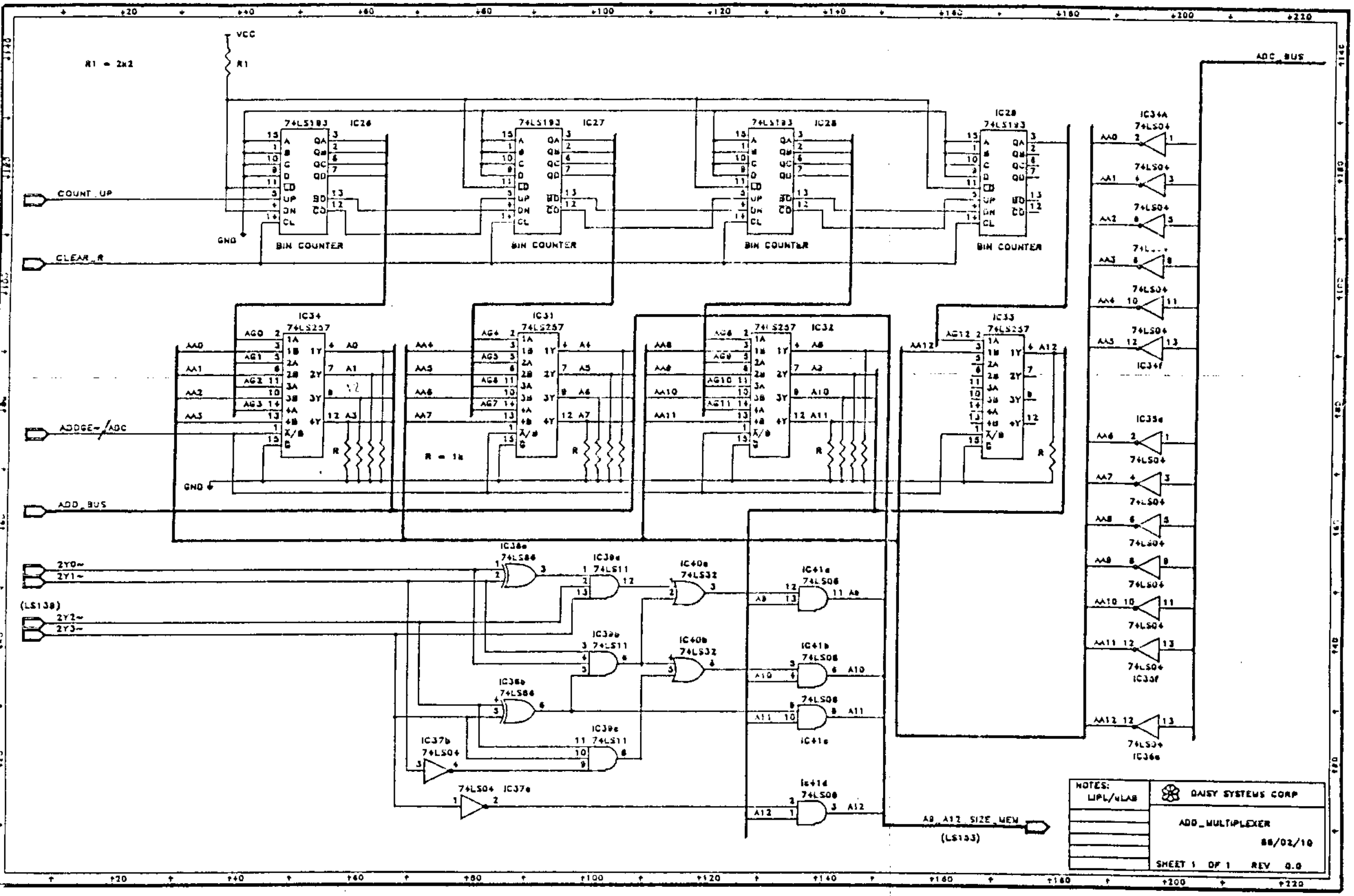


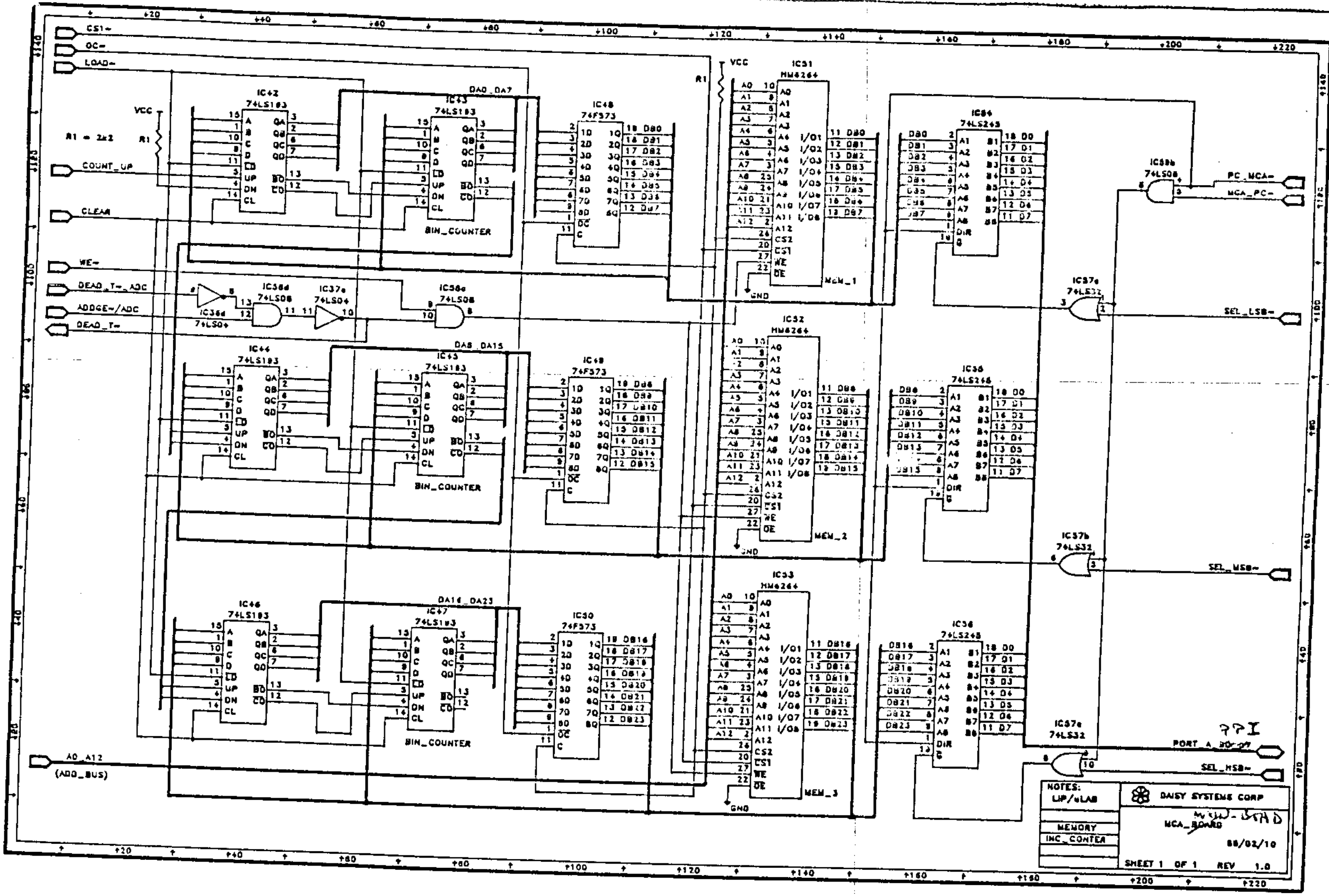
MCA (block_diagram

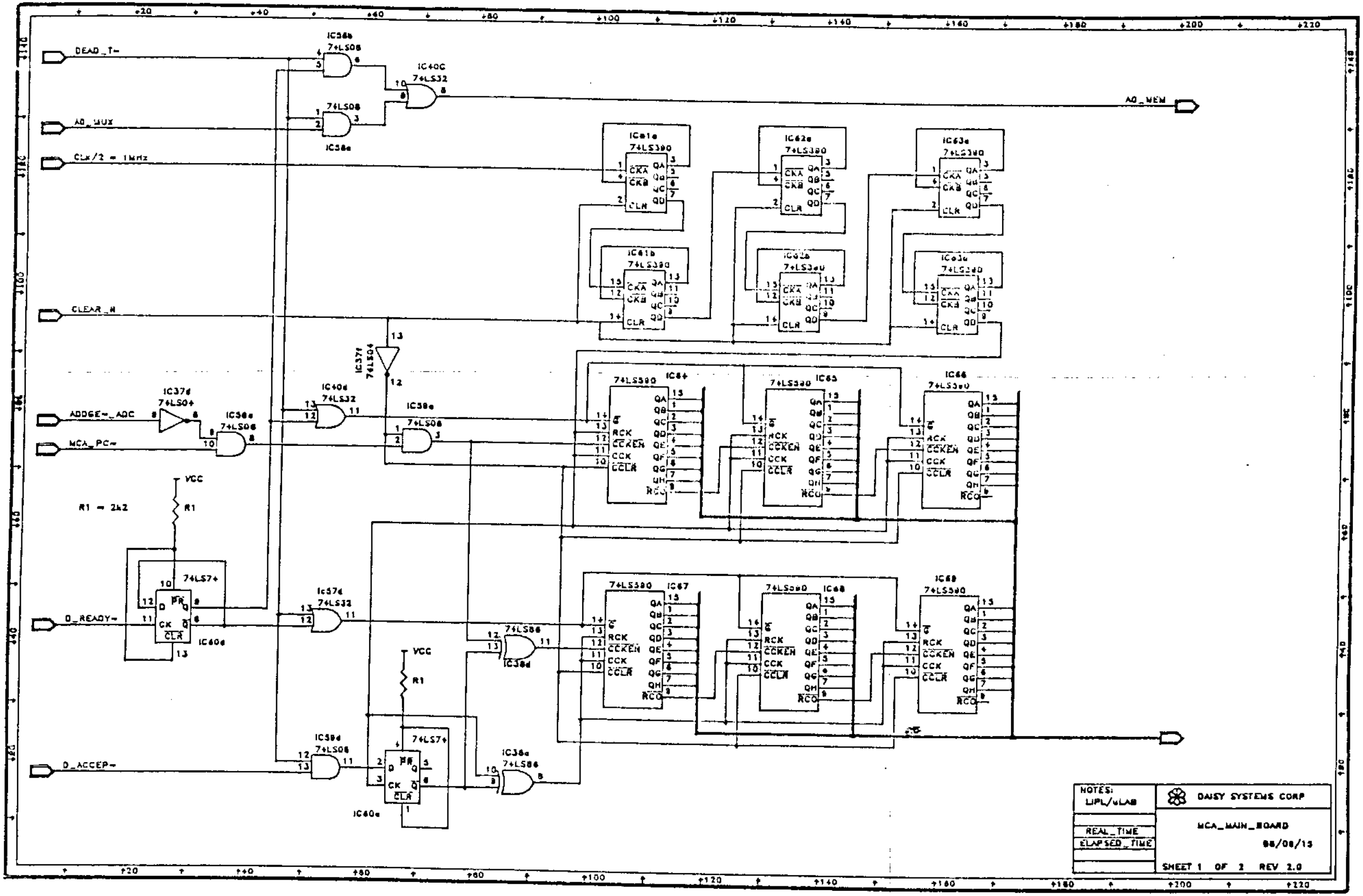
microLAB/LIPL

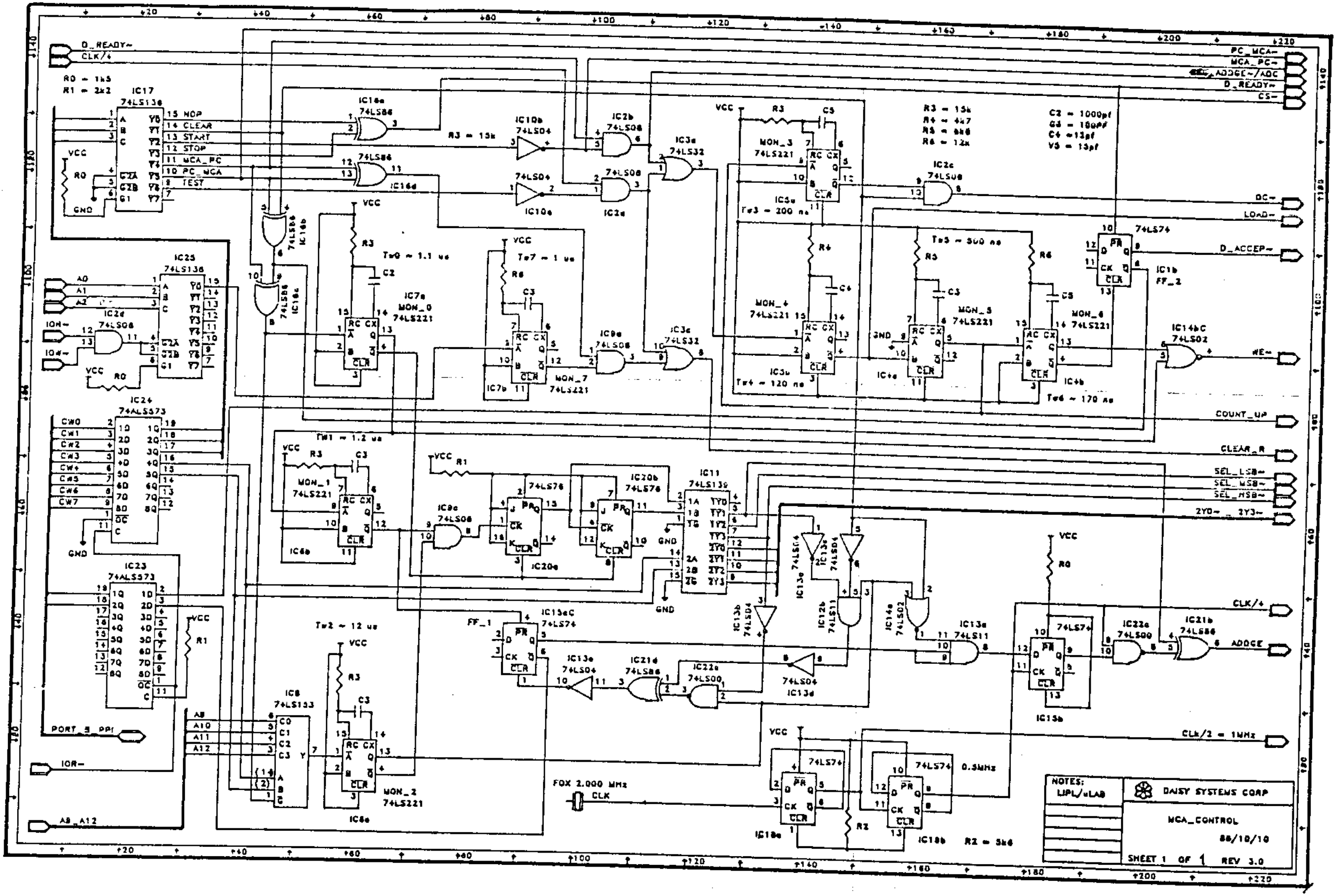
GENERAL PURPOSE INTERFACE




COUNT_UP
CLEAR_R
ADDGE~/ADC
ADD_BUS
ADC_BUS
2Y0~
2Y1~
(LS138)
2Y2~
2Y3~
VCC
R1
R1 = 2k2
GND
R = 1k
74LS193
IC26
IC27
IC28
BIN COUNTER
74LS257
IC34
IC31
IC32
IC33
74LS86
IC38a
IC38b
74LS11
IC39a
IC39b
IC39c
74LS32
IC40a
IC40b
74LS08
IC41a
IC41b
IC41c
IC41d
74LS04
IC34A
IC34f
IC35a
IC35f
IC36a
IC37a
IC37b
A8_A12_SIZE_MEM
(LS133)
NOTES:
UPL/uLAB
DAISY SYSTEMS CORP
ADD_MULTIPLEXER
88/02/10
SHEET 1 OF 1 REV 0.0


CS1~
OC~
LOAD~
COUNT_UP
CLEAR
WE~
DEAD_T~_ADC
ADDGE~/ADC
DEAD_T~
A0_A12
(ADD_BUS)
VCC
R1
R1 = 2k2
IC42
74LS193
IC43
74LS193
BIN_COUNTER
DA0_DA7
IC48
74F573
IC44
74LS193
IC45
74LS193
DA8_DA15
IC49
74F573
IC46
74LS193
IC47
74LS193
DA16_DA23
IC50
74F573
IC36d
74LS08
IC37a
74LS04
IC36a
74LS08
IC51
HM6264
MEM_1
IC52
HM6264
MEM_2
IC53
HM6264
MEM_3
GND
IC54
74LS245
IC55
74LS245
IC56
74LS245
IC58b
74LS08
IC57a
74LS32
IC57b
74LS32
IC57c
74LS32
PC_MCA~
MCA_PC~
SEL_LSB~
SEL_MSB~
PORT_A_PC-07
PPI
NOTES:
UP/uLAB
MEMORY
INC_CONTER
DAISY SYSTEMS CORP
MCA_BOARD
88/02/10
SHEET 1 OF 1
REV 1.0


DEAD_T~
AD_MUX
CLK/2 = 1MHz
CLEAR_R
ADDGE~_ADC
MCA_PC~
D_READY~
D_ACCEP~
AD_MEM
R1 = 2k2
VCC
R1
IC58b 74LS08
IC58a 74LS08
IC40C 74LS32
IC61a 74LS390
IC61b 74LS390
IC62a 74LS390
IC62b 74LS390
IC63a 74LS390
IC63b 74LS390
IC37f 74LS04
IC37d 74LS04
IC58c 74LS08
IC40d 74LS32
IC58e 74LS08
IC64 74LS590
IC65 74LS590
IC66 74LS590
IC67 74LS590
IC68 74LS590
IC69 74LS590
74LS74 IC60d
IC57d 74LS32
74LS86 IC38d
IC38a 74LS86
IC59d 74LS08
74LS74 IC60a
NOTES:
LIPL/uLAB
REAL_TIME
ELAPSED_TIME
DAISY SYSTEMS CORP
MCA_MAIN_BOARD
88/08/15
SHEET 1 OF 2 REV 2.0


NOTES:
LIPL/uLAB
DAISY SYSTEMS CORP
MCA_CONTROL
88/10/10
SHEET 1 OF 1 REV 3.0
D_READY~
CLK/4
PC_MCA~
MCA_PC~
D_READY~
CS~
DC~
LOAD~
D_ACCEP~
WE~
COUNT_UP
CLEAR_R
SEL_LSB~
SEL_MSB~
SEL_HSB~
CLK/4
ADDGE
CLK/2 = 1MHz
PORT_5_PPI
IOR~
A8_A12
FOX 2.000 MHz
CLK
R0 = 1k5
R1 = 2k2
R3 = 15k
R4 = 4k7
R5 = 6k8
R6 = 12k
C2 = 1000pf
C4 = 13pf
R2 = 5k6
0.5MHz