Title

GENERAL PURPOSE DATA ACQUISITION SYSTEM - STATUS REPORT 1. TEST OF QUADRUPOLE SYSTEM

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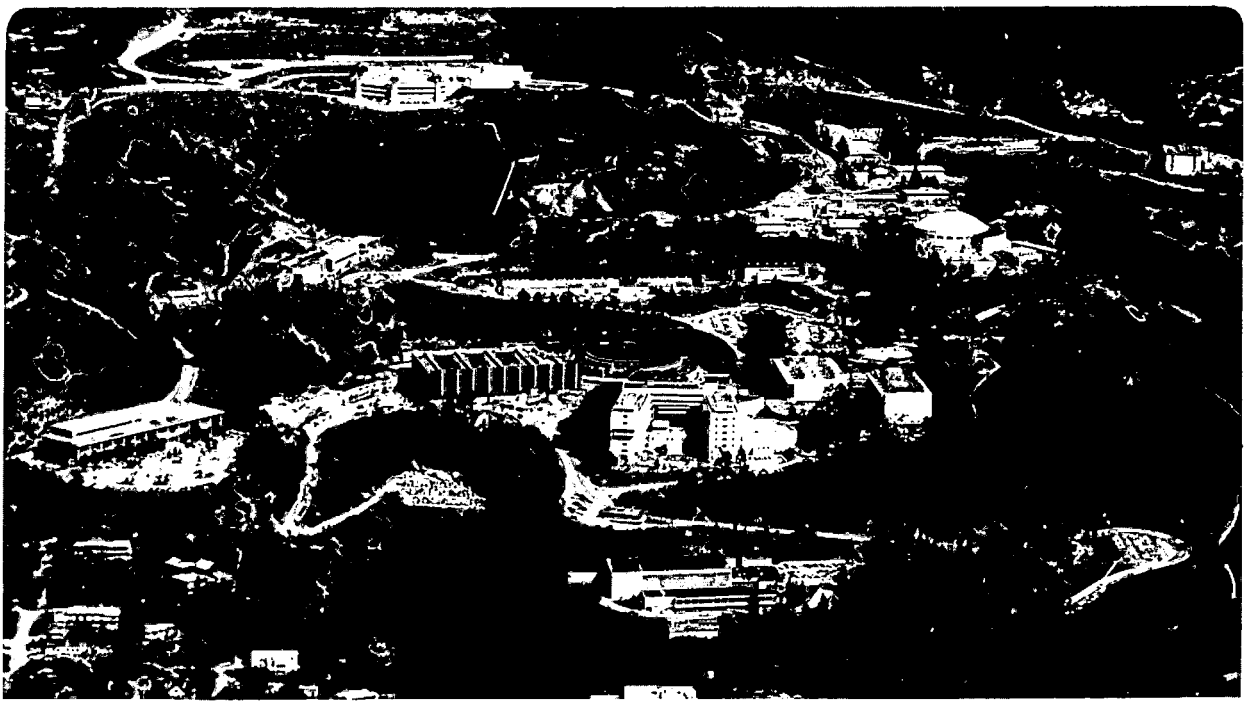
UNIVERSITY OF CALIFORNIA

Engineering & Technical Services Division

For Reference

Not to be taken from this room



DISCLAIMER

LAWRENCE BERKELEY LABORATORY - UNIVERSITY OF CALIFORNIA
ENGINEERING NOTE

CODE	SERIAL	PAGE
MME Book No. 633	MT 303	1 of 17

AUTHOR	DEPARTMENT	LOCATION	DATE
Michael I. Green Donald H. Nelson	Electronics Engineering	B25A-124	July 27, 1981

PROGRAM — PROJECT — JOB

TITLE
General Purpose Data Acquisition System - Status Report 1 Test of Quadrupole System

Introduction

A major milestone in the development of our General Purpose Data Acquisition System was successfully passed in May 1981. On May 28th, we essentially duplicated the results of the Tektronix 4051 computer quadrupole data acquisition/harmonic analysis program with our LSI 11 system.

Description of Comparative Tests

Figure 1 is a block diagram of the Tektronix system which has been used successfully for testing magnets for the past three years. Table I lists the specific hardware and software used for the comparative tests of our LSI 11 system.

Figure 2 and Table II identify the new system configured for quadrupole measurements. Note that a significant portion of the hardware is identical to that used in the Tektronix system. Our philosophy in defining the first usable version of our data acquisition system was to minimize the number of changes to the proven Tektronix system.

We measured an available quadrupole first with the LSI 11 system and immediately afterwards with the Tektronix 4051 system. Three data sets were collected under identical conditions and fourier analyzed by each system.

Test Results

Analysis time has been reduced to ∿15 seconds for the computations that require several minutes for the Tektronix system to perform.

(text continued on page 6.)

SUBJECT
General Purpose Data Acquisition System - Status Report 1
Test of Quadrupole System

NAME
MIG & DHN

DATE
July 27, 1981

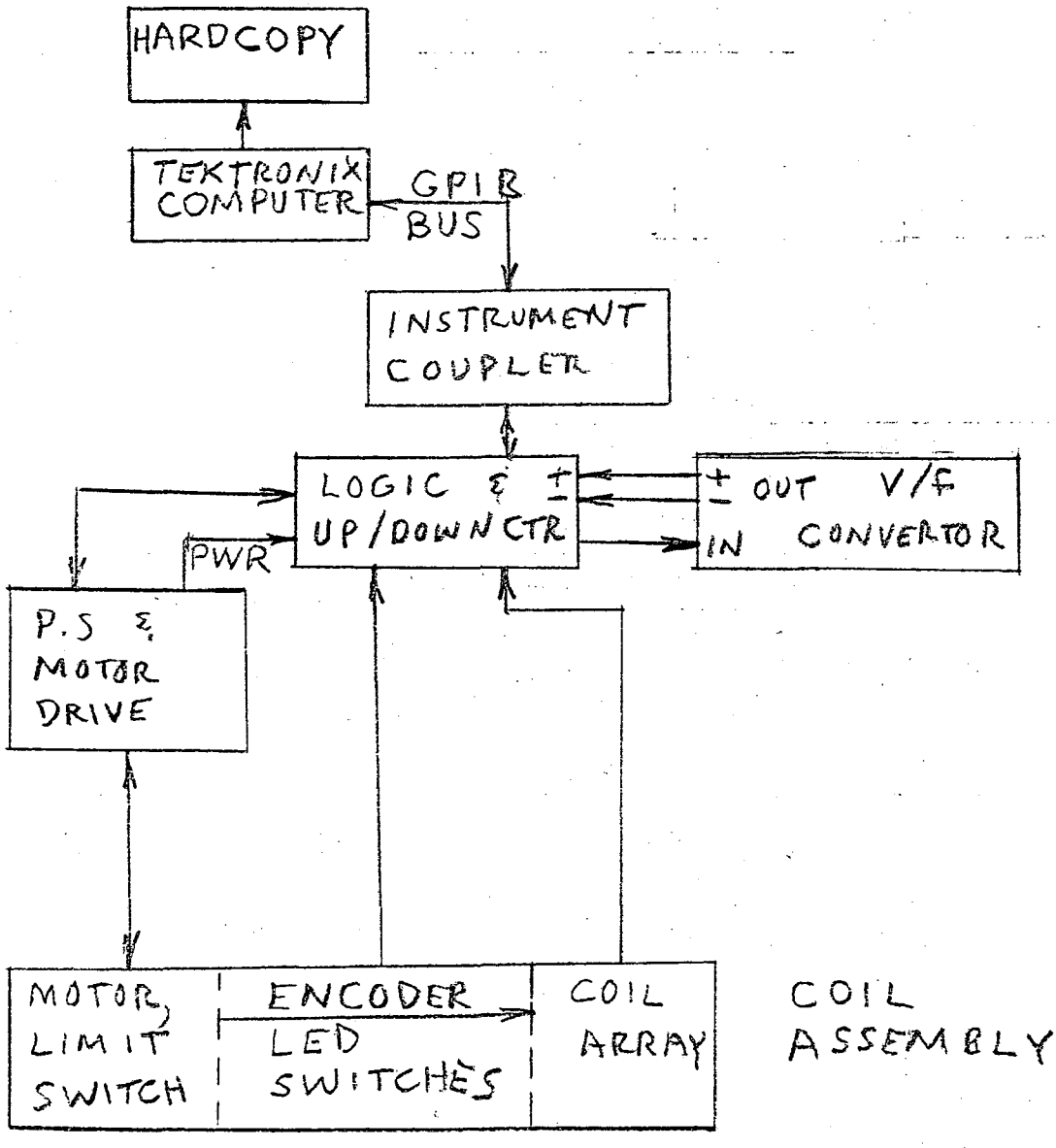


FIG 1 MME MULTIPOLE MEASUREMENT SYSTEM
(ROBERT MAIN'S QUAD ANALYSIS SYSTEM)

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Device	Manufacturer/Model	Identification
Hardware:		
Computer	Tektronix Mod 4051	DOE 504556
Hard Copy	Tektronix Mod 4631	DOE 504505
Instrument Coupler	ICS Mod 4883	S/N 81045
Logic Bin	LBL Drwg. No. 13W4785	—
V/f Convertor	Vidar Mod 260DR-03	124692
Power Supply/MTR Drive	LBL Drwg. No. 13W4724	—
Coil Assembly	LBL Drwg. No. 17M3204	
Software:		
"BASIC" Quadrupole Programs	Tektronix Data Cartridge	MME Data 1

TABLE I Magnetic Measurements Engineering Multipole Measurement System

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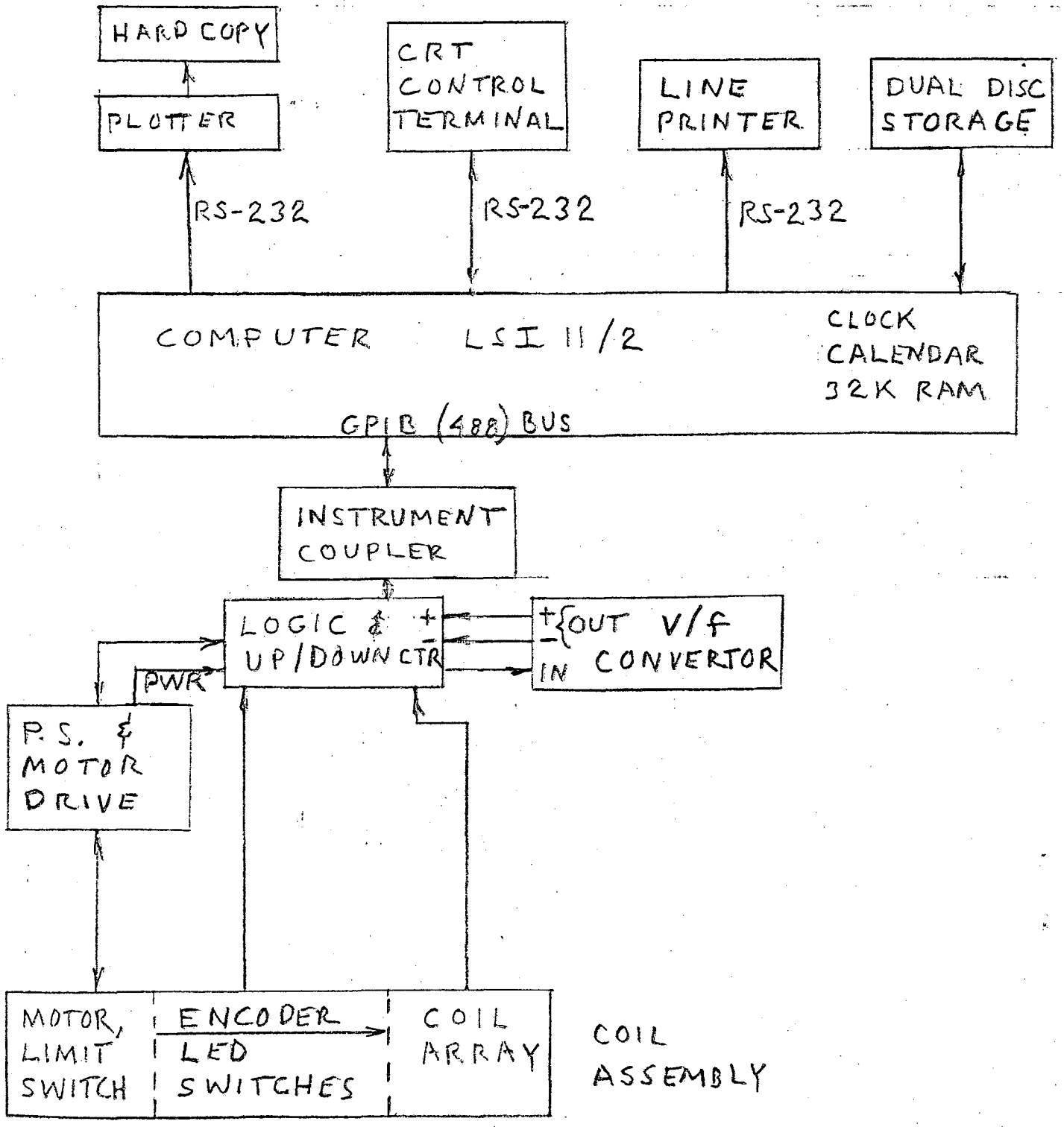

FIG 2 MME DATA ACQUISITION SYSTEM - 1
(QUADRUPOLE DATA ACQUISITION / ANALYSIS)

Device	Manufacturer/Model	Identification
Hardware:		
Computer	DEC LSI 11/2	S/N AB 94847598
CRT Control	HE - Z19	DOE 518712
Printer	LA120-AA	S/N WF14807 DOE 519478
Disk Storage	DSD 440-120	S/N 44-4591 DOE 519465
Plotter (Computer)	Tektronix Mod 4051	DOE 504556
Hard Copy	Tektronix Mod 4631	DOE 504505
Instrument Coupler	ICS Mod 4883	S/N 81045
Logic Bin	LBL Drwg. No. 13W4785	—
V/f Convertor	Vidar Mod 260DR-03	124692
Power Supply/MTR Drive	LBL Drwg. No. 13W4724	—
Coil Assembly	LBL Drwg. No. 17M3204	
Software:		
RT11 Operating System	Floppy Disk	MME No. 16
Quadrupole Data Acquisition/Analysis	Floppy Disk	MME DAS No. 1
Emulator (Auto Load Type)	Tektronix Data Cartridge 4012	MME QA No. 1

TABLE II Magnetic Measurements Engineering Data Acquisition System No. 1

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Test Results (continued from page 1)

Table III summarizes results of the six test runs described above. We have listed significant data to facilitate the comparison. There is considerable variation between data sets, but these variations are a few parts per hundred thousand of the quadrupole magnitude for the "allowed" error terms while the amplitude of the fundamental agrees to 0.1%. A partial explanation for these variations is that the quadrupole is rated to operate at 250 A while we are operating at ∿25 A in order to avoid connecting cooling water to the magnet. Variations observed are beyond the resolution of the measurement system. In fact, at the radius of measurement, the amplitude of the N = 14 term (10 - 12 counts as determined by fourier analysis) is only 15 ppm (of the fundamental) and yet there is less than 0.2% spread in the determination of that error term at the radius of evaluation (i.e., at the radius of the pole tips ∿3.1 cm).

Tables IV, V and VI represent the three LSI 11 system runs and Tables VII, VIII and IX represent the three Tektronix runs.

Theory

Appendix A (in progress as of June 15th) will relate the theory on which these measurement systems are based to the geometry of the rotating coil array.

Subsequent Developments

Since the May 28th demonstration, M.I. Green has cleaned up several subroutines and added others. Table X lists the subroutines that comprise our June 1981 quadrupole software and which will serve as the basis for future development. Unless gross errors are detected, this software will be frozen in its present state. Appendix B (distributed on request only) contains program listings of the software.
(text continued on page 16.)

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Quantity Compared	Units	LSI-11 1	LSI-11 2	LSI-11 3	LSI-11 Avg	σ* (% of Quantity)	Tektronix 1	Tektronix 2	Tektronix 3	Tektronix Avg	σ* (% of Quantity)	(ΔAvg) (Δ %)
Fund. Amplitude	Counts	6520	6537	6519	6525	0.16	6522	6521	6522	6522	0.01	0.04
Fund. Phase	Degrees	5.58	5.60	5.57	5.58**	--	2.78	2.79	2.74	2.77**	--	2.81**
B'L	Tesla	0.4954	0.4944	0.4944	0.4947	0.12	0.494	0.494	0.494	0.494	0.00	0.14
B'L/I	Tesla/A	0.01982	0.01978	0.01978	0.01979	0.12	0.01977	0.01977	0.01979	0.01978	0.06	0.05

* σ ≡ Standard deviation as determined by HP 97 computations

** Difference in phase of fundamental may be attributed to one motor step 360 (degrees)/128 (increments) = 2.81 degrees/increment
5.58 - 2.77 = 2.81 degrees

TABLE III A Comparison of Measurements of Quadrupole Magnitude and Phase

I Harmonic Index (1)	Quantity Compared	Units	LSI-11 1	LSI-11 2	LSI-11 3	Avg (Parts/10^3)	σ* (% of B(2))	Tektronix 1	Tektronix 2	Tektronix 3	Avg (Parts/10^3)	σ* (% of B(2))	ΔAvg (LSI - TEK) (% of B(2))
3	S(3)	Counts	584	590	592			591	596	587			
	B(3)/B2	Parts/10^3	1.727	1.744	1.748	1.738	0.001	1.715	1.731	1.703	1.710	0.001	0.003
	γ_3	Degrees	-190.4	-190.7	-191.2			169.3	169.3	169.9			
4	S(4)	Counts	94	88	93			88	96	93			
	B(4)/B2	Parts/10^3	0.537	0.503	0.532	0.524	0.002	0.505	0.552	0.533	0.530	0.002	-0.001
	γ_4	Degrees	-186.1	-186.0	-185.7			-185.6	-183.6	-188.1			
5	S(5)	Counts	70	68	67			67	68	65			
	B(5)/B2	Parts/10^3	0.547	0.537	0.527	0.537	0.001	0.529	0.535	0.508	0.524	0.001	0.001
	γ_5	Degrees	146.6	144.4	146.2			143.8	143.4	146.9			
6	S(6)	Counts	110	107	108			106	108	106			
	B(6)/B2	Parts/10^3	1.465	0.431	1.433	1.443	0.002	1.416	1.437	1.410	1.421	0.001	0.002
	γ_6	Degrees	-175.2	-175.7	-177.4			-177.8	-175.4	-178.5			
10	S(10)	Counts	53	50	53			51	52	52			
	B(10)/B2	Parts/10^3	4.634	4.419	4.669	4.574	0.014	4.419	4.518	4.573	4.513	0.006	0.006
	γ_{10}	Degrees	-178.6	-180.1	-180.9			-181.0	-182.0	-179.9			
14	S(14)	Counts	10	12	10			10	11	11			
	B(14)/B2	Parts/10^3	5.143	6.553	5.691	5.796	0.071	5.230	5.744	5.857	5.610	0.033	0.019
	γ_{14}	Degrees	-194.7	-192.8	-180.3			-190.3	-183.4	-175.2			

S ≡ Amplitude of error term at radius of measurement
B(I)/B(2) ≡ Dimensionless error term evaluated radius of iron
γ(3) ≡ Phase of error term relative to fundamental

TABLE III B Comparison of Error Terms (Amplitude and Phase)

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LBID-516

2" SC, 2.5" QD 23, 75 BQ- SERIAL# 8 15:11--5/28/81--MIG

--COMPARISON TEST WITH LSI-11

25 AMP. USING 1 MILLIOHM SHUNT
B*xL(eff) (meas.) = 0.494 TESLA = 0.01977 TESLA/AMP.
B(N)/B(2) IN PARTS/1000 AT 0.0319405 M RADIUS.

N	S(N)	B(N)/B(2)	ANGLE	N	S(N)	B(N)/B(2)	ANGLE
3	591	1.7152	169.3	21	2	17.4854	-141.4
4	88	0.5053	-185.6	22	1	12.9131	-87.4
5	67	0.5293	143.8	23	0	0.0000	0.0
6	106	1.4162	-177.8	24	1	0.0000	0.0
7	7	0.1511	120.9	25	2	0.0000	0.0
8	3	0.1048	-100.3	26	2	0.0000	0.0
9	15	0.7940	19.1	27	1	0.0000	0.0
10	51	4.4490	-181.0	28	2	0.0000	0.0
11	3	0.3480	-73.8	29	1	0.0000	0.0
12	2	0.3831	-16.3	30	2	0.0000	0.0
13	2	0.7409	-1.7	31	0	0.0000	0.0
14	10	5.2299	-190.3	32	1	0.0000	0.0
15	3	2.5599	-138.8	33	1	0.0000	0.0
16	1	1.0321	110.6	34	0	0.0000	0.0
17	2	3.9925	-29.7	35	1	0.0000	0.0
18	1	3.9994	-226.8	36	0	0.0000	0.0
19	1	3.9291	39.2	37	1	0.0000	0.0
20	2	15.1544	-111.9	38	1	0.0000	0.0

VIDAR: 0.05 VOLT QUAD BUCKING RADIO 1:171
SEARCH COIL OFF-SET FROM AXIS 0.708 MM AT -173.87 DEG.
DRIFTS 81 & 51 DATA ON FILE #11

TABLE IV

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2" SC, 2.5" QD 23, 75 BQ- SERIAL# 8 15:14--5/28/81--MIG

--FIRST REPEAT OF 15:11 DATA

25 AMP. USING 1 MILLIOHM SHUNT
B*xL(eff) (meas.) = 0.494 TESLA = 0.01977 TESLA/AMP.
B(N)/B(2) IN PARTS/1000 AT 0.0319405 M RADIUS.

N	S(N)	B(N)/B(2)	ANGLE	N	S(N)	B(N)/B(2)	ANGLE
3	596	1.7307	169.3	21	2	17.2021	-155.9
4	96	0.5517	-183.6	22	2	26.6555	-16.0
5	68	0.5346	143.4	23	1	0.0000	0.0
6	100	1.4365	-175.4	24	1	0.0000	0.0
7	9	0.1883	123.8	25	1	0.0000	0.0
8	3	0.1025	-111.7	26	2	0.0000	0.0
9	13	0.7264	8.4	27	1	0.0000	0.0
10	52	4.5180	-182.0	28	2	0.0000	0.0
11	0	0.0444	77.1	29	2	0.0000	0.0
12	3	0.6095	-131.9	30	1	0.0000	0.0
13	3	1.1368	27.7	31	1	0.0000	0.0
14	11	5.7435	-183.4	32	1	0.0000	0.0
15	1	1.1709	132.6	33	1	0.0000	0.0
16	2	2.3776	-214.3	34	1	0.0000	0.0
17	2	3.7687	5.3	35	1	0.0000	0.0
18	2	6.5086	-152.0	36	1	0.0000	0.0
19	1	3.9279	-223.5	37	1	0.0000	0.0
20	0	1.6804	-114.8	38	1	0.0000	0.0

VIDAR: 0.05 VOLT QUAD BUCKING RADIO 1:171
SEARCH COIL OFF-SET FROM AXIS 0.656 MM AT -172.53 DEG.
DRIFTS 60 & 38 DATA ON FILE #11

TABLE V

LAWRENCE BERKELEY LABORATORY · UNIVERSITY OF CALIFORNIA
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2" SC, 2.5" QD 23, 75 BQ- SERIAL# 8 15:18--5/28/81--MIG

--SECOND REPEAT OF 15:11 RUN

25 AMP. USING 1 MILLIOHM SHUNT
B*xL(eff) (meas.) = 0.494 TESLA = 0.01979 TESLA/AMP.
B(N)/B(2) IN PARTS/1000 AT 0.0319405 M RADIUS.

N	S(N)	B(N)/B(2)	ANGLE	N	S(N)	B(N)/B(2)	ANGLE
3	587	1.7026	169.9	21	4	41.8789	-223.2
4	93	0.5333	-188.1	22	2	35.0901	10.1
5	65	0.5079	146.9	23	1	0.0000	0.0
6	106	1.4103	-178.5	24	1	0.0000	0.0
7	8	0.1640	130.5	25	1	0.0000	0.0
8	3	0.0897	-186.3	26	1	0.0000	0.0
9	13	0.7225	12.1	27	2	0.0000	0.0
10	52	4.5726	-179.9	28	1	0.0000	0.0
11	2	0.3144	-39.7	29	1	0.0000	0.0
12	5	1.1362	-79.9	30	1	0.0000	0.0
13	3	0.9572	23.3	31	1	0.0000	0.0
14	11	5.8573	-175.2	32	2	0.0000	0.0
15	2	1.7757	-152.3	33	2	0.0000	0.0
16	2	2.6445	-4.4	34	1	0.0000	0.0
17	1	2.4635	80.9	35	0	0.0000	0.0
18	2	4.9521	75.6	36	2	0.0000	0.0
19	2	8.4878	-172.1	37	0	0.0000	0.0
20	1	8.0704	-2.7	38	1	0.0000	0.0

VIDAR: 0.05 VOLT QUAD BUCKING RADIO 1:171
SEARCH COIL OFF-SET FROM AXIS 0.635 MM AT -172.22 DEG.
DRIFTS 53 & 33 DATA ON FILE #11

TABLE VI

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2' SEARCH COIL, 2.5' QD 23 75BQ8
~25 AMPS, 81/MAY/28 14:19, ALGORITHM AND SBR TEST OF LSI-11
0

7445. COUNTS DRIFT OVER 129 POINTS WITH 58. DRIFT PER POINT
MAXIUMUM AMPLITUDE IS 6520.1 COUNTS

DIPOLE STRENGTH = 0.000333 PH1 = -172.18 PH2 = 5.58

B'L(EFF) = 0.4954 TESLA B'L(eff)/AMP = 0.01982

4936. COUNTS DRIFT OVER 129 POINTS WITH 39. DRIFT PER POINT
MAXIUMUM AMPLITUDE IS 6958.3 COUNTS

N	S(N)	B(N)/B(2)	ANGLE
3	584.	1.7218	-190.4
4	94.	0.5372	-186.1
5	70.	0.5471	146.6
6	110.	1.4646	-175.2
7	9.	0.1876	128.1
8	1.	0.0342	-134.6
9	13.	0.7009	2.7
10	53.	4.6342	-178.6
11	1.	0.0776	-124.8
12	1.	0.1981	-100.6
13	3.	0.8895	-11.6
14	10.	5.1429	-194.7
15	1.	0.4716	-147.1
16	2.	2.4940	-22.4
17	3.	5.2898	11.9
18	3.	8.7362	-270.1
19	0.	1.2015	-16.0
20	2.	11.0551	-21.6
21	4.	49.9470	-190.7
22	3.	55.9310	57.3

TABLE VII

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2" SEARCH COIL, 2.5" OD 23 75BQ8
REPEAT OF 14:19 RUN
0
7439. COUNTS DRIFT OVER 129 POINTS WITH 58. DRIFT PER POINT
MAXIUMUM AMPLITUDE IS 6537.4 COUNTS

DIPOLE STRENGTH = 0.000337 PH1 = -163.66 PH2 = 5.60

B'L(EFF) = 0.4944 TESLA B'L(eff)/AMP = 0.01978
5146. COUNTS DRIFT OVER 129 POINTS WITH 40. DRIFT PER POINT
MAXIUMUM AMPLITUDE IS 6955.0 COUNTS

N	S(N)	B(N)/B(2)	ANGLE
3	590.	1.7440	-190.7
4	88.	0.5028	-186.0
5	68.	0.5366	144.4
6	107.	1.4308	-175.7
7	9.	0.1833	103.9
8	1.	0.0271	-116.4
9	12.	0.6797	9.4
10	50.	4.4186	-180.1
11	3.	0.3747	-39.8
12	3.	0.7178	-124.7
13	3.	1.0133	-2.8
14	12.	6.5526	-192.8
15	2.	1.7427	-249.9
16	1.	1.6408	-36.5
17	0.	0.7180	-50.2
18	1.	2.4761	-209.2
19	3.	12.1000	-202.1
20	2.	13.3143	34.3
21	3.	39.3414	-138.6
22	3.	52.6268	1.8

TABLE VIII

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2" SEARCH COIL, 2.5" OD 23 75B08
SECOND REPEAT OF 14:19 RUN
0
8996. COUNTS DRIFT OVER 129 POINTS WITH 70. DRIFT PER POINT
MAXIUMUM AMPLITUDE IS 6519.0 COUNTS

DIPOLE STRENGTH = 0.000338 PH1 = -170.24 PH2 = 5.57

B'L(EFF) = 0.4944 TESLA B'L(eff)/AMP = 0.01978
6110. COUNTS DRIFT OVER 129 POINTS WITH 48. DRIFT PER POINT
MAXIUMUM AMPLITUDE IS 6974.5 COUNTS

N	S(N)	B(N)/B(2)	ANGLE
3	592.	1.7480	-191.2
4	93.	0.5318	-185.7
5	67.	0.5270	146.2
6	108.	1.4327	-177.4
7	11.	0.2268	122.2
8	3.	0.1151	-92.6
9	12.	0.6370	17.2
10	53.	4.6693	-180.9
11	1.	0.1476	-196.3
12	2.	0.4985	-163.2
13	3.	1.0096	-13.4
14	10.	5.6907	-180.3
15	2.	2.0813	-197.5
16	2.	1.9689	90.9
17	2.	3.0883	-194.1
18	0.	1.1073	-55.2
19	1.	4.9640	-181.8
20	1.	4.1285	-264.8
21	0.	3.9944	-71.9
22	2.	36.8350	-12.0

TABLE IX

```
 16-Jun-81
BELL   .FOR      2   08-Jun-81        QDANAL.FOR      8   11-Jun-81
BELL   .LST      3   08-Jun-81        QDANAL.LST     15   11-Jun-81
BELL   .OBJ      6   08-Jun-81        QDANAL.OBJ     11   11-Jun-81
DEVTBL.TXT       1   29-Apr-81        QDANAL.SAV     85   11-Jun-81
DP2NTG.FOR       3   11-Jun-81        QDSBR  .FOR     3   28-May-81
DP2NTG.LST       6   11-Jun-81        QDSBR  .LST     6   28-May-81
DP2NTG.OBJ       8   11-Jun-81        QDSBR  .OBJ     6   28-May-81
DRFTC  .FOR      3   11-Jun-81        RDATA  .FOR     5   08-Jun-81
DRFTC  .LST      6   26-May-81        RDATA  .LST     8   08-Jun-81
DRFTC  .OBJ      6   26-May-81        RDATA  .OBJ     6   08-Jun-81
F4FFT  .OBJ      4   19-May-80        SAVE1  .FOR     2   18-May-81
G      .COM      1   11-Jun-81        SAVE1  .LST     3   18-May-81
GPIB   .OBJ     11   29-Apr-81        SAVE1  .OBJ     6   18-May-81
HRDWR  .FOR      3   08-Jun-81        SCALE  .FOR     3   22-May-81
HRDWR  .LST      6   08-Jun-81        SCALE  .LST     5   22-May-81
HRDWR  .OBJ      6   08-Jun-81        SCALE  .OBJ     5   22-May-81
INIT   .FOR      3   08-Jun-81        SCOIL1.FOR     4   27-May-81
INIT   .LST      6   08-Jun-81        SCOIL1.LST     7   27-May-81
INIT   .OBJ      6   08-Jun-81        SCOIL1.OBJ     8   27-May-81
PHAMPL.OBJ       2   19-May-80        SCOIL1.TXT     2   29-May-81
PLOT1  .FOR      2   11-Jun-81        VOMIT  .FOR     2   18-May-81
PLOT1  .LST      5   11-Jun-81        VOMIT  .LST     3   18-May-81
PLOT1  .OBJ      6   11-Jun-81        VOMIT  .OBJ     5   18-May-81
PL10LB.OBJ     303   26-Mar-81
 47 Files, 616 Blocks
 358 Free blocks
```

TABLE X Directory for Floppy Disk QA1 & Index to Listings in Appendix A

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Michael I. Green Donald H. Nelson	Electronics Engineering	B25A-124	July 27, 1981

Subsequent Developments (continued from page 6.)

On June 12th, M.I. Green demonstrated that we can produce graphs on the Tektronix viewing screen and hard copy unit from LSI 11 codes, i.e., using the Tektronix as a "dumb" terminal.

On June 26th, we tested the recently fabricated V/f convertor by substituting it for the Vidar V/f. We are currently adding code to exercise the computer controls of the new V/f convertor.

Acknowledgements

We owe a great deal to Bob Main (including the Tektronix system hardware which was transferred to Magnetic Measurements Engineering at the conclusion of the PEP Quadrupole Measurement Programs). His successful development of the Tektronix system (and that of Ferd Voelker in an earlier system) has strongly influenced the design of our General Purpose Data Acquisition System.

Klaus Halbach has been helpful and supportive of our project and has cleared away many theoretical stumbling blocks.

Don Rondeau and Bill Hearn were instrumental in the successful design and fabrication of the LBL V/f convertor.

We thank Clyde Taylor, Bill Gilbert, Glen Lambertson, and Bill Hassenzahl for the opportunity to implement the General Purpose Data Acquisition System in order to test superconducting dipole magnets .

We thank Ed Hartwig and Lee Wagner for backing the modernization of Magnetic Measurements Engineering test equipment.

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