PROPOSAL FOR A SMALL DIGITAL COMPUTER
FOR USE IN MAGNETIC FIELD MEASUREMENTS

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I. Introduction

It is proposed that the National Accelerator Laboratory obtain (purchase or rent with purchase option) a small digital computer for use in magnetic field measurements. This note describes the data handling methods to be used in the field measurements, the data handling system of which the computer is the central part, and gives specifications for the computer and the various peripheral devices.

What we are proposing to build is a compact, portable, highly flexible and easy to use instrument that can be used initially on modeling work and prototype testing for the main ring and booster magnets. It can then be set up and programmed to rapidly perform a series of standardized tests on magnets during accelerator construction. Data obtained can be used directly in the shuffling program. In the more distant future it will find application in mapping beam transport and experimental magnets.

The general principles followed in designing and specifying the system are (1) use software whenever possible since computer speed is not a limitation (2) make the system portable so it can be brought easily to the vicinity of the magnet being measured and (3) make the system self contained so for most use recourse to an additional larger computer is unnecessary.

In planning our magnetic field measuring system we have followed some of the ideas used at Lawrence Radiation Laboratory[1] and Argonne National Laboratory[2].

The system described, exclusive of the mechanical devices for accurate probe positioning would cost $30-50K or $1000-1500/month rental. A very preliminary breakdown is shown in Table I.

II. Data Handling Methods

The process of going from a series of probe measurements to a graph in a notebook should be as direct and rapid as possible consistent with the required accuracy. In our system we divide the process into two stages: data collection and data reduction. Each stage is made as flexible as possible and has provisions for future expansion. Both stages are handled by the same computer. Fig. 1 is a block diagram of the proposed system.

A. Data Collection The efficient way to collect data on pulsed magnets is to keep the probe position fixed while gathering data on a series of excitations and then move the probe to a new position or orientation. In a DC powered magnet it will be simpler to move the probe while maintaining constant current, but the mode of operation to be described does not exclude this possibility. The movable probe might initially consist of 1 - 2 integrating coils or Hall plates[3] but provision will be made to expand to 10 sensors. An additional signal derived from magnet current (shunt) or B (loop around the back leg) will be used to

decide when to take data.

To start with we will have a long coil for $\int$Bdl measurements and end plate design of the B2 magnet, and two point measurement coils to study variations in field in the interior of the B2 magnet for various crenollation patterns and various types of steel. The long coil will have 10 turns and measure 40 cm. by 1 cm. giving a maximum 10 volt signal in the interior of the magnet, and the point measurement coil will have 200 turns and be 0.5 cm. in diameter.[4]

After these initial simple coils, Laslett type coils[5] will be built and pairs of them can be hooked up so the difference is integrated directly to measure gradients or small variations from a central value.

Current and field values will be sampled simultaneously into separate Hold circuits. A multiplexor would then switch each S-H to an analog to digital converter. 14 bits + sign would give a least count of $1/1.6 \times 10^4$ which we believe is adequate. This fixes the convenient word length of the computer at ≥ 16 bits.

Integrator drift can be measured by the system between pulses and the computer will make the necessary corrections and also apply any other calibration factors needed. If Hall probes are used it may be possible to use a simple uncompensated probe and monitor the Hall voltage and temperature simultaneously and then do the calibration in the computer.

In making a field map it is essential that the same current values be measured at each probe position. The following method will insure this. At the beginning of a run a few current values where field plots are needed are fed in on the computer typewriter or other I/O device. The system will sample current and field values at time intervals set by the total system: S-H, multiplex, A to D, and compute time. For sake of discussion let's assume that a set of data comes in every 500 μsec. Only the present and previous sets are stored. When the current value passes one of the initially preset values of current the present and previous set of data are saved for later linear interpolation. An example of a program to do this is shown in Fig. 2. The error from linear inter- polation using magnet current can be kept smaller than 1 gauss if the system speed is 22.5 msec[6]. (There would be even less error if the back leg, B_o, monitoring is used.)

Thus it can be seen that computer speed is not a critical factor. The A to D, however, cannot be too slow because of drift in the sample and hold circuits. If we assume an expanded system of 10 S-H's, then the 10th S-H circuit must drift less than $1/1.6 \times 10^4$ in the time it takes to multiplex and A to D 10 times. This criterion is sufficient to specify a S-H and A to D system.

Digital stepping motors will move the probe between magnet pulses according to a program initially fed in on the computer typewriter.
Much more relevant for exp. magnets then for synchrotron magnets.

B. Data Storage

Data storage will take place between magnet pulses. Future expansion might have as many as 10 sensors sampled at 10 different times during the pulse. Thus 200 16 bit words every 5 seconds must be written on the tape. To allow for the potentially higher data rate in measuring booster magnets and identification words and calibration data we assume 1500 bits/sec. If the information is written on standard 7 track 200 bpi tape, the tape transport must move tape at about 1-1/2"/second which is quite slow.

A scan system slows work but it is fast enuf.

Although the tape speed requirement is minimal we want to write standard 7 or 9 track tapes. The system is designed so that recourse to a large computer will normally not be needed; however, occasions may arise when a more sophisticated treatment of the data is desirable, e. g. data smoothing using high order polynomial fitting. Tapes compatible with a large computer will facilitate such work.

Using a magnetic tape system and the two phase operation described reduces the computer memory requirement. It is true there are alternate and cheaper ways to realize this end. However, the magnetic tape is a key feature in the measurement philosophy. By having a tape, a library of data can be built up and referred to at any later date. It is quite likely that several weeks after a field map was taken one might want to display it in a new way or extract a new graph from it. This will be a trivial matter given the library and the software package in the data reduction phase.

C. Data Reduction

The computer will search the tape for required data, do necessary interpolations, and calibrations, and produce graphs with an on-line X-Y plotter. (Lists of numbers can also be produced using the teletype.) For this operation to be effective we will need to develop an easy to use software package through which the operator of the system can specify his desires on the typewriter and/or through sense switches.

A partial list of options might be

1. Excitation curve

2. Field plot vs. x,y, or z.

3. $\int$ Bdl vs. position

4. Field gradient, or field index vs. position

5. Deviations of field from value at some fixed position

6. Harmonic content of field

7. Contour plot

8. Specification of scale including displaced zero

 in any of the graphs.

Clearly more than one program will be needed to handle all these possibilities. Each program or group of programs would be on a reel of paper tape (or DECtape if a DEC computer is chosen) to be loaded in by the operator. In a future expansion of the computer including adding memory, it might be possible to link these programs together into a single data reduction program.

The data reduction phase places much more severe demands on the computational ability than the data collection phase. We feel a 4096 word computer is a minimal but adequate size with which to operate. Data collection can be done with a very slow machine but for efficient data reduction we should have a basic cycle time of $\leq 2 \mu$sec and hardware multiply/divide.

Table II summarizes the features of some proposed systems obtained in informal discussions with representatives of computer companies. Much more detailed and complete data will be compiled from the written replies to the request for quotation described in IV.

III. Secondary Uses

The primary use and main justification of the computer and its accompanying peripheral equipment have been described above.

A permeameter can easily be attached to the computer to automatize iron sample evaluations.

The multiplexor and A to D system can easily monitor slowly varying analog signals such as can be derived from magnet temperature and water flow in the magnet under test. Such application could lead to preliminary studies on data logging for the main ring control system. Since the system will initially be in the inflatable building where there will also be a model vacuum system ion pump currents can be monitored, and displayed.

Since the computer will have a Fortran compiler it probably will find some limited use for ordinary computations.

IV. Specifications and Request for Quotation.

The National Accelerator Laboratory asks computer manufacturers
to make proposals of computer systems which they will have available by
the summer of this year and which they consider could meet in whole or in
part, the computing needs described. It should be clearly understood
that this request is not to be taken as binding upon the Laboratory to
order any computer proposed, or upon the manufacturers to supply such
systems as may be described at the prices or within the delivery delays
quoted. ‹ The purpose of this request is solely to allow the Laboratory
to make contact with the manufacturers of suitable equipment and to be
informed of the available systems.

The National Accelerator Laboratory is a non-profit research
organization administered by the Universities Research Association, a
group of major U. S. universities. We expect manufacturers to allow
appropriate discounts in their quotation.

In this section we repeat many of the points made above but organize
them in a manner suitable for quotation.

The manufacturer is requested to make his information available on
a comparable basis with respect to the items listed below.

MINIMUM REQUIREMENTS

1. CENTRAL COMPUTER   The computer shall be a stored
     program, general purpose digital computer of modern
     design, constructed entirely with solid-state electronics,
     mainly of silicon monolithic, integrated logic circuits.

2. MINIMUM HARDWARE REQUIREMENTS   A directly addressable fast memory of 4096 words of $\gtrsim 16$ bit length, $\lesssim 2\,\mu$sec storage cycle time, 1 interrupt, 1 index register, hardware multiply and divide circuitry.

The computer should be equipped with a minimal input output device such as an ASR-33   teletype.

The central computer system must operate fully and properly at a performance level of 90% or more during a minimum period of 50 hours used as a basis for computation of the performance level.

3. DATA COLLECTION INTERFACE   This consists of 32 digital inputs, 32 digital outputs (16 pulse and 16 register outputs) and one 16-channel A/D conversion system.   Digital input/output levels and the time duration of the 16 pulse outputs can be anything compatible with the computer.   The A/D system, included 4 S/H amplifier, 16-channel multiplexor and 14-binary bit + sign A to D converter, should be expandable to 10 S/H amplifiers and 128-channel multiplexor.   Differential ended analog input system is required.   This A/D system must be maintained an overall accuracy to a 14-bit resolution after the expansion, e.g. sample and hold 10 channels simultaneously and digitize them in sequence.

4. DATA STORAGE   1 magnetic tape unit, including interface to computer, capable of writing and reading 200 bpi standard 7 or 9 IBM compatible tapes at tape speed $\gtrsim 10$ inches/sec (556 or 800 bpi density is acceptable with a corresponding decrease in speed required).   Rewind speed should be at least as fast as forward speed and a backspace record instruction available.   The tape

system shall be capable of operating with less than 1 error in 6×10^7 bits read or written during at least one hour of operation to establish this performance level. This speed requirement will not be a limitation with most available tape units.

5. DATA REDUCTION INTERFACE   X-Y plotter with remote pen up-down control capability and with pen speed of at least 3 inch/sec to handle standard K-E 8-1/2 x 11" graph paper including interface to the computer.

ENVIRONMENTAL AND PHYSCIAL REQUIREMENTS

1. POWER LINE   The system shall operate on 120 V, 1ϕ AC or 220 V, 3ϕ AC. The system shall be capable of operating satisfactorily given fluctuations in line voltage of ± 10% and frequency of 60 ± 1 cycles. In addition the system shall operate given the distortion of the normal power line sine wave by the magnet pulsed power supply which will be operating simultaneously with the data collection. A sketch of the wave form is shown in Fig. 3. If the computer manufacturer anticipates difficulties from this line voltage distortion he should include remedial measures such as a voltage regulating transformer or small motor-generator set in his proposal.

2. ENVIRONMENT   The system will be used initially in an inflatable air building in the village of Weston. It is expected that the temperature in this building might range

from 50° F. to 100° F. and relative humidity 10-95%.

The system must operate satisfactorily over this range.

If the manufacturer anticipates difficulties with these

requirements we suggest he include in his proposal remedial

measures such as mounting a small air conditioning unit

in one of the relay racks.

3. SENSITIVITY TO MAGNETIC FIELDS   The magnets under

   test will produce stray magnetic fields which could cause

   difficulties if the computer is too close to the magnet.

   We request the manufacturer to state what is the tolerable

   magnetic field and if as option he can supply factory in-

   stalled magnetic shielding around the core memory.

4. PHYSICAL SIZE AND WEIGHT   We would like the complete

   system described above including data collection interface,

   magnetic tape drive, on-line plotter, and I/O teletype and

   any special features needed such as power isolation equipment

   and air conditioning to fit in 2-3 relay racks.   These should

   be bolted together and surrounded by a heavy protective frame

   with casters and a crane hook.   The teletype and plotter can

   be mounted on a desk type protrusion.   The whole system

   should pass through a 34" by 76" door and a single person

   should be capable of pushing it around on a concrete floor.

   (In moving it through a door the desk can be folded up and

   the plotter and teletype carried separately.)

MINIMUM SOFTWARE REQUIREMENTS

The following software would be expected to be delivered with the system.

1. An assembly program for symbolic machine language.

2. A Fortran compiler

3. Diagnostic Programs

FURTHER DESIRABLE HARDWARE FEATURES

1. Boolean hardware instructions

2. Real time clock

3. Sense switches

4. Provision for a cathode ray oscilloscope display

5. Transverse parity checking in tape reading and writing.

FURTHER DESIRABLE SOFTWARE FEATURES

1. Programs to operate the X-Y plotter and the magnetic tape system.

2. A system for debugging assembly or Fortran programs.

3. Double precision arithmetic subroutines.

FUTURE EXPANSION

In order to provide for future expansion we are interested in learning if the following additions and changes are possible and if they can be done in the field.

1. Expansion of memory to 8K or 16K.

2. Addition of more S-H circuits up to a maximum of 1C.

3. Change teletype for Selectric typewriter and photo-

electric paper tape reader.

4. Addition of low cost, completely redundant tape system

(like DECtape) to replace paper tape.

5. Change teletype for line printer and card reader/punch.

QUOTATION

On each of the items described we would like to know separately prices

for purchase, rental with purchase option, yearly cost of maintenance contract,

delivery time, transportation and installation charges.

We would like the quotation to list separately the computer itself,

the input/output teletype, the sample and hold circuits, the multiplexor,

the A to D converter, the magnetic tape transport, the X-Y plotter, the

interfaces for the above peripheral equipment, and any special additions

such as mentioned under environmental requirements.

ADDITIONAL QUESTIONS

1. On each item quoted we also would like to know if the

manufacturer produces the item himself or if it is obtained

from another company.

2. Is 1 or 2's complement arithmetic used?

3. Are the same circuit boards used in any proposed interfaces

as are used in the computer itself?

4. What training courses will be provided for programming and

maintenance?

5. What program testing facilities on a similar computer will

    be available to the Laboratory before installation of a

    computer at the Laboratory?

6. What will be the conditions of a proposed maintenance

    contract (number of hours per day on call service, distance

    to nearest field office)?

7. What logic levels are used in the computer and the interfaces?

8. What are the detail specifications of the data collection interface?
    Please specify them separately.

REFERENCES

1. P. G. Watson and R. F. DiGregorio, Lawrence Radiation Laboratory, Techniques of Magnetic Field Measurement, Proceedings of the International Symposium on Magnet Technology 1965, p. 393, Stanford Linear Accelerator Center, Stanford University.

2. E. C. Berrill and R. S. Odwazny, Argonne National Laboratory, The Use of a High Speed Data Acquisition System in Measuring Large Volume Magnets at the Zero Gradient Synchrotron, Proceedings of the International Symposium on Magnet Technology 1967, p. 675, Stanford Linear Accelerator Center, Stanford University.

3. J. R. Mulady, William M. Brobeck & Associates, Berkeley, California, Precision Magnetic Field Measurements with Hall-Effect Probes, Proceedings of the International Symposium on Magnet Technology 1965, p. 447, Stanford Linear Accelerator Center, Stanford University. This system uses a temperature compensated probe. We propose to replace the hardware circuit with software correction in the computer.

4. We assume $B_{max.}$ = 20,000 gauss and
          a) Long coil
              RC (Time constant) = 3 msec.
              area in the max. B = 15 cm^2
          b) Point measuring coils
              RC = 1 msec.

5. L. J. Laslett, Some Aspects of Search Coil Design, Brookhaven National Laboratory, Associated Universities Inc. June 1954.

6. Assumptions made are

$$\frac{dB}{dI}\Bigg]_{I=0} = 2 \frac{dB}{dI}\Bigg]_{I=I_o}$$

$$\frac{dB}{dt} = \frac{22500}{1500} = 15 \text{ guass/ms.} = \text{constant}$$

where I, current

         B, magnetic field

         t, time

         I_o = 8000 A

         B_o = 22500 gauss

If we take the case of B going from the ramp to the flat top then t min. = 267 μsec. However if measurements are needed in this special case, it can be taken care of either by programming or special circuitry.
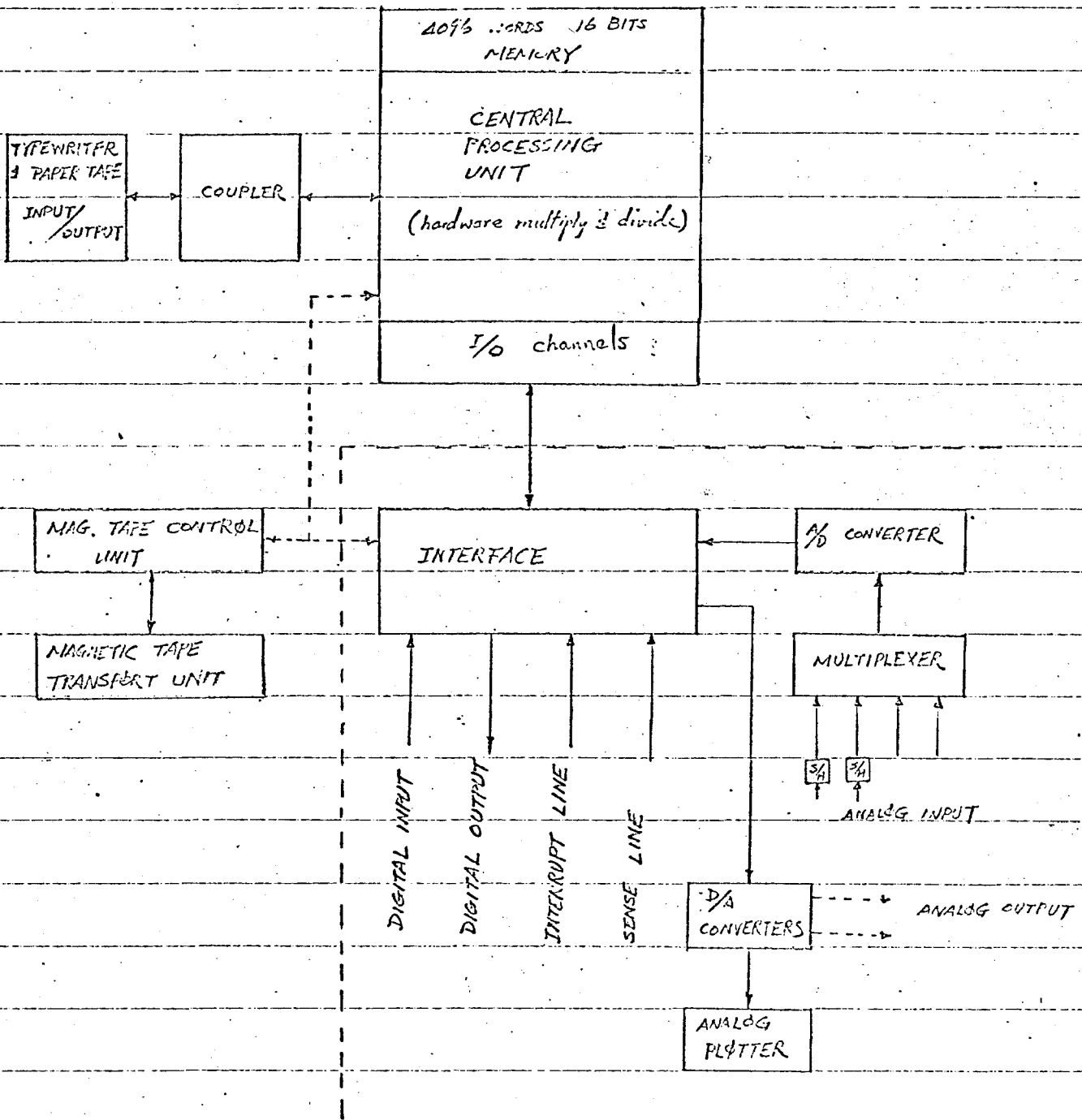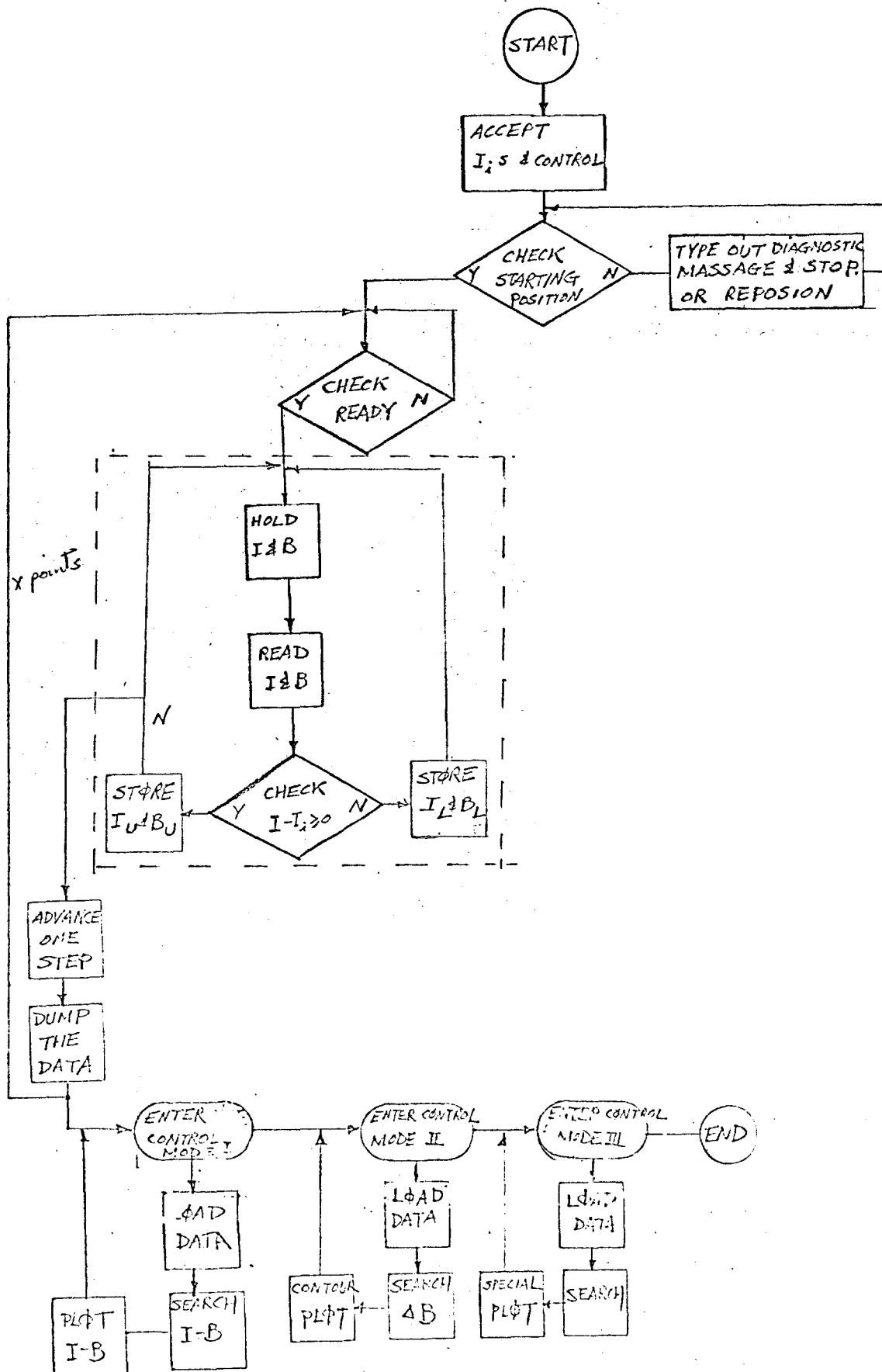
FIG. 1

BLOCK DIAGRAM OF THE MAGNETIC FIELD MEASURING SYSTEM

FIG. 2. EXAMPLE OF THE SOFTWARE BLOCK DIAGRAM

Sample program for SEL810A computer covers the dotted line

portion of the block diagram.

Assumptions are as following:

1) The total number of currents N is stored in "NCUR"

2) Desired currents are stored in "CON", ----,"CON + N".

3) The shunt calibiation has already been done separately.

4) The results are stored in location blocks

"UI",---,"UI + N"	I + ΔI values
"LI",---,"LI + N"	I - ΔI values
"UB",---,"UB + N"	B + ΔB values
"LB",---,"LB + N"	B - ΔB values

|				
	LAA	NCUR		2
	NEG			1
	TAB		Set Index to NCUR	1
L$\phi\phi$P	IBS			1
	BRU	SUB		1
	LϕB	ϕUT	ϕUT	2
SUB	CEU	18, W		3
	DATA	'2001	S/H Circuit Triggered	
	CEU	18, W		3
	DATA	'2002	Selected I Channel	
	CEU	18, W		3
	DATA	'2003	Start A/D Converter	
	AIP	19, W	Current intϕ A Reg.	3
	CEU	18, W		3
	DATA	'2004	Selected B Channel	
	CEU	18, W		3
	DATA	'2003	Start A/D Converter	
	MIP	18, W		3
	DAC	TEMP	B Intϕ Temp	
	CMA	CϕN, 1	Search fϕr Proper I	3
	NϕP			1
	BRU	LϕC	Lϕwer Limit	1
	STA	UI, 1	Upper Limit	2
	LAA	TEMP		2
	STA	UB, 1		2
	BRU	L$\phi\phi$P	Return	1
LϕC	STA	LI, 1		2
	LAA	TEMP		2
	STA	LB, 1		2
	BRU	SUB		1

Total   33 cycles

or 66 μs + 2 A/D conversion time
per short loop

FULL RECTIFY

PHASED BACK

IMPACT
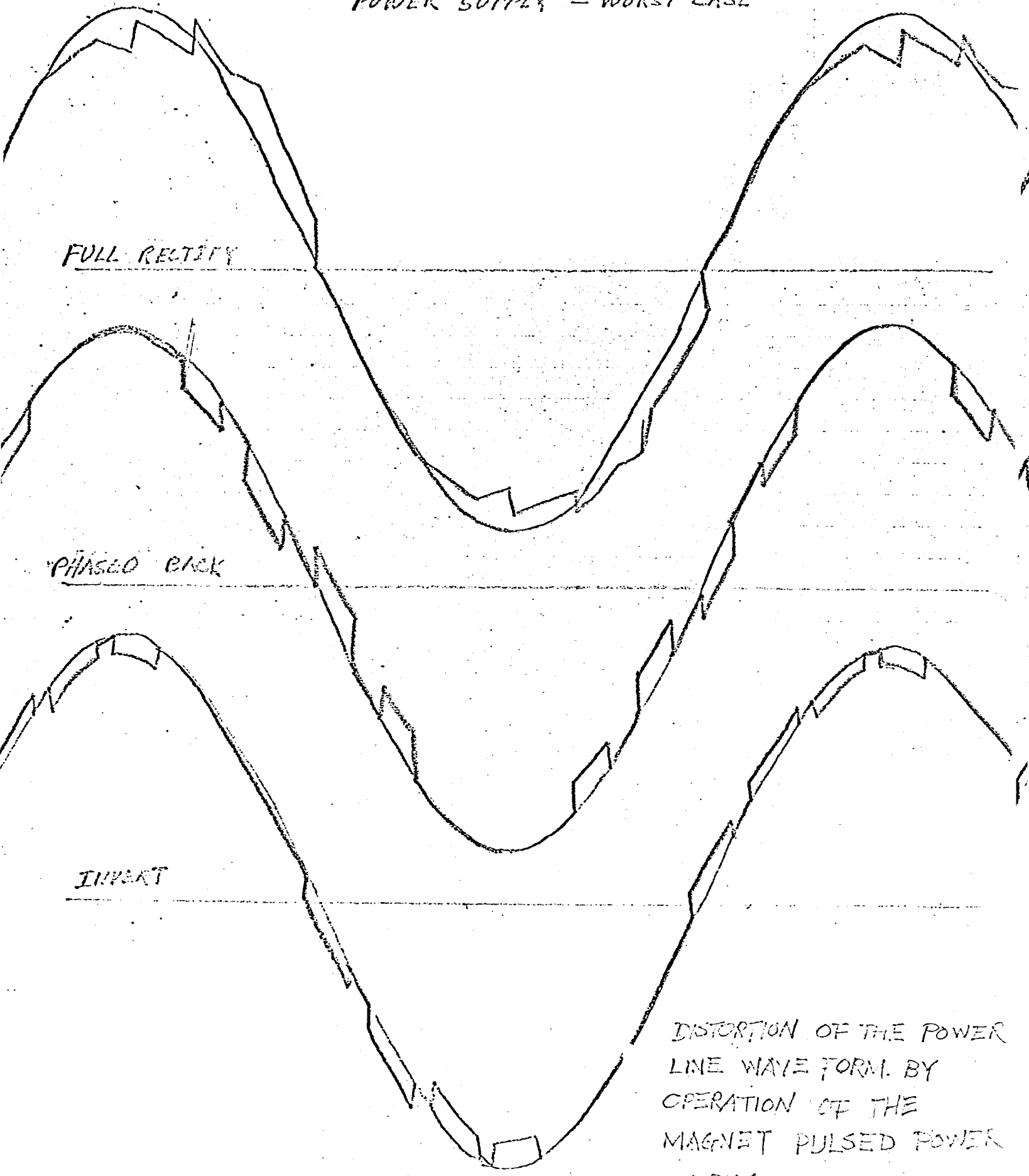
DISTORTION OF THE POWER
LINE WAVE FORM. BY
OPERATION OF THE
MAGNET PULSED POWER
SUPPLY

FIG. 3

TABLE I: APPROXIMATE COST OF THE SYSTEM

Computer	$ 16,000.
Teletype with paper tape I/O	2,000.
Magnetic tape unit	10,000.
A/D System - Include:	
16 Channel Multilexer &	
4 S/H Amplifier	8,000.
Analog Plotter	2,000.
Digital inputs and outputs	2,000.

TOTAL $ 40,000.

TABLE II: PRELIMINARY TABLULATION OF FEATURES OF COMPUTERS BEING CONSIDERED FOR MAGNETIC FIELD MEASUREMENTS.

MODELS	SEL 810A	Varian Data 620I	HP 2116A
Word Size (bits)	16	16	16
Direct Addressable Memory Size (words)			
a. Basic Size	4096	4096	4096
b. Maximum Size	32768	32768	32768
Memory Parity	no	no	no
Memory Protect	no	no	last 64 location
Storage Cycle Time (μs)	1.75	1.8	1.6
Store Time (μs)	3.5	3.6	3.2
Add Time (μs)	3.5	3.6	3.2
*Multiply Time (μs)	7	18	19.2
*Divide Time (μs)	10.5	18~25	21
Number of Instructions in Hardware	53	107	70
Number of Accumulators	1	1	2
Number of Index Registers		1	0
Registers Displayed	5	1 x 5	5
Peripheral Device Included	ASR 33	ASR 33	ASR 33
AC Power Supply	115^v±10% 60 cps±1%	115^v±10% 60±2 cps	115^v±10% 50~60 cps
Power Consumption (w)	1200	340	1600
Power Fail Safe & Interrupt	yes	no	no
Number of Interrupts			
a. Basic	2	0	0
b. Maximum	256	64	55
c. Programmable	yes	yes	yes
d. Minimum Service Time (μs)		3.6	4.2
Environment			
a. Temperature	50~90°F	0~45°C	0~55°C
b. Humidity	10~95%	10~90%	10~95%
Logic Level	0, +3.5^v	0, +3.5^v	0, +3.5^v
Physical Size (L" x W" x H")	26 x 23¼ x 62	15 x 19 x 10½	18⅜ x 16¾ x 31½
Weight (lb.)	300	70	230
Cost	18,000	16,400	25,000

MODELS	HP 2115A	SDS Sigma 2	DDP 516
Word Size (bits)	16	16	16
Direct Addressable Memory Size (words)			
a. Basic Size	4096	4096 (8K)	4096
b. Maximum Size	8192	65536	32768
Memory Parity	no	no	yes
Memory Protect	no	no	yes
Storage Cycle Time (µs)	2.0	0.9	0.96
Store Time (µs)	4.0	2.25	1.92
Add Time (µs)	4.0	2.25	1.92
*Multiply Time (µs)	24.0	10.35	5.28
*Divide Time (µs)	26.0	10.80	10.56
Number of Instructions in Hardware	70	42	72
Number of Accumulators	2	2	2
Number of Index Registers	0	2	1
Registers Displayed	5	1 × 9	1 × 4
Peripheral Device Included	ASR-33	ASR 35 & PAPER TAPE I/O	ASR 33
AC Power Supply	115ᵛ±10% 50~60 cps	3∅ 208ᵛ±10% 45~65 cps	115ᵛ±10% 60±2 cps
Power Consumption (w)	1600	1300 W	1000 W
Power Fail Safe & Interrupt	no	no	yes
Number of Interrupts			
a. Basic	0	0	1
b. Maximum	40	144	48
c. Programmable	yes	yes	yes
d. Minimum Service Time (µs)	5.2	4	2.88
Environment			
a. Temperature	10~40°C	40~125°F	0~45°C
b. Humidity	10~95%	10~90%	
Logic Level		0, +4ᵛ	0, +6ᵛ
Physical Size (L" x W" x H")	18⅜ × 16¾ × 22¾	30 × 30 × 62	24 × 24 × 38
Weight (lb.)	165	500	250
Cost	16,500	42,000	28,500

MODELS	DDP416	CDC1700	IBM1800
Word Size (bits)	16	16	16
Direct Addressable Memory Size (words)			
a. Basic Size	4096	4096	4096
b. Maximum Size	16384		
Memory Parity		yes	yes
Memory Protect		yes	yes
Storage Cycle Time (μs)	0.96	1.1	2
Store Time (μs)	1.92	2.2	4.5
Add Time (μs)	1.92	2.2	4.5
*Multiply Time (μs)	292 (s)	7	15.25
*Divide Time (μs)	336 (s)	9	42.75
Number of Instructions in Hardware	40		
Number of Accumulators	2	1	2+ extend
Number of Index Registers	0	1	3
Registers Displayed		1 × 5	4 × 5, 1 × 10
Peripheral Device Included	ASR 33	KSR 35 with paper I/o	Selectric T/W paper I/o
AC Power Supply		3φ 208V ±10% 60 cps	3φ 208 or 230 +10V -8% 60±½ cps
Power Consumption (w)		2000 VA	5200 VA
Power Fail Safe & Interrupt		yes	no
Number of Interrupts			
a. Basic	1	2	12
b. Maximum	48		
c. Programmable	yes		
d. Minimum Service Time (μs)	2.88		
Environment			
a. Temperature		40~120°F	40~120°F
b. Humidity			10~95%
Logic Level			0, +3V
Physical Size (L" x W" x H")		73¾ ×26×41¼	33×62×76.5
Weight (lb.)		850	2000
Cost	16,900	35,300	75,600

MODELS	IBM 1130	EAI 640	INTERDATA MODEL 4
Word Size (bits)		16	16
Direct Addressable Memory Size (words)			
a. Basic Size		4096	4 K bytes
b. Maximum Size		32768	65K bytes
Memory Parity		no	no
Memory Protect			
Storage Cycle Time (μs)		1.65	1.5
Store Time (μs)		3.3	3.9
Add Time (μs)		3.3	3.9
*Multiply Time (μs)		18.15	25
*Divide Time (μs)		18.97	32
Number of Instructions in Hardware		62	70
Number of Accumulators			
Number of Index Registers			15
Registers Displayed			
Peripheral Device Included			ASR 33
AC Power Supply			
Power Consumption (w)			300
Power Fail Safe & Interrupt			
Number of Interrupts			
a. Basic			1
b. Maximum			256
c. Programmable			yes
d. Minimum Service Time (μs)			12
Environment			
a. Temperature			
b. Humidity			
Logic Level			
Physical Size (L" x W" x H")			
Weight (lb.)			
Cost			

MODELS	INTERDATA MODEL 3	REDCOR 685	
Word Size (bits)	16		
Direct Addressable Memory Size (words)			
a. Basic Size	4K bytes		
b. Maximum Size	65K bytes		
Memory Parity	no		
Memory Protect		SEE VARIAN 620 I	
Storage Cycle Time (µs)	1.8		
Store Time (µs)	34		
Add Time (µs)	34		
*Multiply Time (µs)	150		
*Divide Time (µs)	200		
Number of Instructions in Hardware	70		
Number of Accumulators			
Number of Index Registers	15		
Registers Displayed			
Peripheral Device Included	ASR 33		
AC Power Supply			
Power Consumption (w)	300		
Power Fail Safe & Interrupt			
Number of Interrupts			
a. Basic	1		
b. Maximum	256		
c. Programmable	yes		
d. Minimum Service Time (µs)	120		
Environment			
a. Temperature			
b. Humidity			
Logic Level			
Physical Size (L" x W" x H")			
Weight (lb.)			
Cost			