N72-25289

REDUCTION OF SKYLAB 2 GROUND WINDS WIND TUNNEL DATA

ANNUAL REPORT

BAGANOFF ASSOCIATES, INC.

COMPUTER TECHNOLOGY SPECIALIST
Noise Control, Structural Response, Cross-Correlation Analysis

314-383-2432

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St. Louis, Missouri 63136

REDUCTION OF SKYLAB 2 GROUND WINDS WIND TUNNEL DATA

ANNUAL REPORT

REPORT NO. 605 COPY NO. 14

April 5, 1972

Prepared for the George C. Marshall Space Flight Center, Huntsville, Alabama, under Contract No. NAS8-26703, DCN 1-1-75-10052 (1F), covering the Period April 8, 1971 through April 7, 1972

Michael J. Rolfes

BAGANOFF ASSOCIATES, INC.

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ABSTRACT

A dampometer was designed and fabricated for measuring the amount of damping in the wind tunnel test model. Also, the Ground Winds Data Reduction System (GWDRS) was taken to Langley Research Center and manned by two Baganoff Associates' (BAI) personnel in support of wind tunnel tests on the Skylab 2 program. Upon completion of the tests, the GWDRS, along with magnetic tapes of data recorded during the test, were brought back to BAI for final data reduction.

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2.0 DESIGN, FABRICATION AND TESTING OF A DAMPOMETER

2.1) General - When conducting a ground winds wind tunnel test in which the amount of damping of the test model is a variable, much time is needed to calibrate the damper system every time the model undergoes a configuration change. Procedure for damper calibration is to use the damper system to excite the model at resonant frequency, constant amplitude, and then abruptly cut off excitation. The decaying signal from an accelerometer is recorded on an oscillograph, and the amount of structural damping is determined by reading the log decrement. Since many trials are required before the system is fully calibrated, this procedure is very laborious.

In order to eliminate the reading of stripchart traces, a device which analyzes the decaying accelerometer signal and calculates the percent of damping in real time was developed. The prototype device, referred to as a Dampometer, is described in the following paragraphs along with results of various tests on the instrument.

2.2) Theory of Operation - At the end of this section are complete schematics and logic diagrams of the Dampometer system. The Dampometer is a hybrid device using analog computing elements and digital control. Referring to the drawing 9000, the Dampometer functions as follows:

The signal to be analyzed is brought in to the instrument through a connector at the rear of the cabinet and is amplified by the input amplifier. By adjusting the level adjust pot mounted on the front panel

1.0 INTRODUCTION

This is the Annual Report under Contract No. NAS8-26703, (DCN-1-1-75-10052 (1F)). Under this contract, a prototype device to measure viscous damping in a structure, hereafter referred to as a Dampometer, was designed and fabricated. The Dampometer was used during a wind tunnel test to measure damping of the test model. After the wind tunnel test, the Dampometer was modified, further tested, and then delivered to the Marshall Space Flight Center, Huntsville, Alabama.

Also under this contract, Baganoff Associates, Incorporated (BAI) transported the Ground Winds Data Reduction System (GWDRS) to Langley Research Center, Hampton, Virginia. The GWDRS was supported by two BAI personnel while reducing on-line data from wind tunnel tests for the Skylab 2 program. Real time data reduction provided NASA personnel with accurate results during the actual testing.

After the wind tunnel tests were completed, the GWDRS was brought back to BAI to perform final data reduction of the data recorded during the tunnel tests. Samples of the final data are contained in Section (5.0) of this Report.

the signal is brought up to the fullscale amplitude of the system as read on a digital panel meter mounted on the front panel. An analog peak detector is used to determine the peak value of the incoming waveform so that the meter reads volts zero to peak.

Initially, the incoming signal is of constant amplitude, and the level adjust pot used to adjust the system for fullscale. This being accomplished, the START switch is depressed which enters the digital value of the peak input amplitude into the A_o storage register, and enables the control logic to begin a solution.

A digital peak detector provides a pulse for each peak of the incoming signal. This digital pulse triggers the digital meter to sample the analog value precisely at the positive peak of the input signal. Once the start button has been pressed and A_o stored in the register, each new peak value A_n along with A_o is used to compute the log ratio, LOG $\frac{A_o}{A_n}$. As long as the input remains steady state $A_n = A_o$ so that the log ratio is zero. Once the input amplitude begins to decay, the log ratio becomes some value other than zero, a digital pulse is generated by the THRESHOLD ON circuit which goes to the control logic. The control logic in turn switches the STANDBY-OPERATE relay to OPERATE and enables the number of cycles counter.

The number of cycles counter counts the incoming peaks and is converted to an analog voltage by a D to A converter. This voltage goes to an analog divider, where the analog value of the log ratio is divided by the number of cycles to compute percent of damping as expressed by the equation $\xi = \frac{1}{n} \text{ LOG } \frac{A_o}{An}$. Since the actual eouation for damping is

$$\xi = \frac{1}{2\pi n} \ln \frac{A_o}{A_n}$$

the solution must be scaled by a SCALE ADJ. pot.

When in the OPERATE position, the STANDBY-OPERATE relay connects the panel meter to the output of the analog computing circuitry. Each new input waveform peak triggers the meter which now reads the solution from the computing circuitry.

In order to limit the solution to any given number of input cycles up to 99, a limit switch was provided. The count on the limit switch is compared to the count in the number of cycles counter and automatically shuts off the system when the number of cycles equals the number on the limit switch. To insure that the input signal level does not decay below the capabilities of the analog circuitry before the cycle limit was reached, a THRESHOLD OFF circuit was provided. When the signal level falls below a preset limit, the solution is terminated, and the final value is stored on the panel meter readout.

The value stored on the panel meter readout is percent of damping, and this value will remain until the RESET button is depressed resetting the Dampometer to the initial conditions.

2.3) Wind Tunnel Tests - The prototype Dampometer was taken to Langley Research Center for evaluation during a wind tunnel test. Both an oscillograph and the dampometer were used to measure damping of the test model. While calibrating the damper system, oscillograph traces were taken of the decays, and the solution of the dampometer recorded. Damping values were determined from the oscillograph traces by reading the log decrement. These values were compared to the recorded Dampometer values.

Whenever the input waveform was steady with little or no beating, the Dampometer agreed with the log decrements fairly well for damping values less then 3.5%. However, when there were amplitude fluctuations in the input signal. the Dampometer solutions were not in agreement with the log decrement values.

For values of damping greater than 3.5%, the Dampometer would not give a good solution even if the input signal had no amplitude fluctuations. This was due mostly to the signal not decaying from a peak value. For large values of damping, very few peaks are available before the input signal decayed below the cutoff threshold. Therefore, if there is a small error in the number of cycles, as would occur when the input is cutoff somewhere other than at the peak, then there will be a large error in the Dampometer solution.

2.4) Dampometer Modifications - Upon completion of the wind tunnel test, the Dampometer was brought back to St. Louis for modification and further testing. In order to increase resolution for high values of damping, the gain of amplifier A1 following the D to A converter which converts the number of cycles counter to an analog voltage was increased (see drawing 9007). This reduced the maximum number of cycles obtainable on the limit switch from 99 to 33, but will have the effect of increasing the resolution of the divider circuit which computes $\frac{1}{n} \text{LOG} \frac{A_o}{A_n}$.

An additional circuit was added to the Dampometer which provides an analog switch for the shaker system for future testing, see drawing 9014. If this circuit is used. the forcing function will be cutoff at the peak value of the response signal being analyzed by the Dampometer. This modification should help to improve accuracy for large damping values.

2.5) Laboratory Testing of Dampometer - After the Dampometer was modified as described in section 2.4, the instrument was tested for accuracy and repeatability using data recorded at the wind tunnel, and also data generated with an analog circuit which simulated a second order damped system. The effect of the number of cycles used in the solution was also tested.

2.5.1) Wind Tunnel Data - While the model damper system was being calibrated in the wind tunnel, a number of records were recorded on magnetic tape for various amounts of damping. A total of 31 decays were recorded with damping values from .48% to 7.86%. Each record was reduced three times with the Dampometer. and recorded once on a strip chart recorder. The three readings were averaged, and this value plotted against the damping value read from the strip chart.

2.5.2) Damping Generator - A circuit which is the realization of the equation,

$$\ddot{X} + 2 \zeta \omega_o \dot{X} + \omega_o^2 X = F \cos \omega t$$

was built in order to generate a damped sinewave as a test input to the Dampometer. Figure (2.1) is a schematic and functional block diagram of the second order system. Eleven records were tested with values of damping from 1.38% to 8.60% damping. The damping records were recorded on magnetic tape for playback into the Dampometer. Each record was reduced three times and plotted against the value read from a strip chart record.

2.5.3) Effect of Number of Cycles On The Solution - For each peak value of the decaying input data, the Dampometer calculates a new solution. After the input amplitude decays below 200 millivolts, or the number of cycles set on the limit switch is reached, which ever happens first, the Dampometer stops and holds the last solution displayed on the digital panel meter. To test the effect of various limits on the number of cycles switch, two damping values from the damping generator data were used. In each case, the solution was stopped at various limits ranging from 1 cycle to 30 cycles.

2.5.4) Data - Copies of the data recorded during the tests described above are enclosed. A summary plot of the tabulated data is also enclosed.

2.5.5) Results - As can be seen from the summary plot enclosed later in this section, the wind tunnel data above 4% damping becomes very scattered and is considerably lower than the ideal curve. However, for the damping generator data, the Dampometer values remain good up to 7% damping. For the damping generator data, the worse case error was 8.3% of reading for record 7. Excluding record 7, the average error was 2.6% of reading.

To test the effects of the number of cycles on the Dampometer solution two cases were tested, 1.44% and 3.68% damping. For the 1.44% damping case, the Dampometer gave fairly repeatable results from a limit of 2 cycles up to a limit of 20 cycles. Above 20 cycles the Dampometer readings increased. For the 3.68% damping case, consistent results were not obtained until the cutoff was set at 10 cycles. Any limit above 10 cycles gave repeatable results.

2.5.6) Discussion of Results - Using the stylized data from the damping generator as input, the Dampometer proved to be a reasonably accurate instrument up to 7% damping. For actual wind tunnel data, accuracy was good only up to 4% damping. What could have caused the difference is the fact that the wind tunnel data did not begin decaying from a peak value. Although the forcing function driving the model was cut off at a peak, phase shifts in the response signal, in this case, the lower strain gage, caused a decay to begin before a peak value. Therefore, the first peak used in calculating damping was not a full cycle but some fraction thereof. As the percent of damping gets larger, a small fraction of a cycle error will cause a large error in the final result. When the damping generator was used, the input signal was always cut off at a peak value.

Results of the test of the effect of the number of cycles on the Dampometer solution were puzzling. The first trial, 1.44% damping, would seem to indicate that as long as a minimum of two cycles are used good results could be expected. However, when the second case was tested, 3.68% damping, good results were not obtained until 10 cycles were used. This would seem to indicate a slew rate problem in that the final value, because it is large, cannot be reached in the time for less than 10 cycles. This theory will be investigated by further testing.

2.5.7) - Conclusions - From the test results it was determined that the best cycle limit for all values of damping is 15 cycles. Also it is advisable to repeat each test case three times and average the three readings obtained.

Both the wind tunnel and stylized data inputs were relatively noise free and had fairly good decay slopes. Test results are therefore valid only for this type of data. The Dampometer is very sensitive to noise, and a spike will cause it to trigger too soon.

When setting up the Dampometer, the steady state input should not fluctuate more than 50 millivolts as read on the Dampometer panel meter. For cases where there is a severe slope change in the signal decay, it is advisable to limit the number of cycles to cutoff the solution before the slope change.

Provided that the analog switch circuit added to the system is used, The Dampometer will meet the following specifications:

Range:	.000 to 7.00% damping
Accuracy:	± 3% of reading
Frequency Range:	5 Hz to 100 Hz
Input Voltage Range	0.60 to 3.5 Volts O-P

After the laboratory tests were completed, the dampometer was shipped to Marshall Space Flight Center, Huntsville, Alabama for use in their laboratories.

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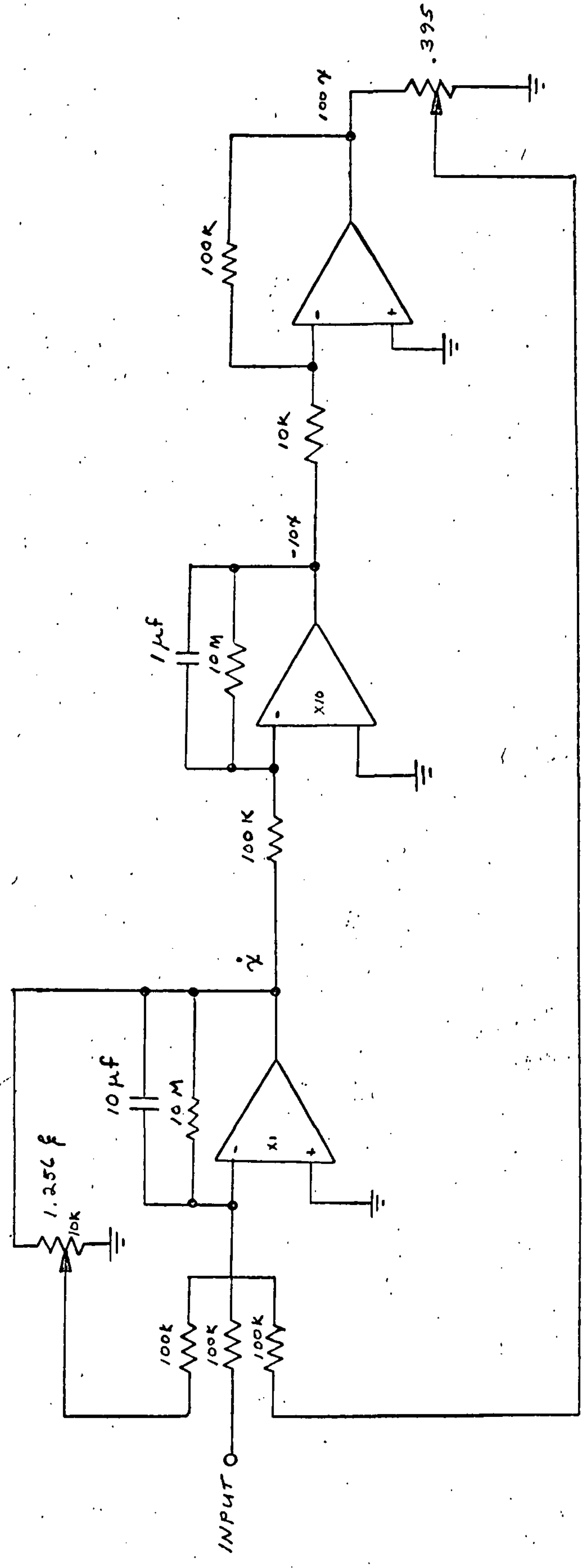
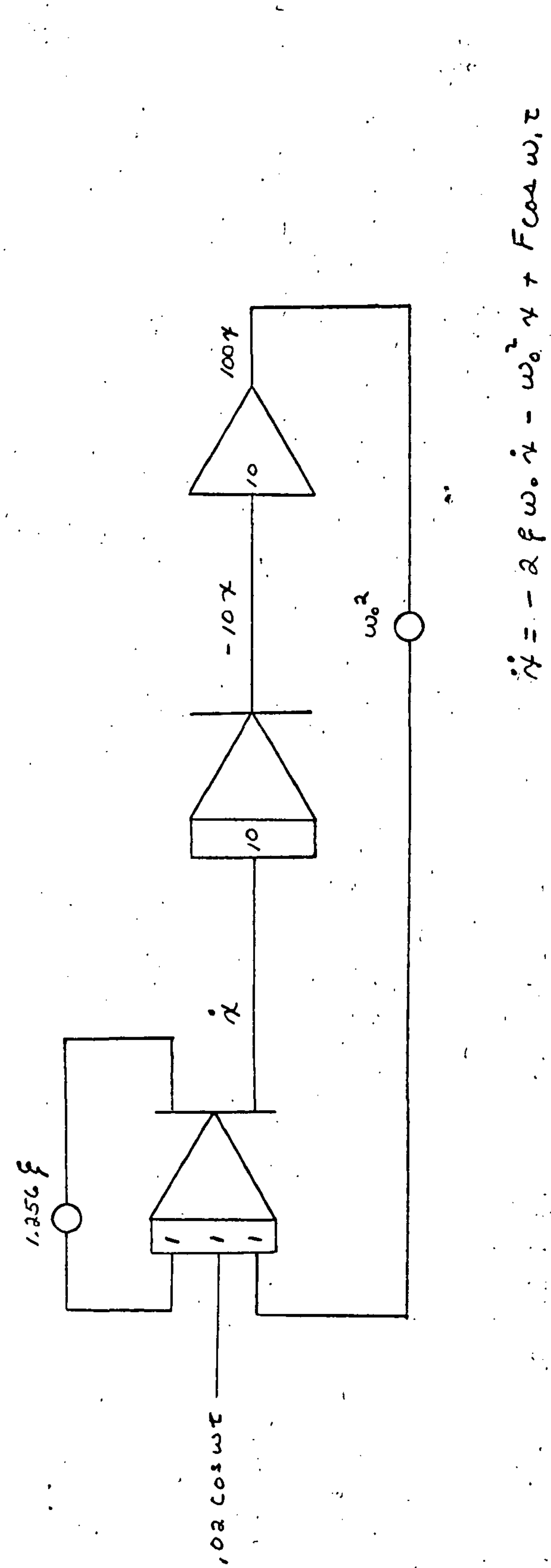
$f = 10$
$\omega_0 = 62.8$
$F = 2$
$\omega_0 = \omega_1$





$\ddot{x} = -2\xi\omega_0\dot{x} - \omega_0^2 x + F\cos\omega_1\tau$

$.01\ddot{x} = -1.256\xi\dot{x} - 39.5x + .02\cos\omega_1\tau$

Figure (2.1) Schematic and Block Diagram

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DAMPOMETER EVALUATION TESTS

WIND TUNNEL DATA, BASE STRAIN GAGE

Date: 12/16/71

Record No.	Log. Dec. Damping %	Dampometer Reading %	% Average	Cycle Limit
1	.61	.74 .75 .74	.74	15
2	*1.83 *2.35	2.25 2.27 2.25	2.26	10
3	3.67	3.75 3.74 3.70	3.73	10
4	5.00	4.67 4.68 4.47	4.67	10
5	.36	.36 .45 .43	.41	15
6	.61	.73 .74 .74	.74	15
7	3.55	3.14 3.31 3.19	3.31	10
8	5.5	5.00 5.08 4.93 3.70	5.10	10 4
9	7.34	6.21 5.27 5.76	5.75	10

* - Bad Decay Slope

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DAMPOMETER EVALUATION TESTS

WIND TUNNEL DATA, BASE STRAIN GAGE

Date: 12/16/71

Record No.	Log. Dec. Damping %	Dampometer Reading %	% Average	Cycle Limit
10	.648	.79 .80 .78	.79	15
11	3.39	3.34 3.34 3.43	3.34	10
12	5.5	4.93 5.20 4.82	4.98	10
13	7.86	5.75 5.10 5.90	5.83	10
14	.735	.80 .80 .83	.81	10
15	2.32	2.26 2.21 2.23	2.23	10
16	3.80	3.75 3.68 3.63	3.69	10
17	5.25	4.44 5.02 5.09	5.05	10
18	1.04 .92	.99 .98 1.00	1.00	10
19	2.10	2.29 2.30 2.29	2.29	10

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DAMPOMETER EVALUATION TESTS

WIND TUNNEL DATA, BASE STRAIN GAGE

Date: 12/16/71

Record No.	Log. Dec. Damping %	Dampometer Reading %	% Average	Cycle Limit
20	2.25	2.31 2.28 2.30	2.29	10
21	3.80	3.80 3.61 3.81	3.80	10
22	4.78 5.25	4.65 4.73 4.98	4.79	15
23	.63	.96 .99 .95	.97	10
24	3.06	3.16 3.21 3.22	3.19	10
25	5.5	4.86 4.97 4.78	4.87	10
26	6.9	6.16 5.94 5.95	6.01	10
27	.86	1.02 .91 .93	.95	10
28	3.14	3.09 3.11 3.15	3.12	10

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DAMPOMETER EVALUATION TESTS

WIND TUNNEL DATA, BASE STRAIN GAGE

Date: 12/16/71

Record No.	Log. Dec. Damping %	Dampometer Reading %	% Average	Cycle Limit
29	5.25	4.60 4.85 4.60	4.68	10
30	7.85	5.86 6.04 5.84	5.91	10
31	.48	.54 .56 .54	.55	15

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DAMPOMETER EVALUATION TESTS

DAMPING GENERATOR DATA

CYCLE LIMIT FOR ALL READINGS = 14   Date: 12/21/71

Record No.	Log. Dec. Damping %	Dampometer Reading %	% Average	Dampometer Reading %	% Average	% Avg. of All 6 Readings
1	8.6	7.36 7.12 7.18	7.22	7.29 7.34 7.18	7.27	7.24
2	6.95	6.90 6.40 7.27	6.85	6.95 6.99 6.43	6.79	6.82
3	6.00	6.31 5.81 5.54	5.88	6.17 5.55 6.17	5.96	5.92
4	5.50	5.16 5.32 5.65	5.38	5.07 5.44 5.27	5.26	5.32
5	4.40	4.54 4.65 4.38	4.52	4.99 4.73 4.91	4.88	4.70
6	3.68	3.90 3.67 3.72	3.76	3.50 3.92 3.51	3.64	3.70
7	2.75	3.25 2.60 2.94	2.73	2.83 3.20 3.19	3.07	3.00
8	1.38	1.53 1.44 1.42	1.46	1.41 1.54 1.42	1.45	1.46
9	1.44	1.47 1.58 1.53	1.51	1.51 1.49 1.49	1.49	1.51
10	1.40	1.48 1.50 1.46	1.48	1.46 1.46 1.50	1.47	1.47

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DAMPOMETER EVALUATION TESTS

DAMPING GENERATOR DATA

CYCLE LIMIT FOR ALL BEARINGS = 14

Date: 12/21/71

Record No.	Log. Dec. Damping %	Dampometer Reading %	% Average	Dampometer Reading %	% Average	% Avg. of All 6 Readings
11	1.32	1.55	1.53	1.49	1.50	1.52
		1.53		1.51		
		1.52		1.52		

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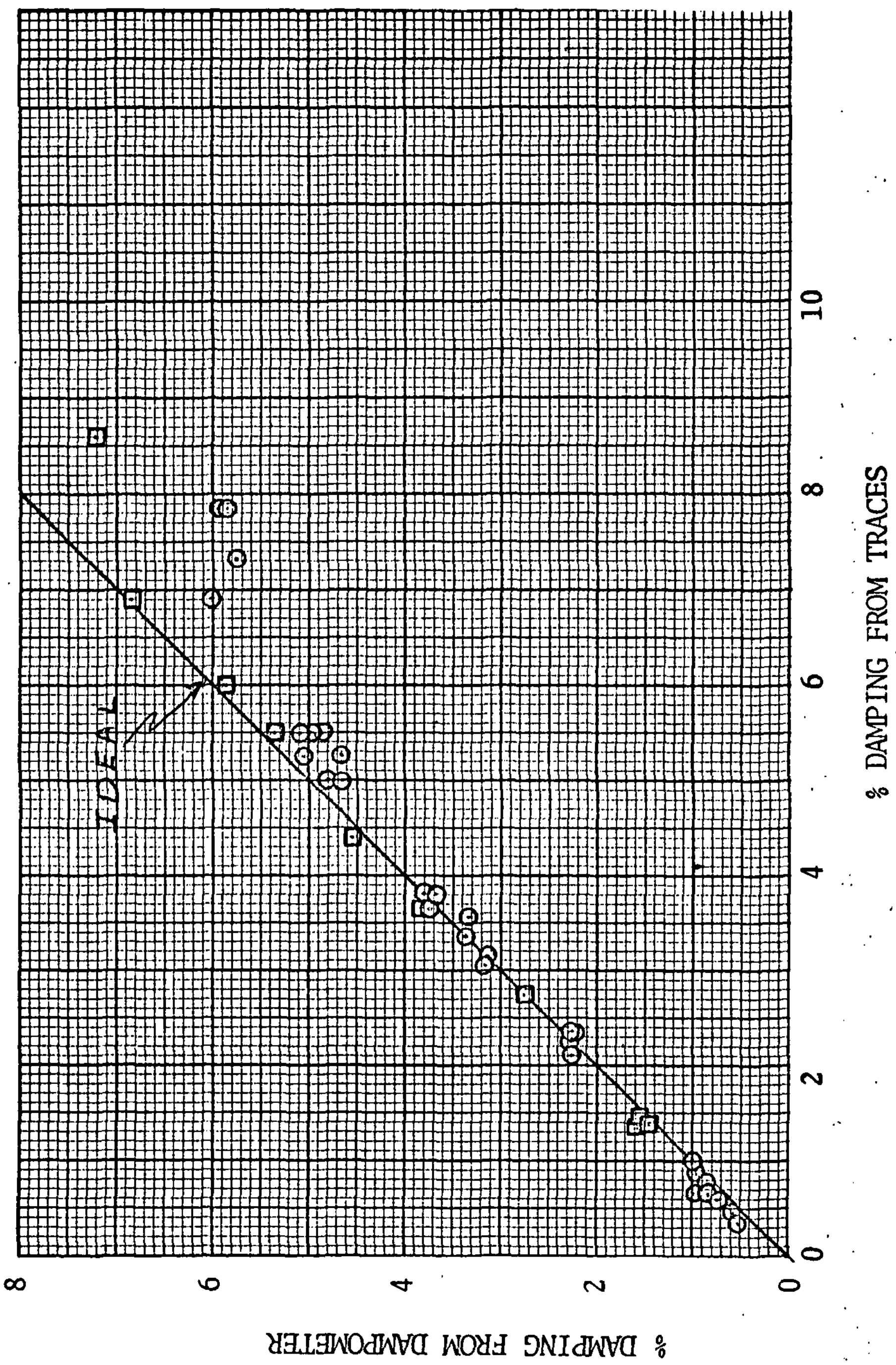
DAMPOMETER NUMBER OF CYCLES TEST

DAMPING GENERATOR DATA

Date: 12/21/71

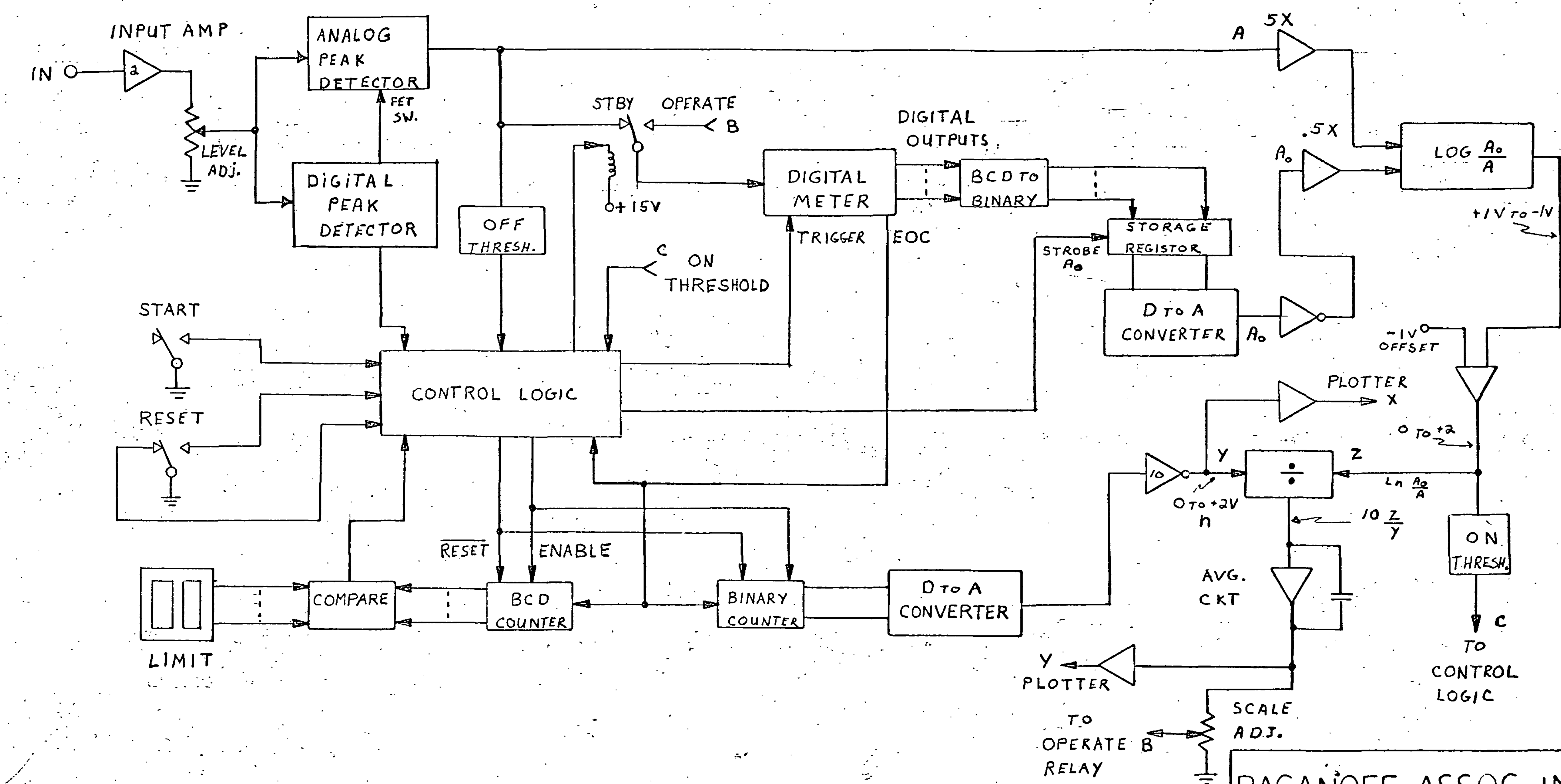
Record No.	Log Dec. Damping %	Dampometer Damping %	Cycle Limit
9	1.44	2.51	1
		1.45	2
		1.47	5
		1.43	10
		1.47	15
		1.58	20
		1.76	25
		1.80	30
6	3.68	2.00	1
		1.52	2
		2.01	3
		2.43	4
		2.65	5
		2.86	6
		3.03	7
		3.16	8
		3.24	9
		3.53	10
		3.45	15
		3.59	20



⊙ WIND TUNNEL DATA

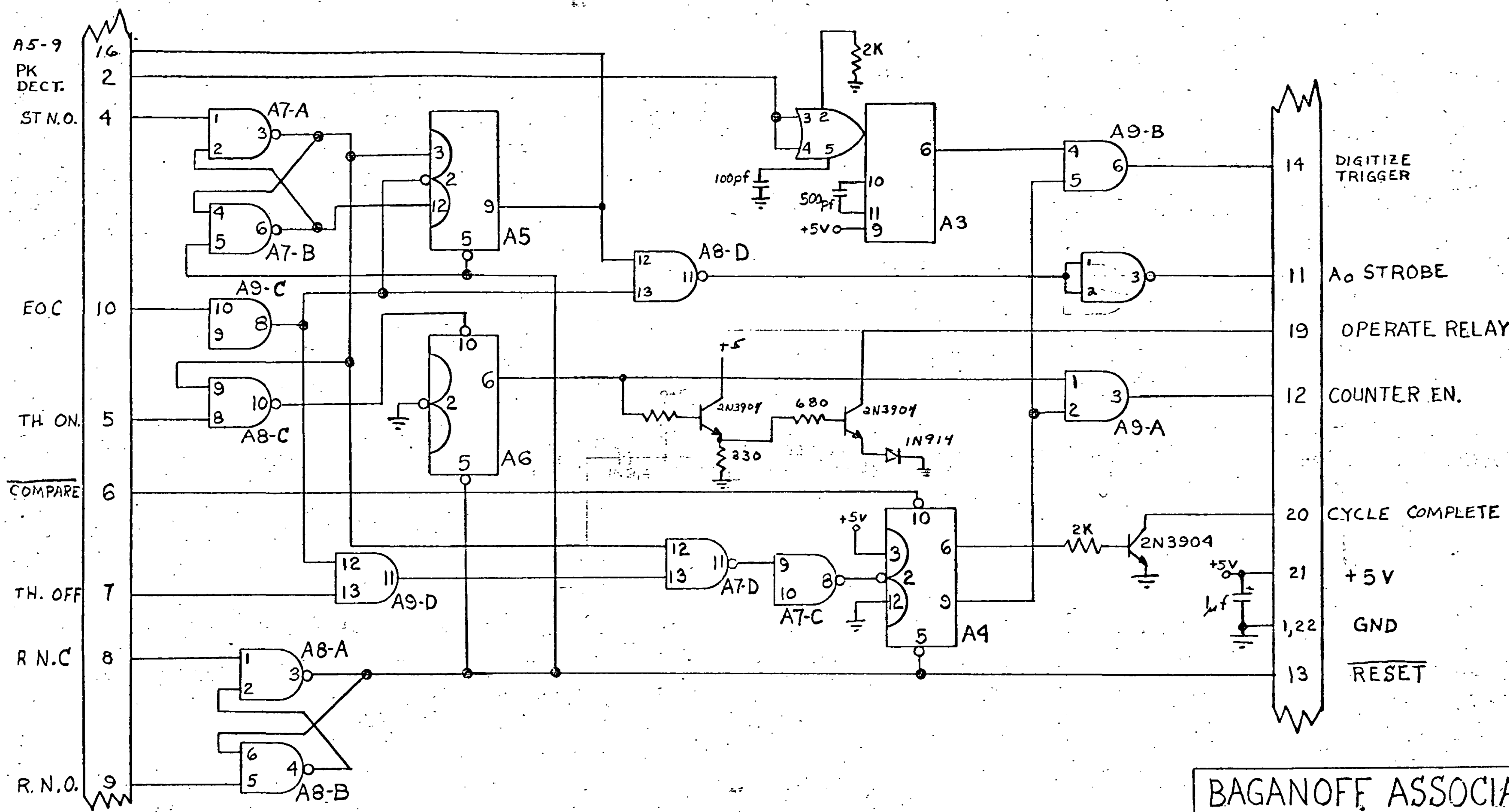
⊡ DAMPING GENERATOR DATA

AVERAGE OF THREE READINGS ON THE DAMPOMETER VERSUS DAMPING CALCULATED FROM OSCILLOGRAPH RECORDS



BAGANOFF ASSOC. IN

M/R revised	5-6-71 7-26-71	BLOCK DIAGRAM DAMPOMETER
9000		



NOTES: 1. ALL CIRCUITS PIN 7-GND, PIN 14-+5V
2. CIRCUIT TYPES - A3, MC851P—
A4, A5, A6, MC845P—A7, MC846P—
A8, MC857P—A9, MC3001P

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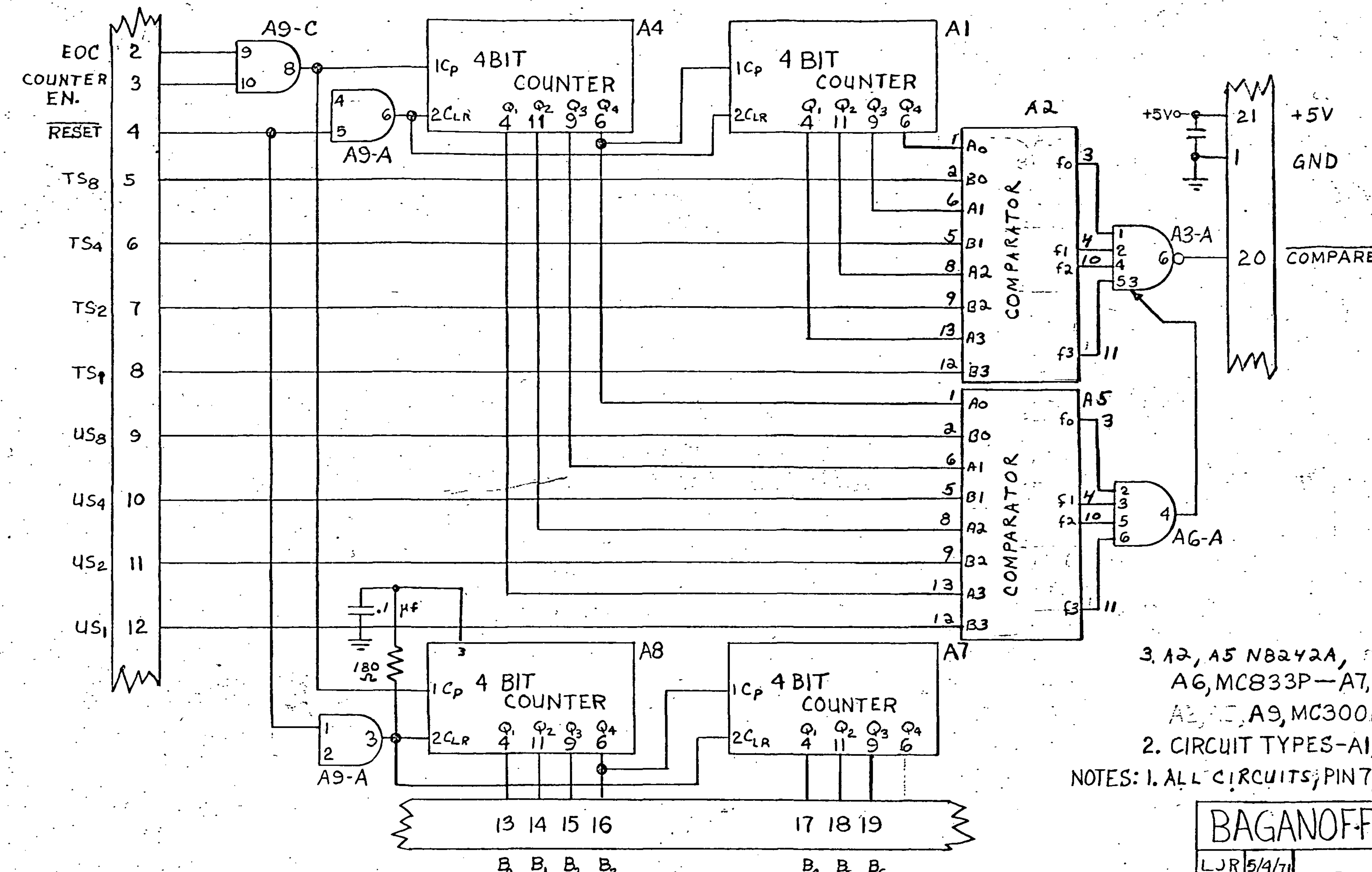
LJR	5/4/71	CONTROL LOGIC
Revised	MLR 12/27/72	
9001		



NOTES: 1. ALL CIRCUITS; PIN 7, GND - PIN 14, +5V

2. CIRCUIT TYPES - A1, A4, MC838P -
A9, MC3001P - A3, MC830P -
A6, MC833P - A7, A8, MC839P

3. A2, A5 N8242A,

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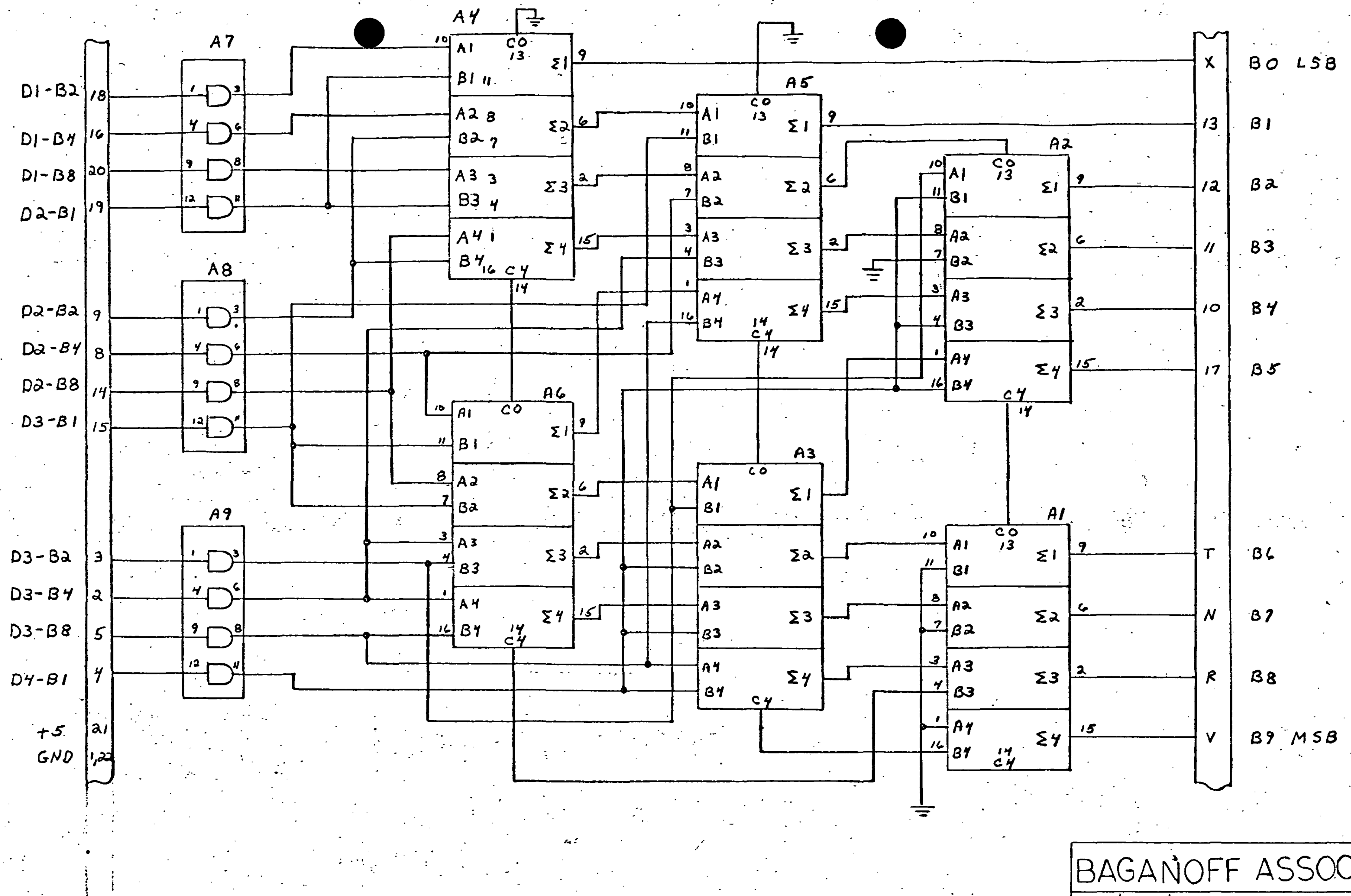
LJR	5/4/71	COUNTER & COMPARE
Revised	7-26-71	
9002		



NOTES:
1. A1 THRU A6 ARE SN7483N, Vcc = PIN 5, GND = PIN 12
2. A7, A8, A9 ARE MC3001P, Vcc = PIN 14, GND = PIN 7

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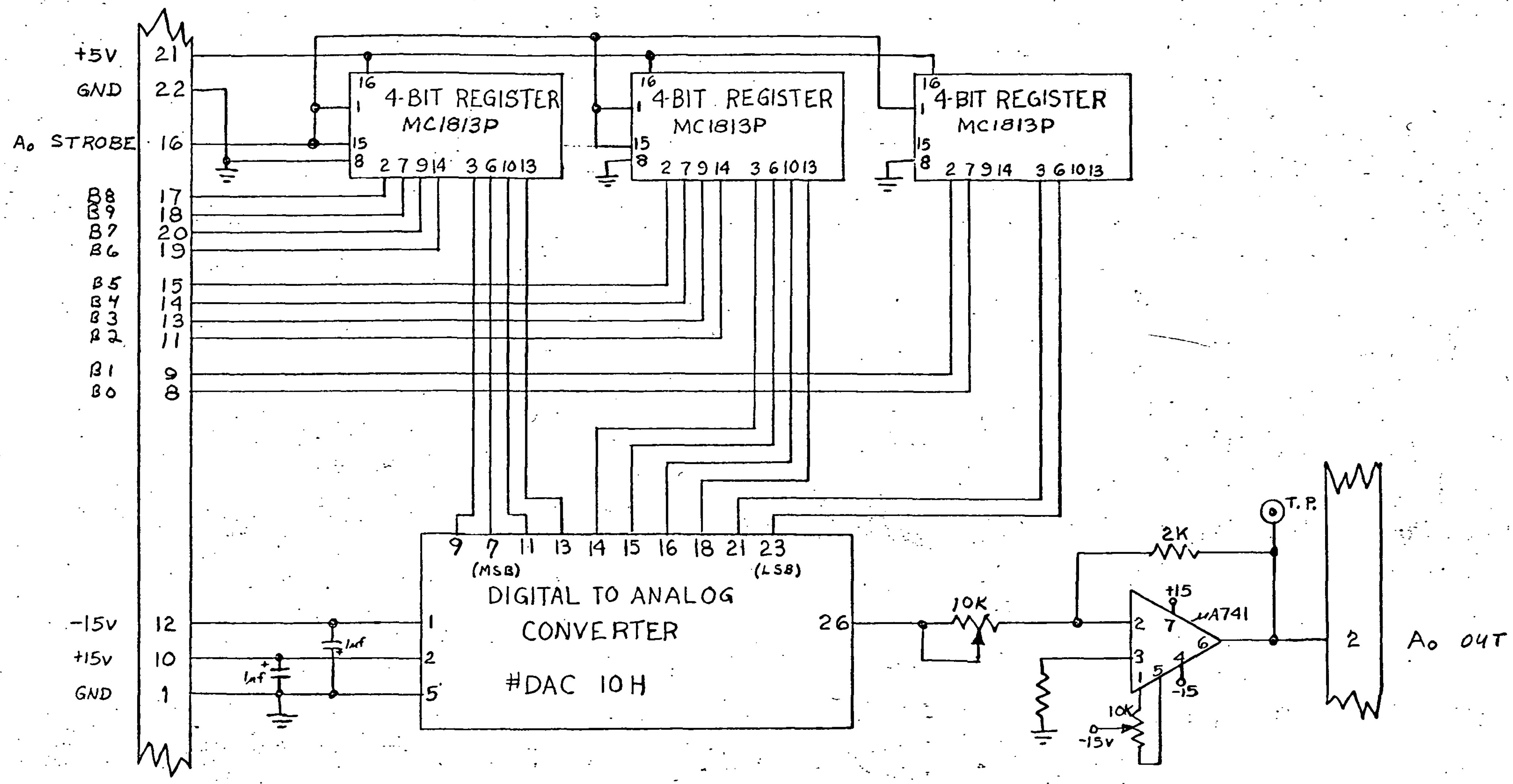
M/R	7-6-71	BCD TO BINARY CONVERTER

9003



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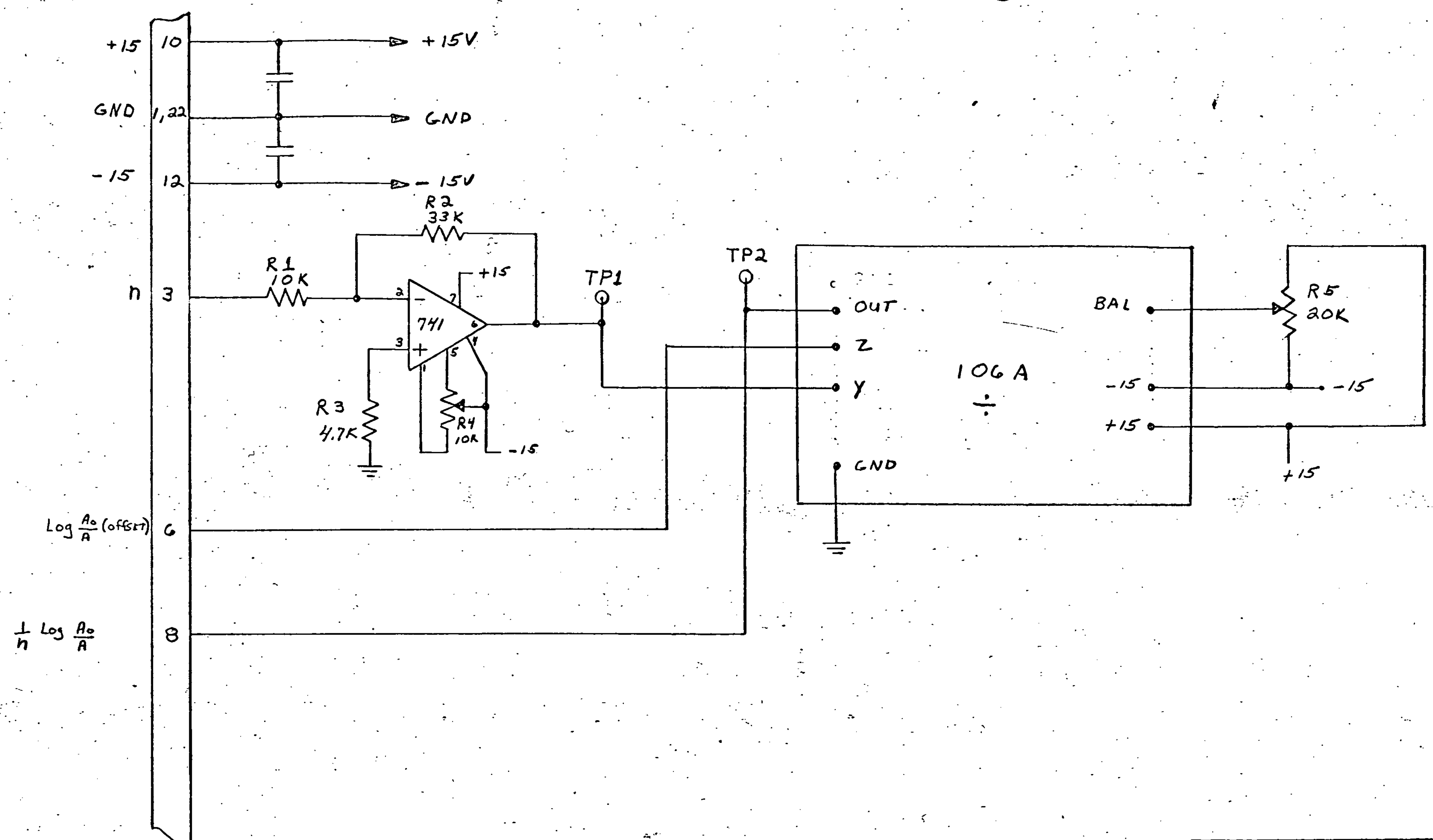
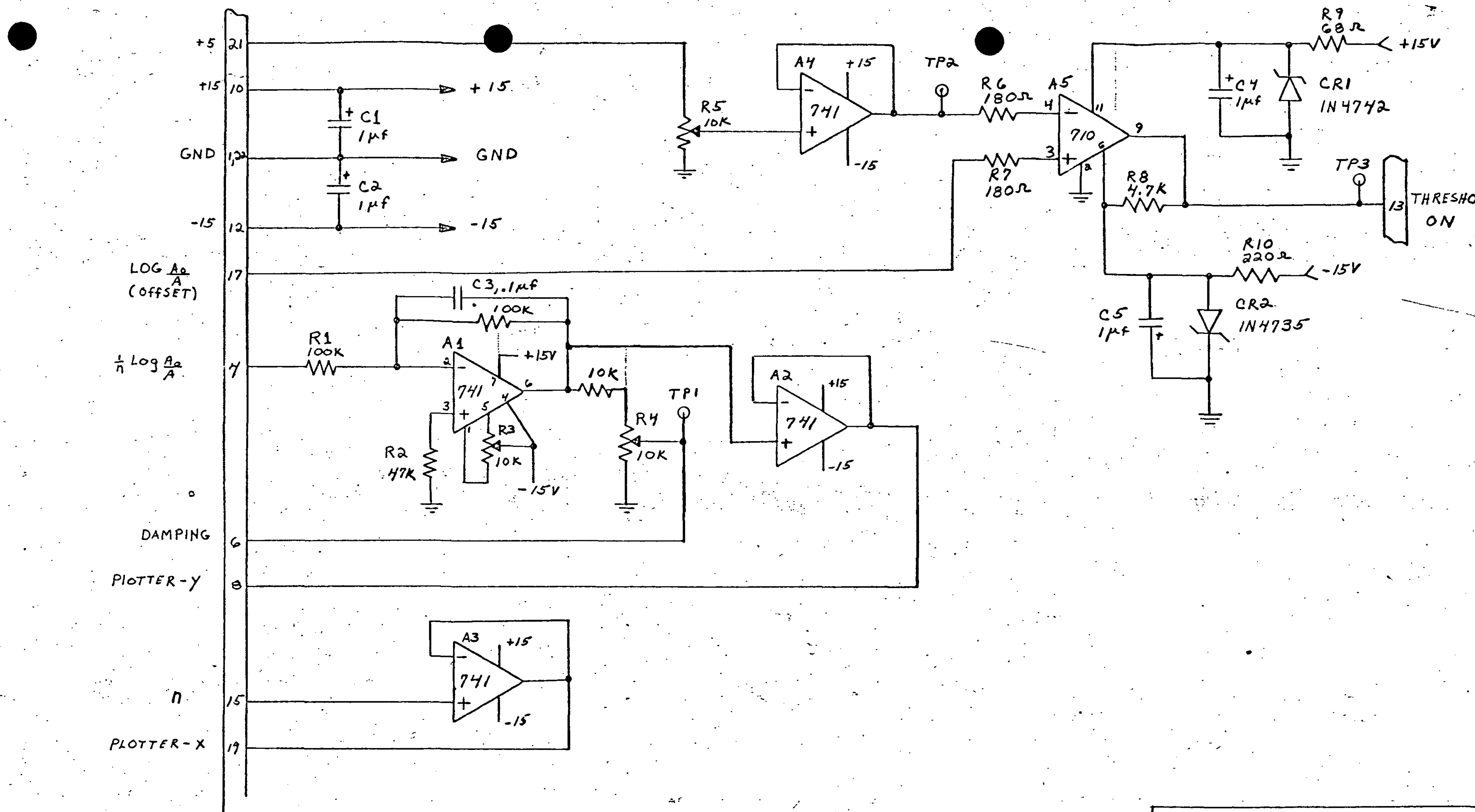
LJR	5/11/71	A_0 STORAGE
9004		



BAGANOFF ASSOC. INC.		
M/R	7-9-71	ANALOG DIVIDER CIRCUIT
9005		



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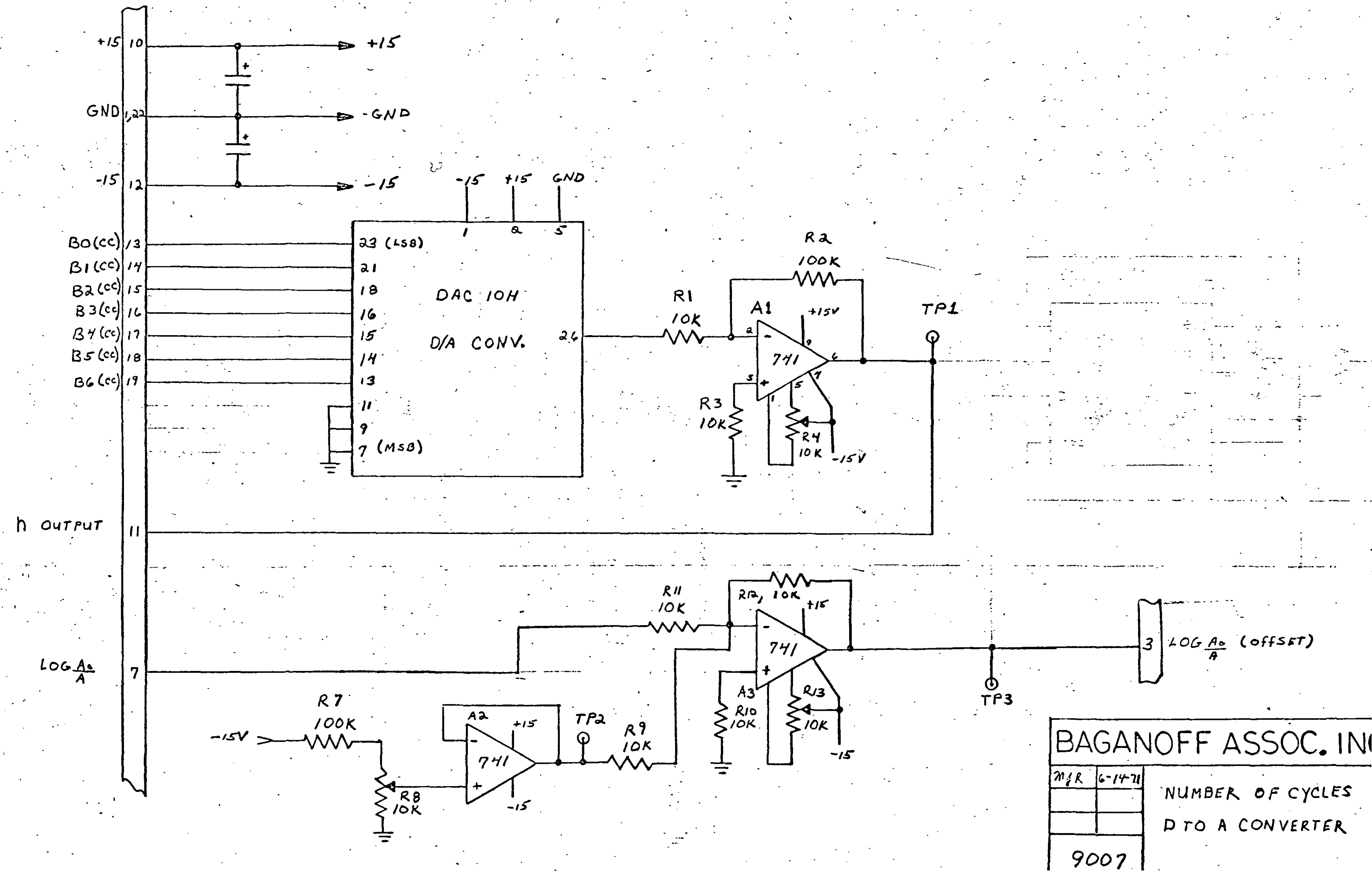
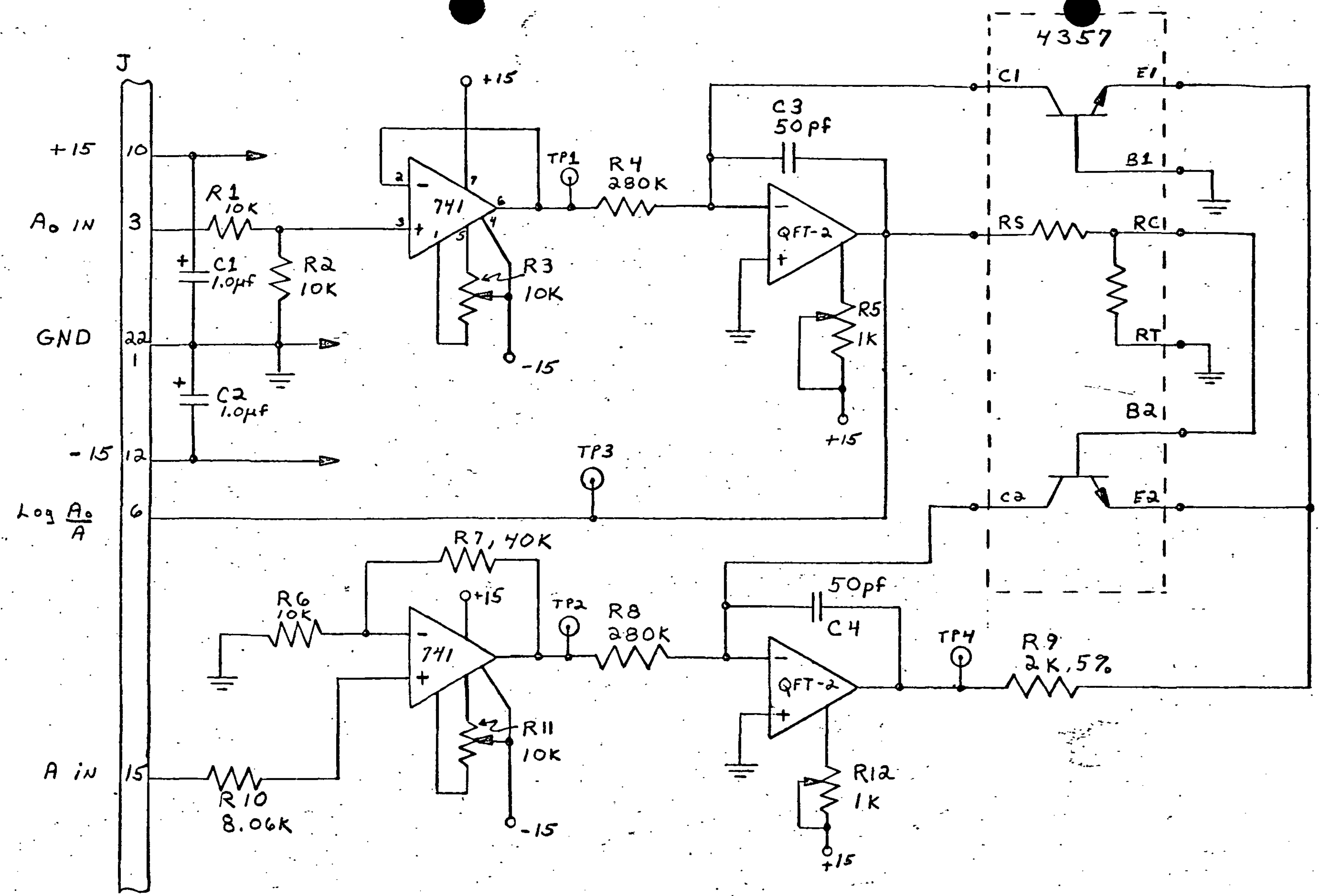
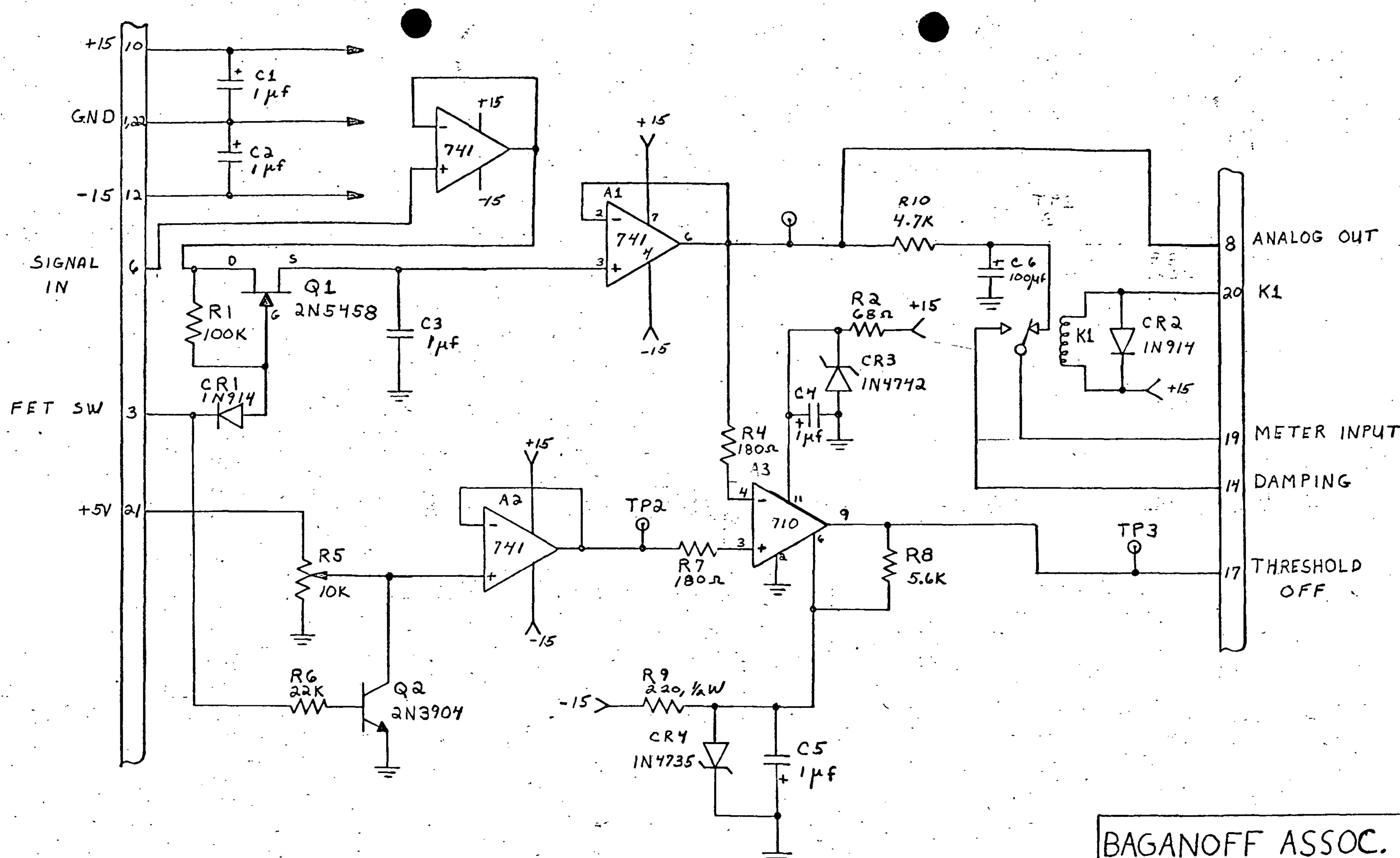
MJR	6-16-71	INTAGRATOR AND THRESHOLD ON
9006		


+15 10
GND 1,22
-15 12
+15
-GND
-15
-15 +15 GND
B0(cc) 13
B1(cc) 14
B2(cc) 15
B3(cc) 16
B4(cc) 17
B5(cc) 18
B6(cc) 19
23 (LSB)
21
18
16
15
14
13
11
9
7 (MSB)
DAC 10H
D/A CONV.
24
R1 10K
R2 100K
A1
741
+15V
-15V
TP1
R3 10K
R4 10K
h OUTPUT 11
LOG A0/A 7
R11 10K
R12, 10K
+15
741
A3
R10 10K
R13 10K
-15
TP3
3 LOG A0/A (OFFSET)
R7 100K
-15V
R8 10K
A2
741
+15
-15
TP2
R9 10K
BAGANOFF ASSOC. INC
NUMBER OF CYCLES
D TO A CONVERTER
6-14-71
9007



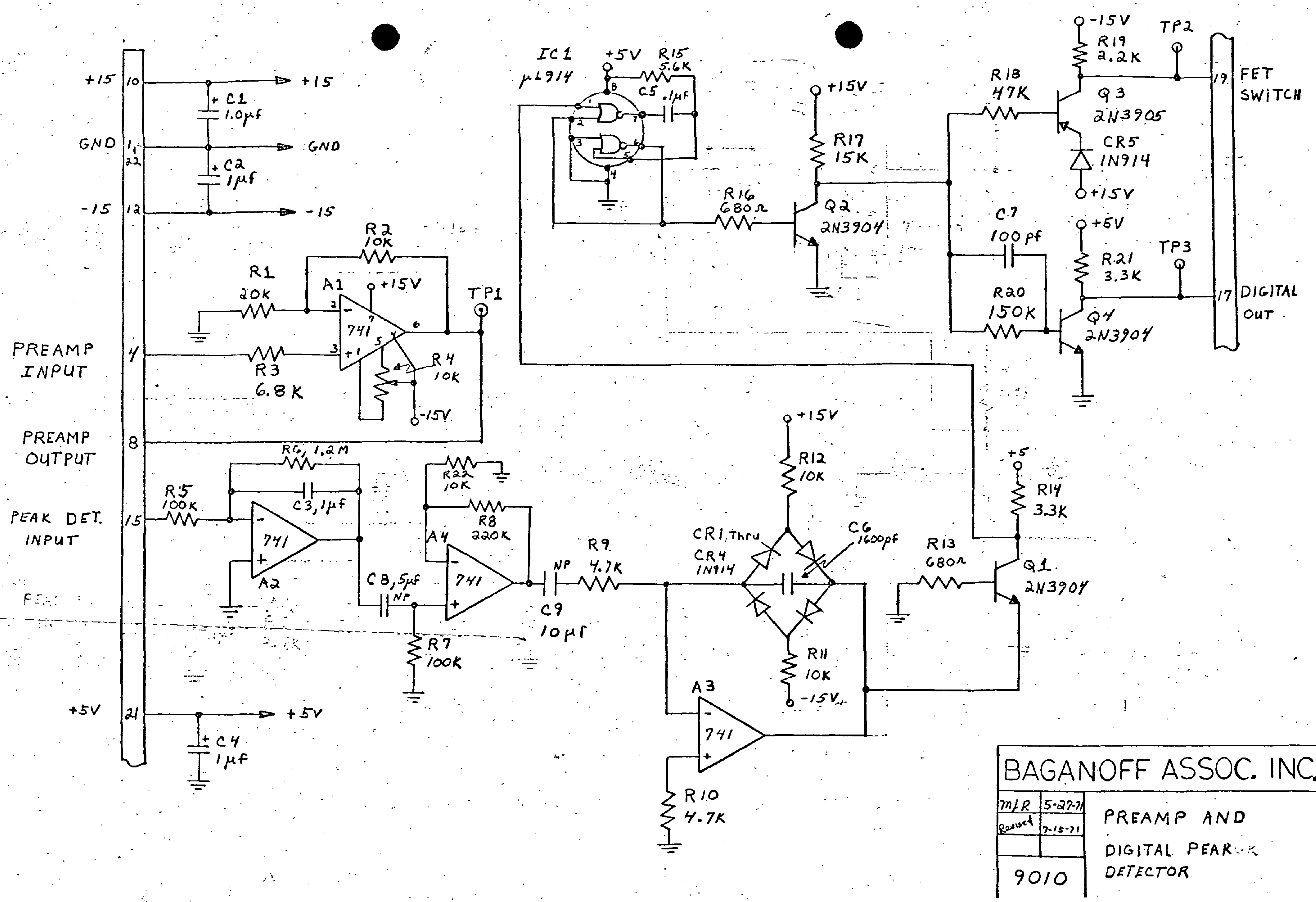
1. All RESISTORS ARE 1/4 WATT 1% UNLESS OTHERWISE NOTED

BAGANOFF ASSO. INC.		
M/R	4-3-71	LOG RATIO CIRCUIT
9008		



BAGANOFF ASSOC. INC

M/R	6-1-71	ANALOG PEAK DETECTOR AND THRESHOLD OFF
Revised	7-26-71	
9009		



+15
GND
-15
PREAMP INPUT
PREAMP OUTPUT
PEAK DET. INPUT
+5V
C1 1.0μf
C2 1μf
C4 1μf
R1 20K
R2 10K
R3 6.8K
R4 10K
A1
741
TP1
R5 100K
R6, 1.2M
C3, .1μf
A2
C8, 5μf NP
R7 100K
R22 10K
R8 220K
A4
C9 10μf NP
R9 4.7K
CR1 thru CR4 1N914
C6 1600pf
R12 10K
R11 10K
A3
R10 4.7K
R13 680Ω
Q1 2N3904
R14 3.3K
IC1 μL914
R15 5.6K
C5 .1μf
R16 680Ω
Q2 2N3904
R17 15K
R18 47K
Q3 2N3905
R19 2.2K
CR5 1N914
TP2
FET SWITCH
C7 100pf
R20 150K
R21 3.3K
Q4 2N3904
TP3
DIGITAL OUT
BAGANOFF ASSOC. INC.
MLR 5-27-71
Revised 7-15-71
9010
PREAMP AND DIGITAL PEAK DETECTOR

ANALOG SW.	PIN No	PREAMP AND DIGITAL PEAK DETECTOR	ANALOG PEAK DET. AND Thresh. off	LOG RATIO CIRCUIT	D TO A CONVERTER	INTEGRATOR AND THRESHOLD ON	ANALOG DIVIDE	A_0 STORAGE	BCD TO BINARY CONVERTER	COUNTER and COMPARE	CONTROL LOGIC	
GND	1	GND	GND	GND	GND	GND	GND	GND	1 / A	GND	GND	1
	2							A_0 OUT	D3 B4 2 / B	EOC	PEAK DECT	2
INPUT	3		FET SWITCH	A_0 IN	Log $\frac{A_0}{A}$ (offset)		n		D3 B2 3 / C	COUNTER EN.		3
	4	PREAMP INPUT				$\frac{1}{n}$ LOG $\frac{A_0}{A}$			D4 B1 4 / D	$\overline{RESET}$	ST. N.O.	4
	5								D3 B8 5 / E	TS8	THRESH. ON	5
OUTPUT	6		SIGNAL IN	Log A_0/A		DAMPING	Log $\frac{A_0}{A}$ (offset)		6 / F	TS4	$\overline{COMPARE}$	6
	7				LOG $\frac{A_0}{A}$				7 / H	TS2	THRESH. OFF	7
	8	PREAMP OUTPUT	ANALOG (A) OUT			PLOTTER-Y	$\frac{1}{n}$ Log $\frac{A_0}{A}$	B0	D2 B4 8 / J	TS1	R N.C.	8
	9							B1	D2 B2 9 / K	US8	R N.O	9
+15	10	+15	+15	+15	+15	+15	+15	+15V	B4 10 / L	US4	EOC	10
	11				n OUTPUT			B2	B3 11 / M	US2	A_0 STROBE	11
-15	12	-15	-15	-15	-15	-15	-15	-15V	B2 12 / N B7	US1	COUNTER EN.	12
	13				B0 (CC)	THRESHOLD ON		B3	B1 13 / P	B_0 (CC)	$\overline{RESET}$	13
	14		DAMPING		B1 (CC)			B4	D2 B8 14 / R B8	B_1 (CC)	DIGITIZE TRIG.	14
	15	PEAK DET. INPUT		A IN	B2 (CC)	n		B5	D3 B1 15 / S	B_2 (CC)		15
$\overline{RESET}$	16				B3 (CC)			A_0 STROBE	D1 B4 16 / T B6	B_3 (CC)	A5-9	16
	17	DIGITAL OUT	THRESHOLD OFF		B4 (CC)	LOG $\frac{A_0}{A}$ (OFFSET)		B8	B5 17 / U	B_4 (CC)		17
A5-9	18				B5 (CC)			B9	D1 B2 18 / V B9	B_5 (CC)		18
	19	FET SWITCH	METER INPUT		B6 (CC)	PLOTTER-X		B6	D2 B1 19 / W	B_6 (CC)	OP. RELAY (K)	19
PEAK DET.	20		K1					B7	D1 B8 20 / X B0	$\overline{COMPARE}$	CYCLE COMP.	20
+5	21	+5	+5	+5	+5	+5	+5	+5V	+5 21 / Y +5	+5V	+5V	21
GND	22	GND	GND	GND	GND	GND	GND	GND	GND 22 / Z GND	GND	GND	22
		10	9	8	7	6	5	4	3	2	1	

BAGANOFF ASSOC. INC.

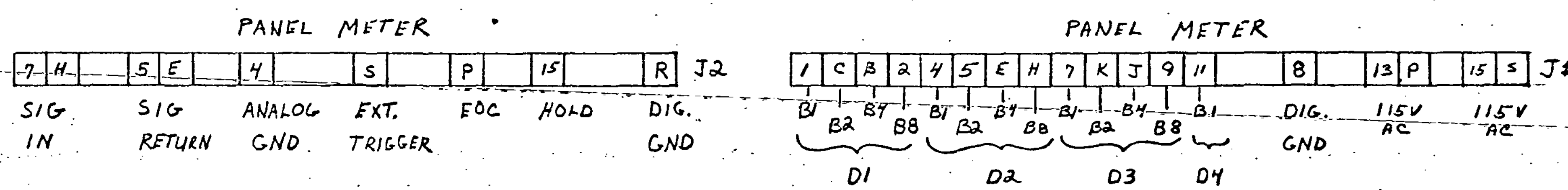
M/R	7-6-71	CARD FILE
9011		

S2 - CARD FILE

Pin	Assignment
1	PRE AMP OUTPUT
2	PEAK DETECTOR INPUT
3	METER INPUT
4	U1 (DIGITAL SWITCH)
5	U2 (DIGITAL SWITCH)
6	U4 (DIGITAL SWITCH)
7	U8 (DIGITAL SWITCH)
8	EXT. TRIGGER (DIGITIZE)
9	EOC
10	B1 (D1)
11	B2 (D1)
12	B4 (D1)
13	B8 (D1)
14	B1 (D2)
15	B2 (D2)
16	B4 (D2)
17	B8 (D2)
18	B1 D3
19	+5V
20	SHIELD (PINS 1 + 2)
21	SHIELD (PIN 3)
22	T1 (DIGITAL SWITCH)
23	T2 (DIGITAL SWITCH)
24	T4 (DIGITAL SWITCH)
25	T8 (DIGITAL SWITCH)
26	CYCLE COMPLETE
27	
28	
29	
30	RESET N.O.
31	RESET N.C.
32	START N.O
33	
34	
35	
36	
37	GND

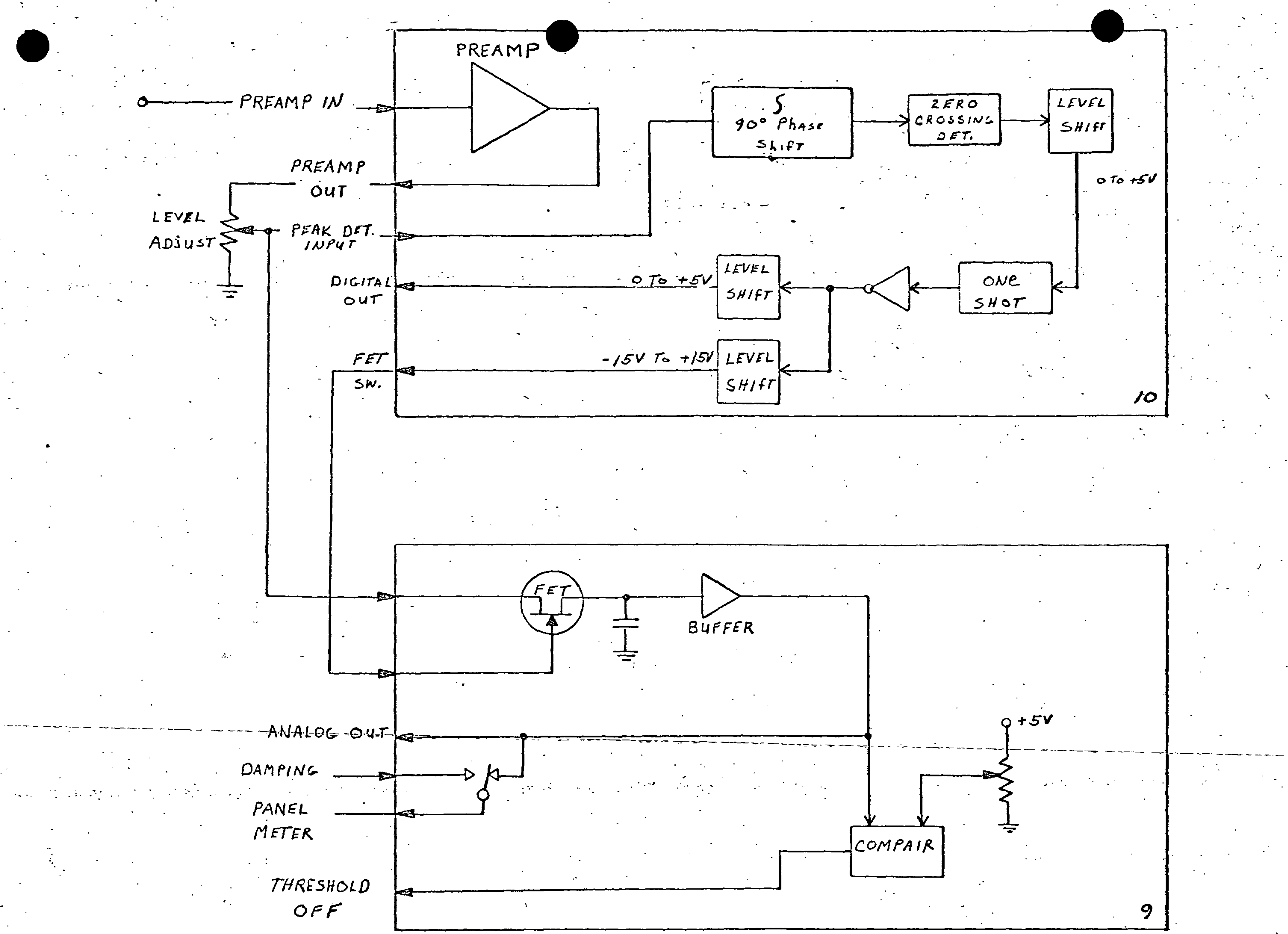
P1 CARD FILE

Pin	Assignment
A	+5V
B	ANALOG SWITCH INPUT
C	GND
D	SHIELD (ANALOG SWITCH INPUT)
E	Y OUTPUT SHIELD
F	SHIELD (ANALOG SWITCH OUTPUT)
H	-15V
J	X OUTPUT
K	Y OUTPUT
L	ANALOG SWITCH OUTPUT
M	INPUT SHIELD
N	X OUTPUT SHIELD
P	+15V
R	INPUT



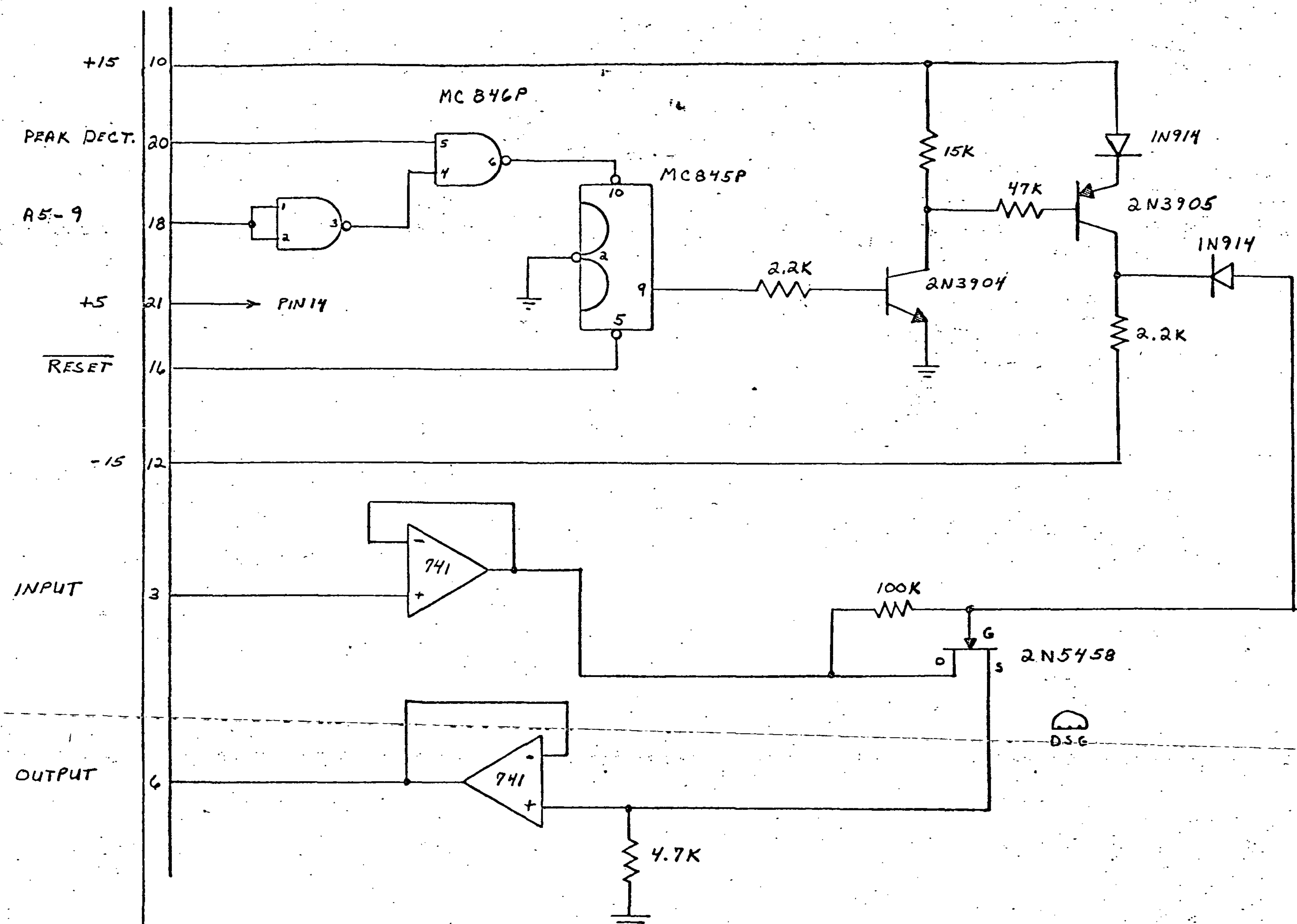
BAGANOFF ASSOC. INC.

M.I.R.	6-7-71	CONNECTOR PIN ASSIGNMENTS
9012		



BAGANOFF ASSOC. INC

M/R	6-7-71	BLOCK DIAGRAM
Revised	7-15-71	ANALOG AND DIGITAL PEAK DETECTOR
9013		



ANALOG SWITCH
12/27/71
m/l 9014

3.0 SUPPORT OF WIND TUNNEL TESTS

Baganoff Associates Incorporated (BAI) under previous contracts to NASA has developed a system to reduce wind tunnel data, either from magnetic tape or on-line at the test site. For the Skylab 2 program, the Ground Winds Data Reduction System (GWDRS) was installed in the control room of the wind tunnel at Langley Research Center, Hampton, Virginia. A fourteen track tape recorder is contained in the GWDRS, as well as a special purpose analog computer and a six pen X-Y plotter. Therefore, the GWDRS served both as the main data recording device, and as an on-line data reduction system.

Data were collected and recorded on the tape recorder from two pairs of strain gages at different levels on the model. Also the outputs of a pair of accelerometers on the damper, and a pair of tip accelerometers were recorded. While the data were being recorded, the analog computer reduced the data from the base strain gages into fullscale static and dynamic bending moments, and plotted the results versus wind velocity on the X-Y plotter. NASA personnel directing the testing were thereby furnished with on-line monitoring of critical loads, and also had data immediately available to evaluate the testing progress.

Upon completion of the wind tunnel tests, BAI transported the GWDRS back to its headquarters in St. Louis. Data tapes were dubbed and sent to BAI for final reduction.

4.0 DATA REDUCTION

4.1) General - Data reduced under Contract NAS8-26703 were collected at the Langley Transonic Dynamics Wind Tunnel. The tunnel was equipped with a rotating platform on which the model and launcher umbilical tower were mounted, providing the capability to change the wind azimuth angle. Model dynamic pressures up to 185 psf were tested simulating fullscale wind velocities up to 70 knots.

4.2) Wind Tunnel Models - The models used in these tests are 5% scale versions of the vehicle launcher umbilical tower and S1B, Skylab 2 rocket. The S1B model was tested under five simulated configurations, empty primary, empty secondary, intermediate weight (RP1 IN S1B STAGE, SPACECRAFT FUELED), completely fueled primary, and completely fueled secondary. The S1B model was equipped with a variable damping system, the damping being controlled by instrumentation in the tunnel control room.

4.3) Instrumentation - Instrumentation was provided on the S1B model to measure in-plane and out-of-plane bending moments at model stations 11.18, and 59.25 (fullscale stations 203.27, and 1077.27 respectively). This was accomplished by attaching a pair of strain gages at these body stations at a 90 degree angle with each other. In-plane bending moments are defined as those caused by forces acting in the vehicle-launcher umbilical tower plane of symmetry, while out-of-plane bending moments are due to forces perpendicular to the plane of symmetry.

In addition to the strain gages, in-plane and out-of-plane accelerometers were located on the damper, and a pair of accelerometers were located at the tip of the model.

Wind tunnel pressure (H-P) was measured in the tunnel at a point equivalent to fullscale vehicle body station 1500.

4.4) Data Reduction - Wind tunnel data reduction involves separating the lift and drag components from a pair of strain gages, computing the static and dynamic bending moments, and combining them to compute the resultant vector. This analysis is accomplished by using the special purpose analog computer in the Ground Winds Data Reduction System (GWDRS).

Figure (4.1) defines the lift and drag components as related to a pair of in-plane and out-of-plane strain gages. Each lift and drag vector contains both static and dynamic components. Using matched filters, the GWDRS separates the static and dynamic portions of the strain gage signals and sums the appropriate components to compute static and dynamic lift and drag bending moments. The resultant bending moment is obtained by computing the square root of the sum of lift and drag bending moments squared. All parameters are simultaneously plotted versus velocity which is computed by taking the square root of the wind tunnel pressure (H-P).

Figure (4.2) is a block diagram of the GWDRS. Signals from a strain gage pair are filtered by low pass and bandpass filters into static and dynamic components. Each component is then separated into lift and drag vectors by means of potentiometers P1 through P8. These potentiometers are also used to scale the data from model to fullscale and to compensate for gain/attenuation settings of the instrumentation. Following the potentiometers are four summing amplifiers which add the instantaneous values of static and dynamic lift and drag to compute Static Lift, Dynamic Lift, Static Drag, and Dynamic Drag Bending Moments. These solutions are brought out to Y-axes of the X-Y plotter for recording.

From the first four summing amplifiers, static and dynamic signals are added together to form the total Lift and Drag Bending Moments. These bending moments are then squared, summed, and the square root of the sum taken. At the output of these computations the Resultant Bending Moment is obtained. The Resultant B. M. is brought out to the X-Y plotter for recording.

The GWDRS also calculates the fullscale wind velocity by scaling the H-P input (dynamic pressure) with potentiometer P9 and taking the square root. Velocity is related to dynamic pressure by the equation:

$$\text{H-P} = \frac{1}{2} p \, v^2$$

Therefore, P9 lumps together the constant $\frac{1}{2} p$, the velocity scale factor to transform from model to fullscale and compensates for the gain/attenuation settings of the instrumentation. The computed velocity is brought out to the X-axis of the X-Y plotter so that all of the aforementioned bending moments are plotted against velocity.

While it is necessary to discuss the activities of the analog computer in a serial manner, all of the above computations are performed instantaneously at the same moment in time. Lift and Drag Bending Moments, Velocity, Dynamic Pressure, and Resultant Bending Moment are all solutions obtained from signals from the model instrumentation.

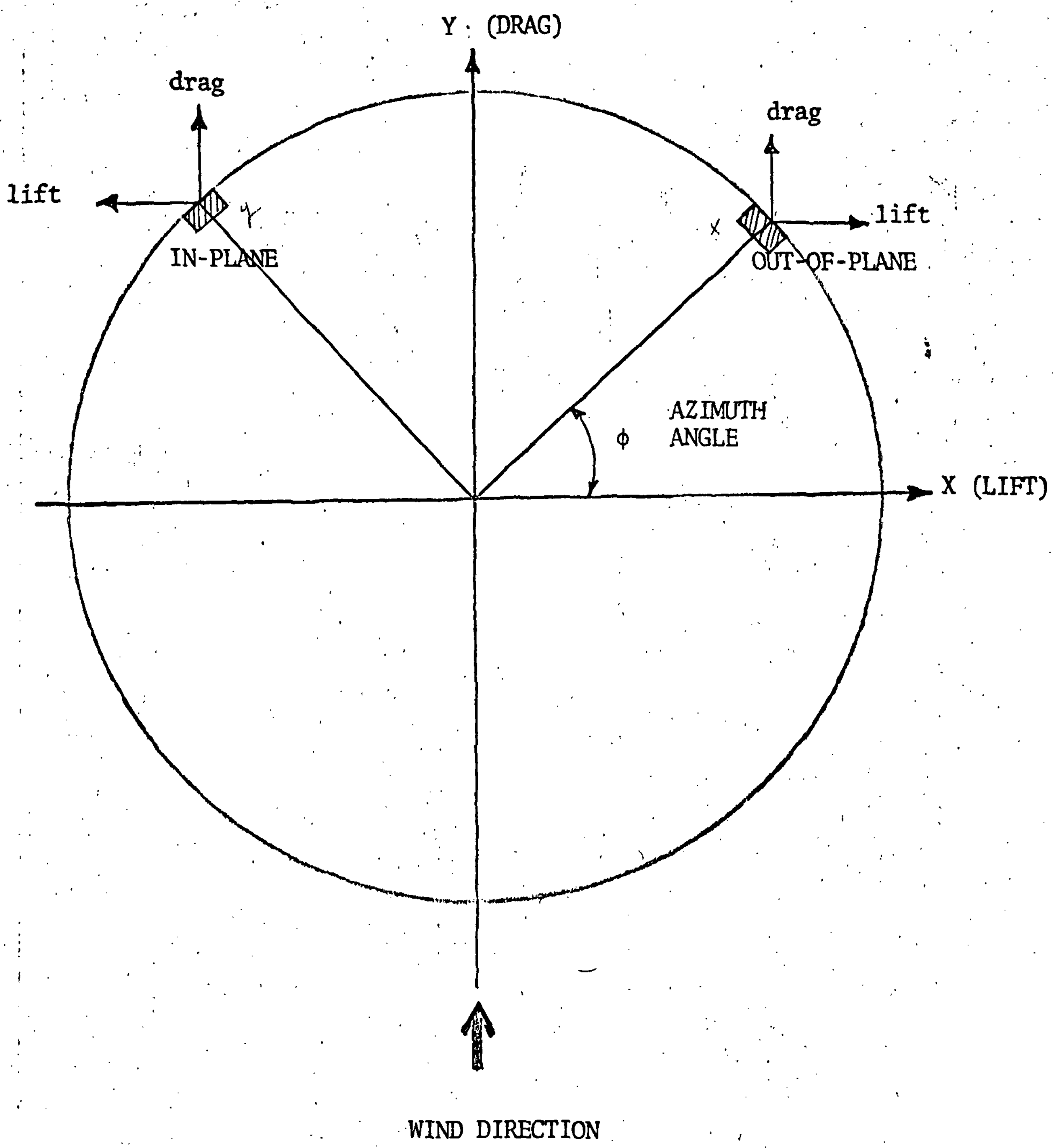


FIGURE (4.1): LIFT AND DRAG BENDING MOMENTS

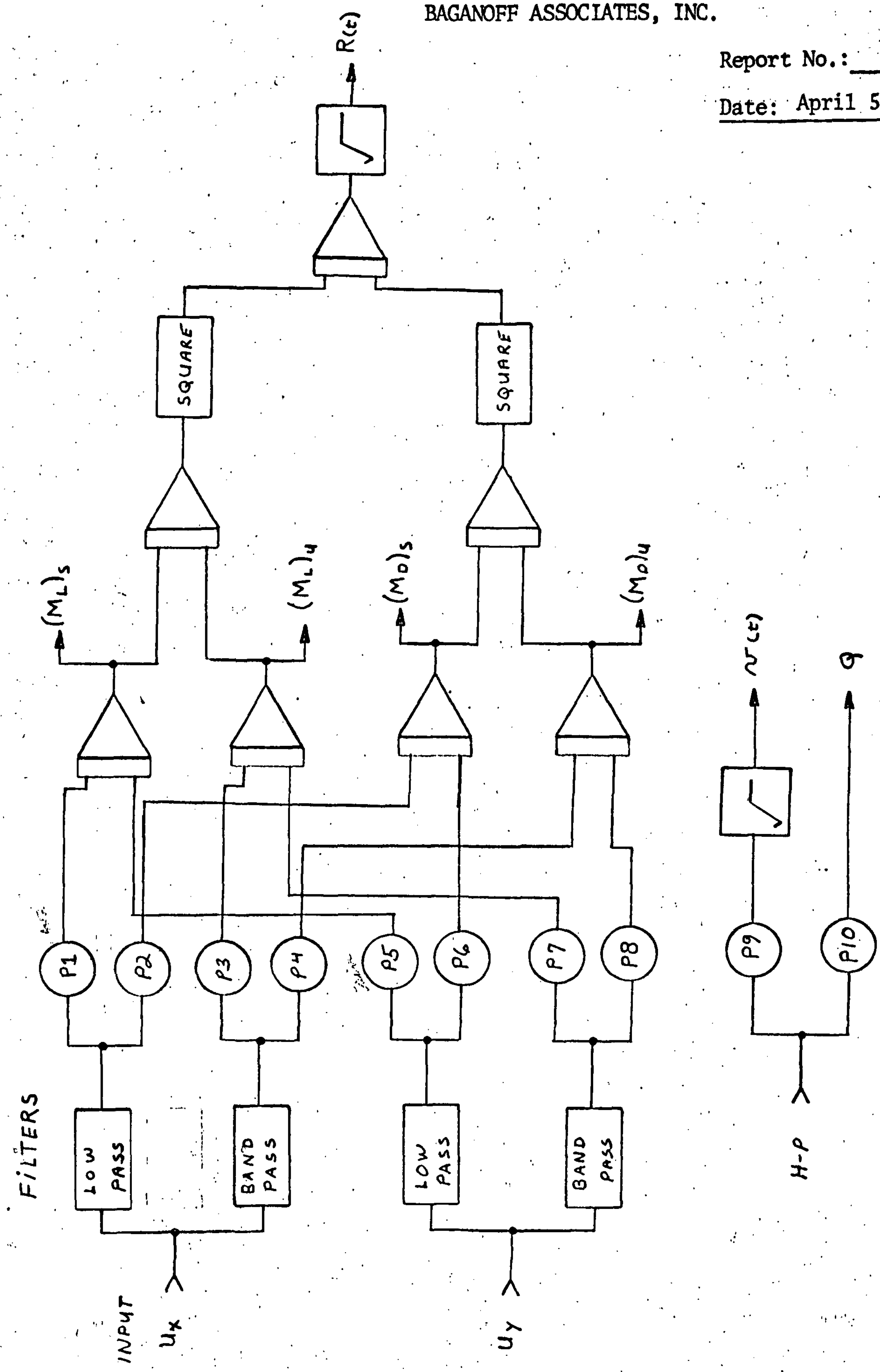


FIGURE (4.2): BLOCK DIAGRAM, ANALOG COMPUTER SECTION OF GROUND WINDS DATA REDUCTION SYSTEM

5.0 RESULTS

Under this contract a total of 178 data points were reduced. For each data point the following plots were made:

A. Resultant Bending Moment Versus Velocity

B. Dynamic Lift Bending Moment Versus Velocity

C. Static Lift Bending Moment Versus Velocity

D. Dynamic Drag Bending Moment Versus Velocity

E. Static Drag Bending Moment Versus Velocity

F. Static Drag Bending Moment Versus Dynamic Pressure

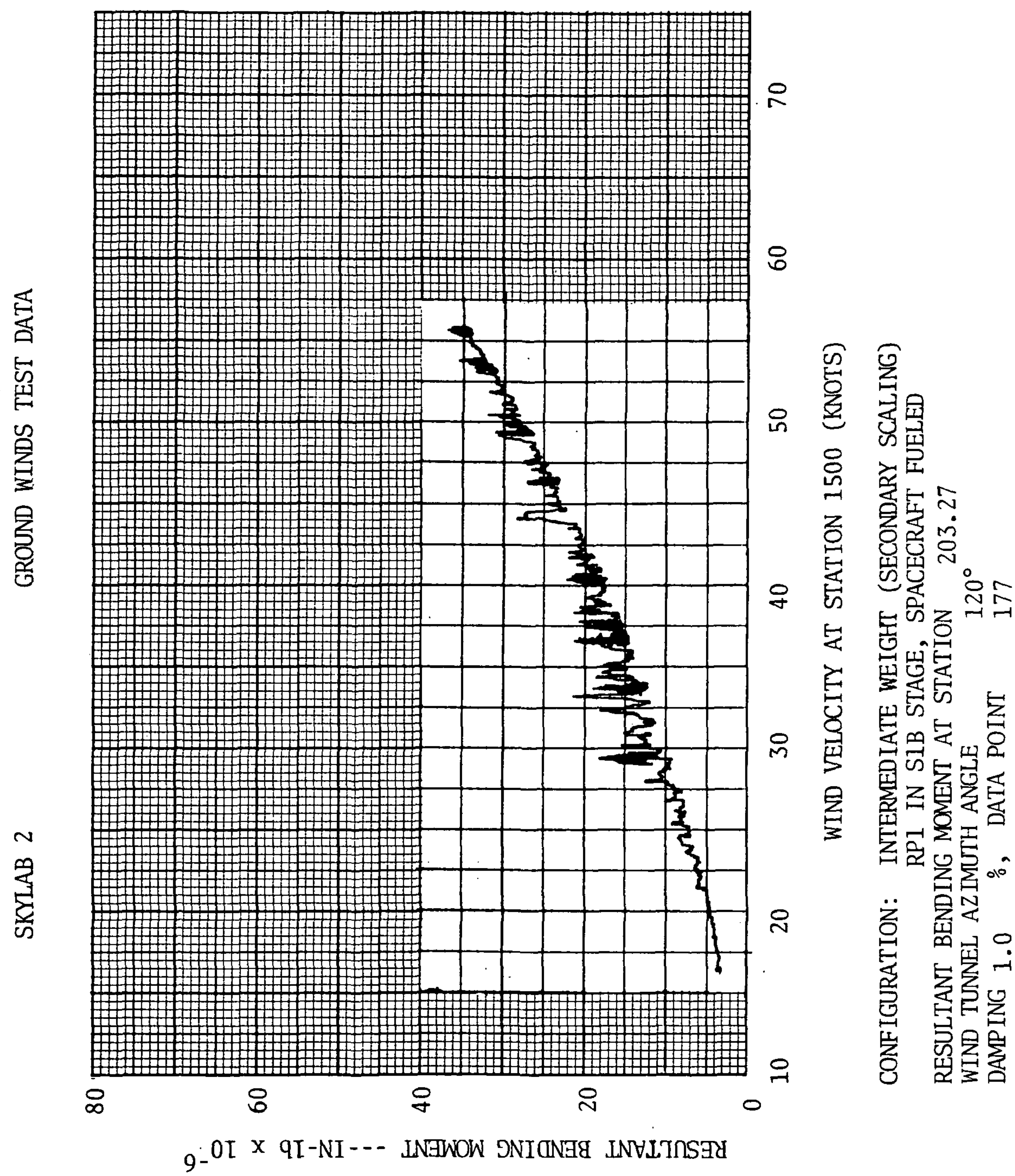
Data from the first level of strain gages were reduced. Therefore a total of 1,068 data plots were produced and delivered to NASA/MSFC personnel. These plots were in addition to the preliminary data provided during the actual wind tunnel tests.

Sample plots from one of the data points are enclosed at the end of this section. The sample set of plots consists of the six bending moment plots mentioned above for the first level of strain gage instrumented body stations. For final presentation, the data plots were cut from the X-Y plotter paper and mounted on master forms on which the pertinent information pertaining to the given data points had been typed.

BAGANOFF ASSOCIATES, INC.

Report No. 604

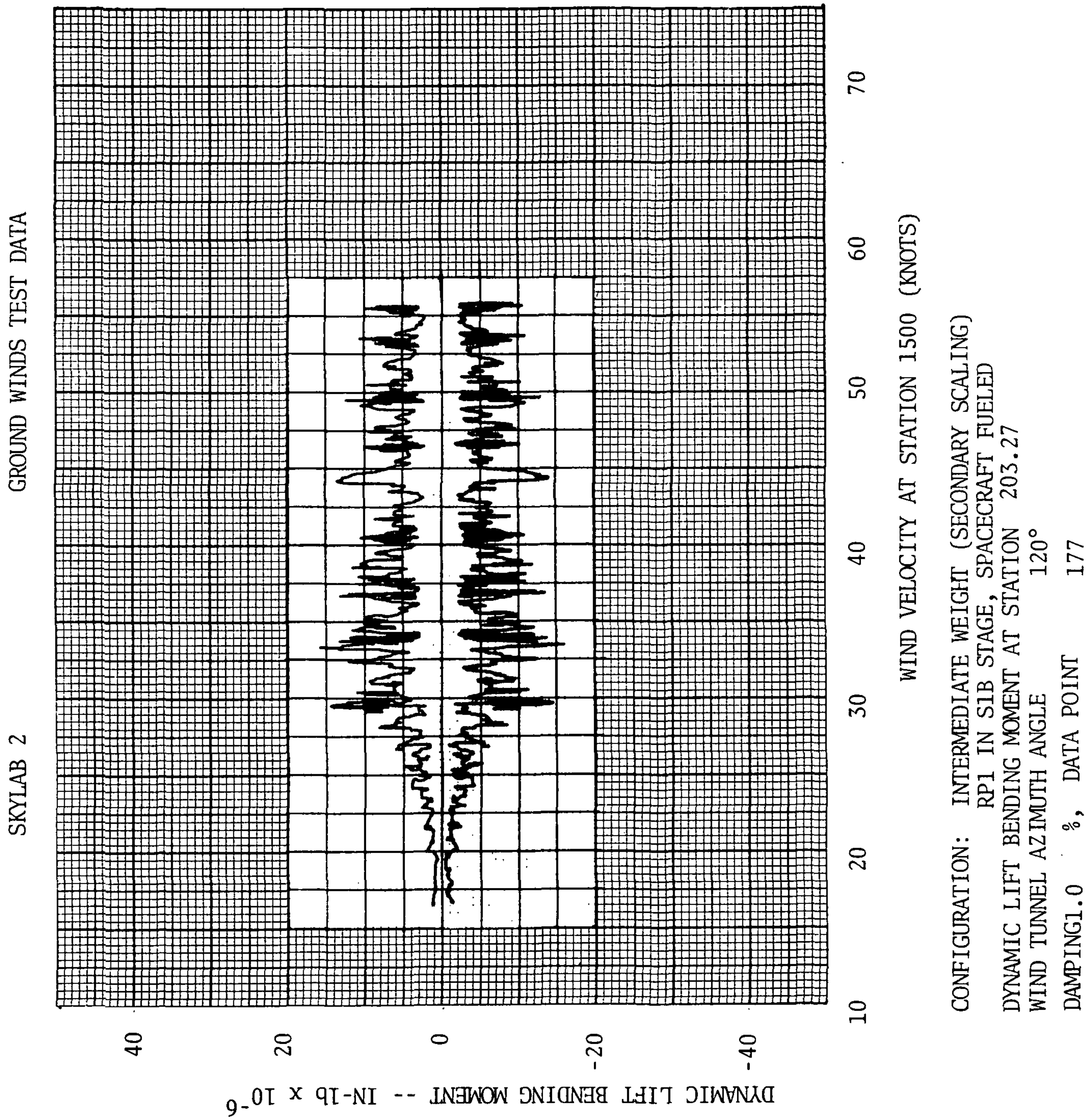
Date: April 6, 1972



BAGANOFF ASSOCIATES, INC.

Report No. 604

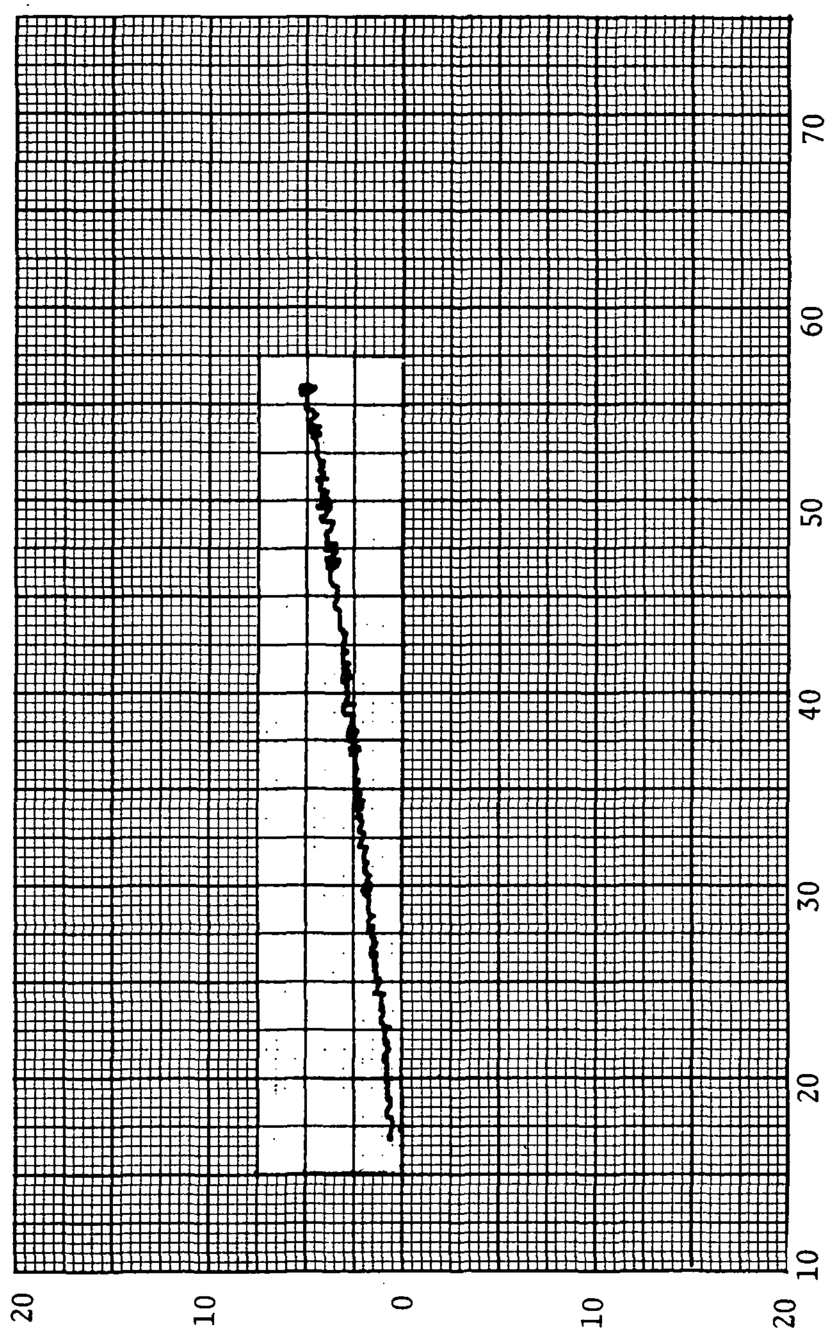
Date: April 6, 1972



BAGANOFF ASSOCIATES, INC.

Report No. 604

Date: April 6, 1972



CONFIGURATION: INTERMEDIATE WEIGHT (SECONDARY SCALING)
RP1 IN S1B STAGE, SPACECRAFT FUELED
STATIC LIFT BENDING MOMENT AT STATION 203.27
WIND TUNNEL AZIMUTH ANGLE 120°
DAMPING 1.0 %, DATA POINT 177

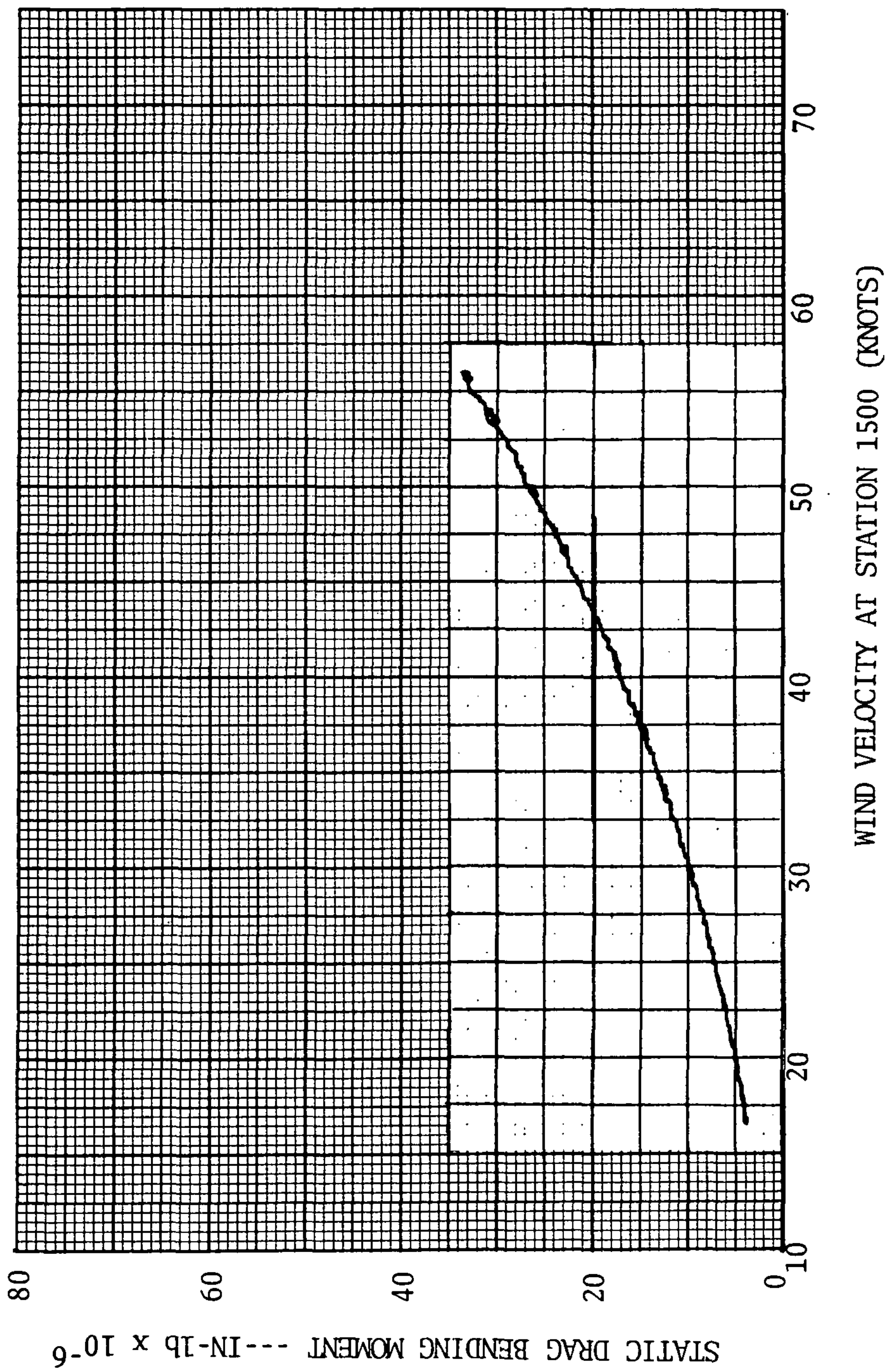
BAGANOFF ASSOCIATES, INC.

Report No. 604

Date: April 6, 1972

SKYLAB 2

GROUND WINDS TEST DATA



CONFIGURATION: INTERMEDIATE WEIGHT (SECONDARY SCALING)
RP1 IN S1B STAGE, SPACECRAFT FUELED

STATIC DRAG BENDING MOMENT AT STATION 203.27

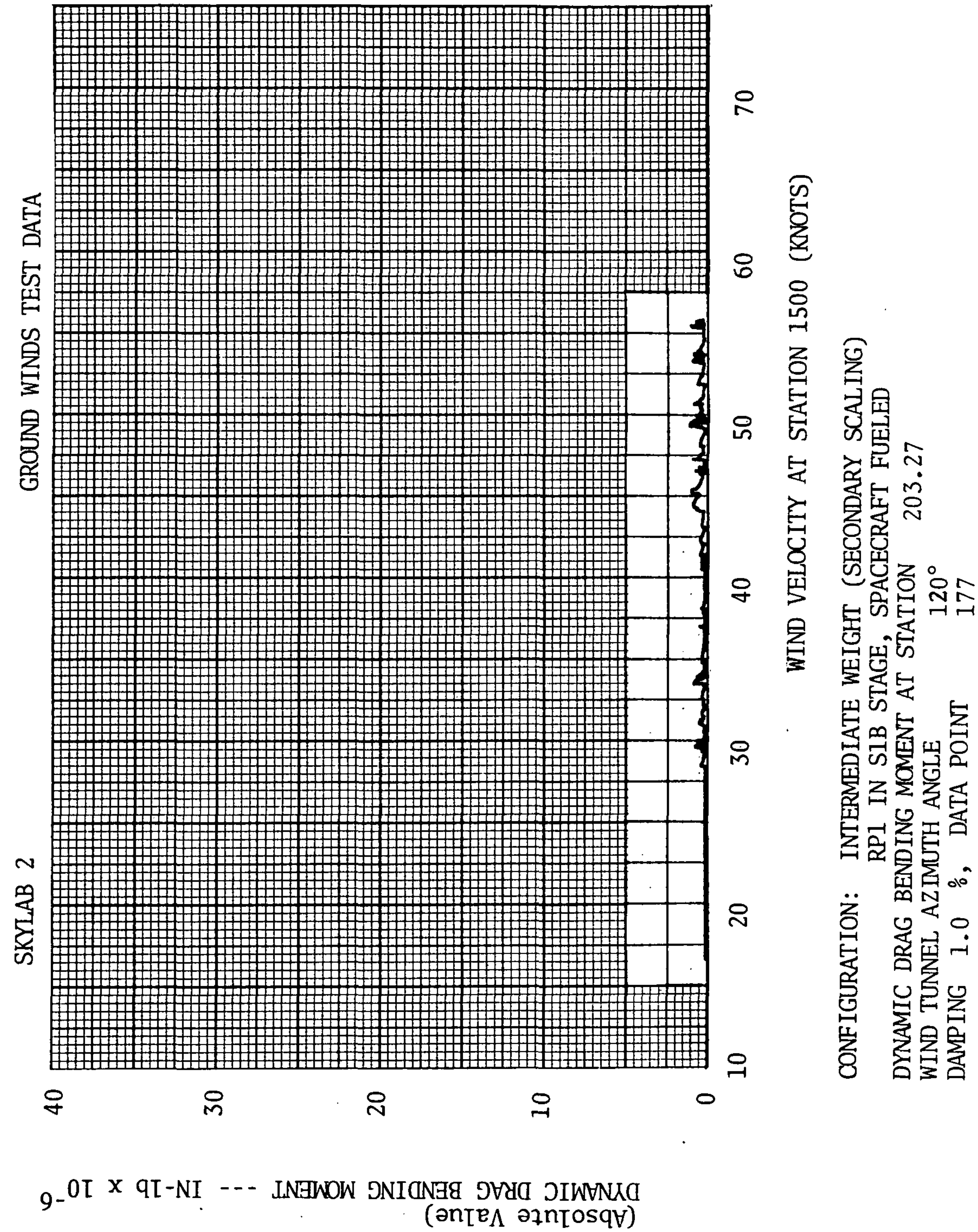
WIND TUNNEL AZIMUTH ANGLE 120°

DAMPING 1.0 %, DATA POINT 177

BAGANOFF ASSOCIATES, INC.

Report No. 604

Date: April 6, 1972



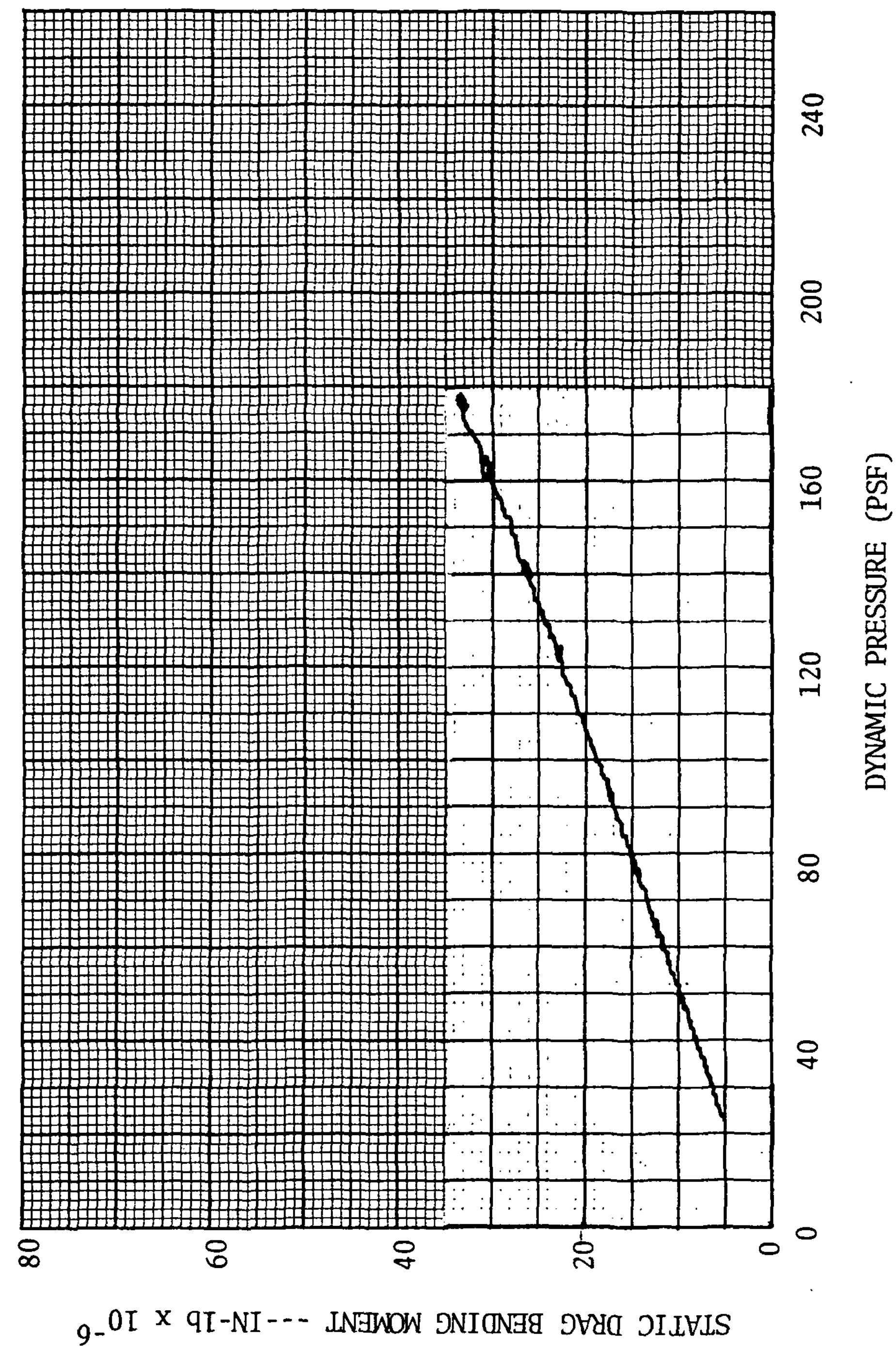
BAGANOFF ASSOCIATES, INC.

Report No. 604

Date: April 6, 1972

SKYLAB 2

GROUND WINDS TEST DATA



CONFIGURATION: INTERMEDIATE WEIGHT (SECONDARY SCALING)
RP1 IN S1B STAGE, SPACECRAFT FUELED

STATIC DRAG BENDING MOMENT AT STATION 203.27

WIND TUNNEL AZIMUTH ANGLE 120°

DAMPING 1.0 %, DATA POINT 177

6.0 CONCLUSION

The Dampometer which was developed under this contract proved to be accurate for ideal conditions of viscous damping. However, most structures are complex and do not respond in an ideal logarithmic decay as is required by the Dampometer. This being the case, the Dampometer would have limited applications in most structural conditions.

The Ground Winds Data Reduction System (GWDRS) in supporting wind tunnel tests, has established itself as a valuable test instrument which should be a requirement for conducting all future ground winds tests. In addition to on-line data reduction, the GWDRS is capable of functioning as a production data reduction system.