ELECTRONICS AND SPACE DIVISION

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RADAR PERFORMANCE IMPROVEMENT

FINAL REPORT

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TRACKING TECHNIQUES BRANCH

CONTRACT NUMBER: NAS 9-14760

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ELECTRONICS AND SPACE DIVISION
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(December 1, 1975 to July 31, 1976)

RADAR PERFORMANCE IMPROVEMENT

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APPENDICES

I. INTRODUCTION

In June 1973 the Electronics and Space Division of the Emerson Electric Co. proposed its AN/APQ-153 Fire Control Radar modified to provide angle tracking capability for evaluation by the National Aeronautics and Space Administration, Manned Space Center, for application as a test bed rendezvous system for the Space Shuttle.

This proposal was accepted and in July 1974 the Tracking and Communications Development Division of NASA/Johnson Space Center, Houston, received delivery of the Emerson Electric modified version of the operational AN/APQ-153 Fire Control Radar system.

In the time period from December 1974 to June 1975 Emersons' system underwent comparative evaluation with an RCA modified Apollo Rendezvous Radar (MARR). These activities in Rendezvous Radar test and evaluation were carried out by Lockheed Electronics Co., Inc., for the Tracking Techniques Branch, TACD of NASA/Johnson.

In November 1975 Emerson was placed under contract (NAS 9-14760) titled Radar Performance Improvements in order to provide some low cost but very desirable performance increases. This work was completed in June 1976 and the following constitutes the final engineering report. Consider the Contract Statement of Work, and the amendment to the Statement of Work, paragraph 3.3 on Interface Design, both reproduced in Appendix A. Consistent with this statement this final report is divided into three major sections: II. Frequency Agile AFC Modifications, III. Range Rate Improvement Modifications, and IV. Radar to Computer Interface Design. The Mods Marked-Up drawings are included in Appendix B. Finally, a Comparison Between Non-Coherent and Coherent Radars was done as an extra task and is included in Section V.

In Section II the Frequency Agile AFC Modifications are outlined in detail. With these changes it is estimated that the range at which the probability of single scan detection is 0.8 or greater is increased by at least 35%. Perhaps of more importance is the prediction that the target-induced range tracking part of the errors will be reduced by at least a factor of 2.5. These improvements may be confirmed in the coming test program by the ability to switch the Frequency Agility in and out.

In Section III the Range Rate Improvement Modifications are well indicated. The analysis shows that the changes made relative to the range-rate output should result in range-rate noise errors on the order of ± 3 ft/sec. With these modifications, and an additional simple single pole RC filter (RC = 1 second) on the range-rate output point the maximum excursion due to system "noise" over a 30 second observation period on an oscilloscope presentation was ± 1 foot per second.

In Section IV the Radar to Computer Interface Design is presented. This design includes a schematic, parts list, and functional description. The design provides the necessary conversion to digitally interface with sufficient isolation to prevent excessive loading and/or distortion and pick-up.

Section V contains a preliminary parametric design and comparison of non-coherent and coherent radar systems for the Shuttle Rendezvous range and range-rate error requirements.

In summary, these analyses indicate that the Shuttle Rendezvous range and range-rate requirements of $3\sigma_R = 1$ ft and $3\sigma_{\dot{R}} = 1$ ft/sec, respectively, can be made by a Ku-Band Non-Coherent Pulse Radar providing the range tracker instrumentation is improved correspondingly. With the Frequency Agility capability and the changes made to our all analog range tracker, and the demonstrated system "noise" level at the range rate output indicate that the Improved AN/APQ-153 NASA radar system can approach these requirements. Thus, with further development and the range-tracker employing the final optimum bandwidth and using digital instrumentation, it is an easy extrapolation to a Ku-Band Non-Coherent Pulse radar system which meets the stringent shuttle rendezvous range and range-rate accuracies. Further, it appears that the pulse-to-pulse frequency agility, practical on the Ku-Band Non-Coherent Pulse system, and extremely difficult with the Coherent system, will reduce the target-induced range and range-rate errors (dominating at near ranges less than 1000 ft) by a factor of 2.5 or more.

II. FREQUENCY AGILE AFC MODIFICATIONS

The major advantages of introducing frequency agility are two: (1) the detection ranges (for which single scan detection probabilities are 0.5 to 0.9) are significantly increased (see Figure II), and (2) the target induced range tracking errors due to reflection energy centroid random motion back and forth on the target (glint or scintillation phenomena) are reduced by at least a factor of 2.5 whether leading-edge tracking or other tracking techniques are employed. In the close-in range and range rate tracking problem, this factor can significantly reduce the errors, because the errors will primarily be these target induced ones, not ones due to receiver noise or range tracking instrumentation.

II.1 Frequency Agility Kit

The frequency agility kit was completely assembled at Emerson and successfully demonstrated to NASA engineering personnel during the latter part of March. It was delivered to NASA/Houston by Jack Kubicek of Emerson Electric during the early part of April. The following list indicates the modifications made to include the frequency agility in the NASA system.

I. Modifications to NASA Receiver/Transmitter

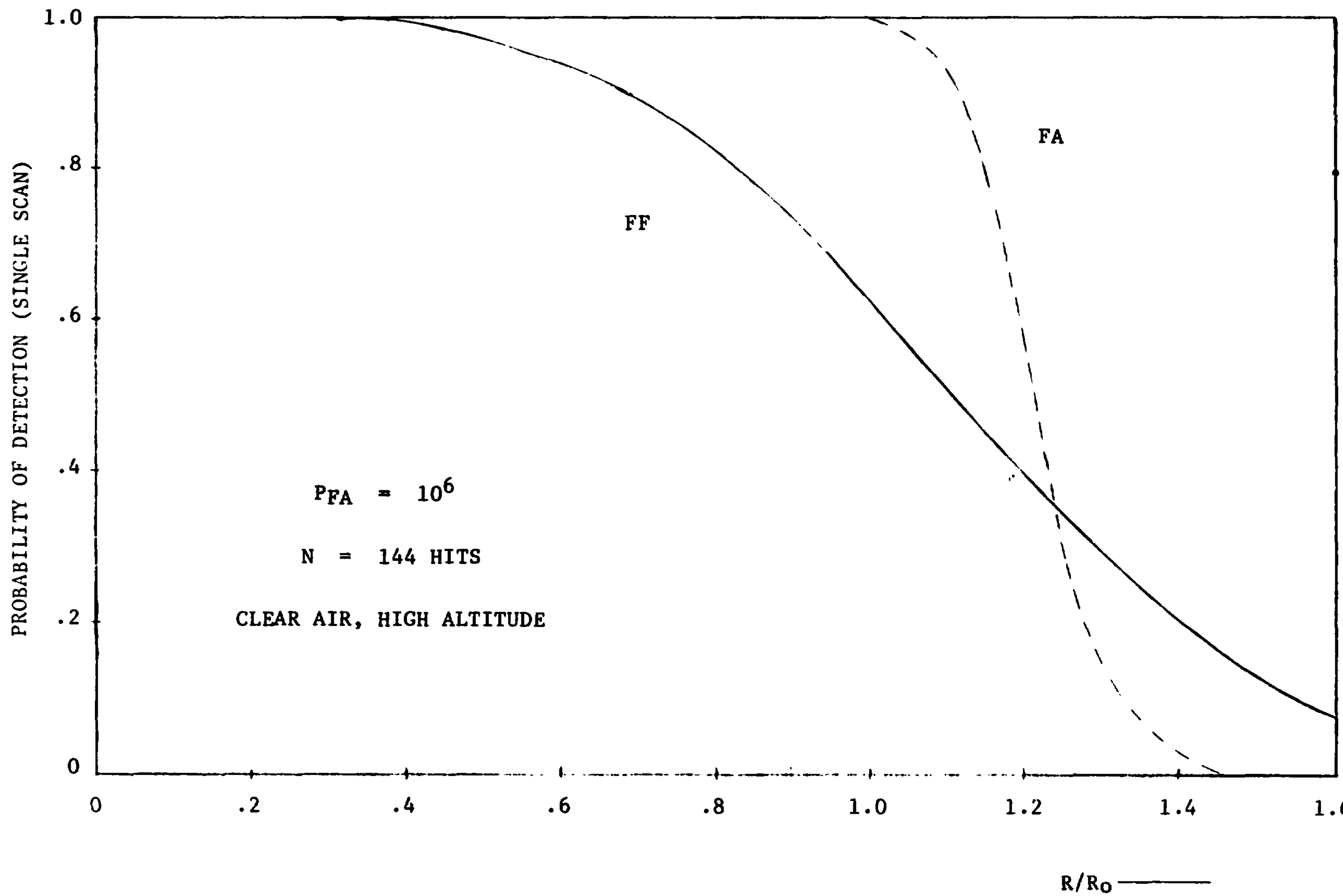
Affected Drawings: 656950

1. Add wire between TB1 terminal #2 to A10J5 Pin 9 (+ 30 V).
2. Replace above deck wire harness on basic R/T with 633775-1 wire harness.

FIGURE II

FREQUENCY AGILITY DETECTION RANGE

BW_{AZ} = 5.2°   AZ SWEEP = 90°/SEC   PRF = 2500 Hz



3. Replace basic local oscillator A3A9 with agile L.O. 633738-1.
4. Replace basic magnetron (633133-1) with agile magnetron (633737-1).
5. Replace post AMP/AFC assembly (633157-307) with POST AMP/AFC assembly (633980-1).
6. Replace air duct assembly (633413-1) with air duct assembly (633413-5).
7. Replace bracket assembly (633301-1) with bracket assembly (633864-1).
8. Replace R/T top cover with modified cover.

II. Modifications to NASA Processor

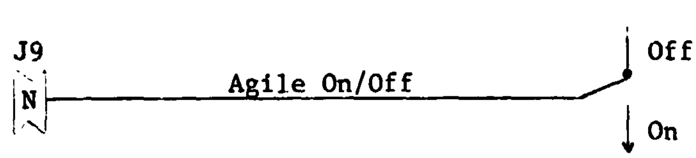
Affected Drawings: 656973

1. To interface with the processor the AFC #2 signal must be disconnected from the AFC BIT monitor (A1A3). This is accomplished by removing R73 from the A1A3 card.

III. System Cable and FCR Simulator/Monitor Modifications

Affected Drawings: 656902, 656901

1. Frequency agility On/Off command.
   a. The R/T will be in the frequency agile mode when the R/T connector J1 pin F is connected to signal ground.
   b. The R/T will be in the fixed frequency mode when the connector J1 pin F is open.
2. Frequency agility On/Off command installation.
   a. Remove wire between R/T connector J1 pin F and processor connector J4 pin F. (+ 28 VDC/14 VAC RET.)
   b. Add wire between R/T connector J1 pin F and the FCR simulator/monitor J9 pin N.
   c. Add a switch in the FCR simulator/monitor as shown below:



The marked-up darwings are included to document the changes made. These drawings are listed as follows and are included in Appendix B:

Receiver Transmitter Radar	634300
Power Supply Trans. and AFC Bit	656973-1
Circuit Card Assembly Power Supply Bit	656973-2

System Wiring Schematic Radar Processor to Xmitter Receiver	656901
FCR Interface Simulator/Monitor	656902
Circuit Card Assembly, Frequency Agility, AFC	633922
AFC Assembly, Post Amplifier Assembly	633980
Circuit Card Assembly, Post Amplifier	633156

II.2 Frequency Agility Description and Performance

The operational performance of the pulse radar is improved by the use of the frequency agility where the transmitted frequency is changed on a pulse-to-pulse basis. The peak-to-peak frequency excursion is 100 MHz at an agility rate of 100 Hz. Frequency agility is mechanized in the receiver/transmitter LRU as shown in Figure II.2-1. The 6543 magnetron was replaced with an agile magnetron which has the same high voltage and RF interface with the modulator as the present magnetron.

To mechanize frequency agility in a coaxial magnetron one can dither a timing plunger or drive an expanding ring at the agile rate to vary the cavity dimensions. In either case, a permanent magnetron (PM) resolver is attached to the motor shaft to provide a readout voltage proportional to the transmitter frequency. This output is used in the coarse AFC loop.

The frequency agility technique requires that on a pulse-to-pulse basis the transmitter frequency be separated by an amount greater than the receiver bandwidth (3 MHz). This requires the transmitter output to be frequency modulated. The frequency modulation and agile rate are determined to be 100 MHz and 100 Hz, respectively. Since the transmitter frequency is changed on a pulse-to-pulse basis, the AFC local oscillator (LO) must track the varying transmitter frequency. A block diagram of the frequency agility system is shown in Figure II.2-2. The AFC loop is required to sample the transmitted RF frequency during the transmit pulse and then to generate a local oscillator frequency separated from the transmitter frequency by the

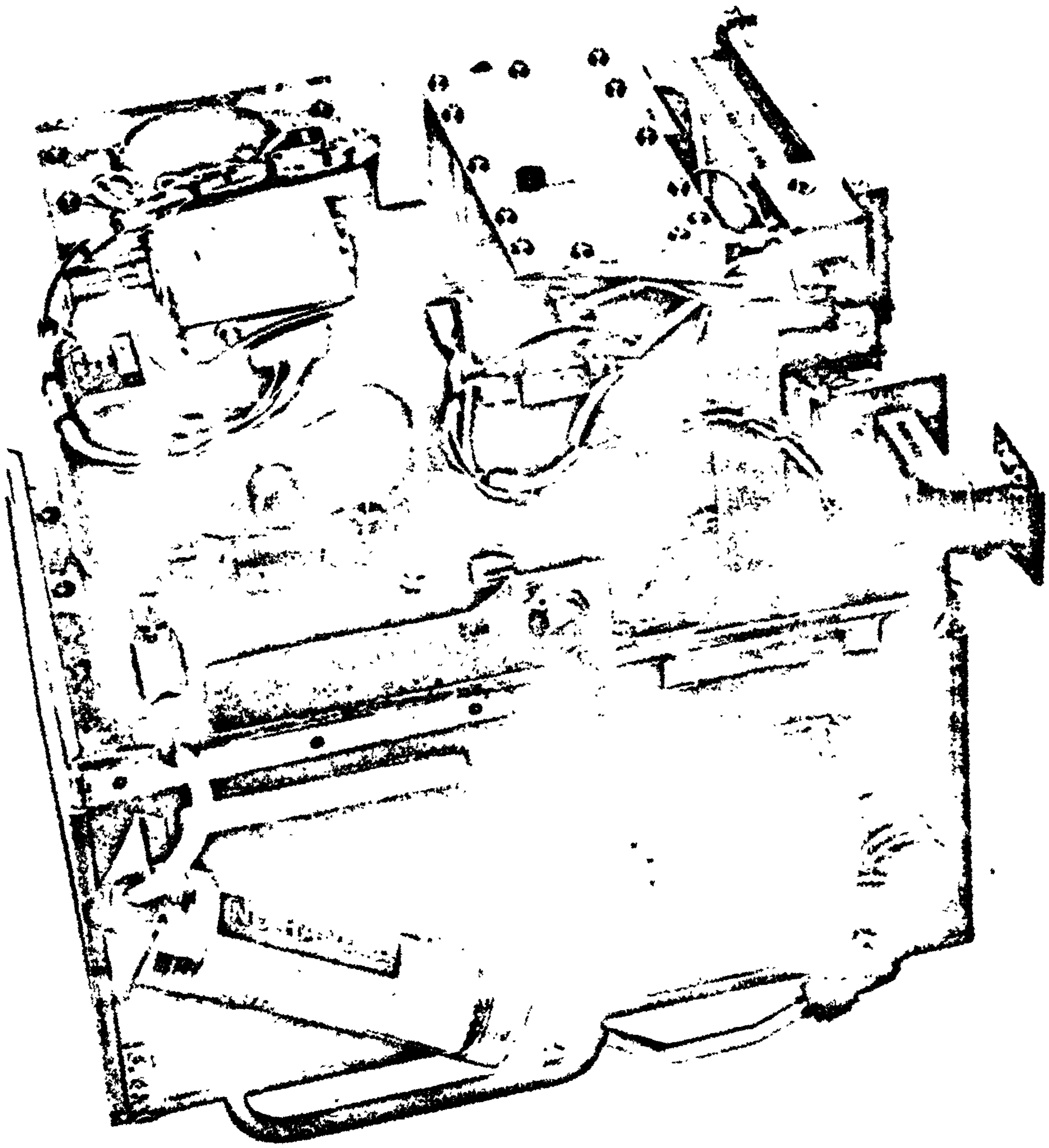
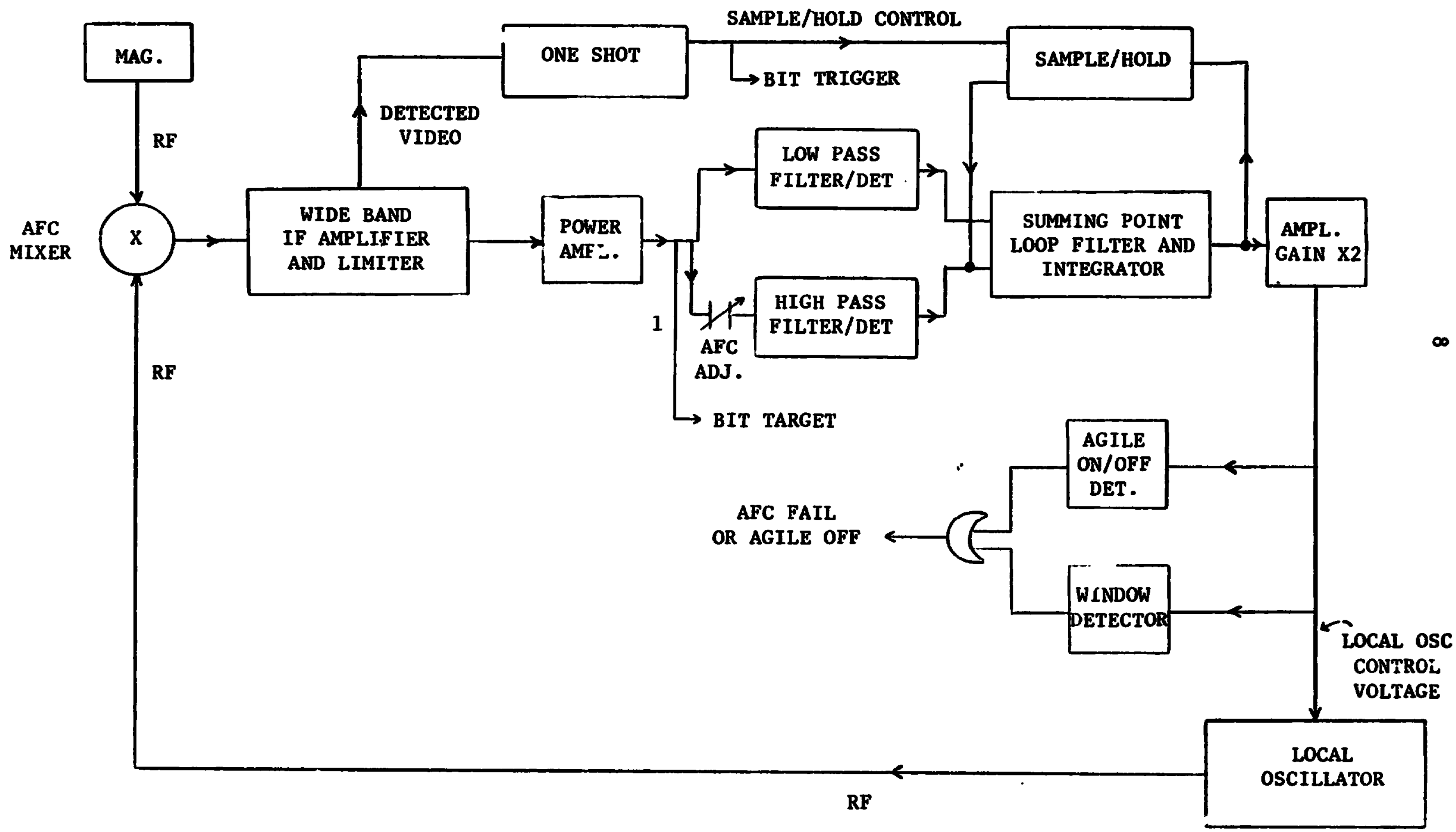


FIGURE II.2-1

FREQUENCY AGILITY TRANSMITTER/RECEIVER

FIGURE II.2-2

AGILE AFC BLOCK DIAGRAM



system IF. As the transmitter frequency changes from pulse-to-pulse, the tracking local oscillator stabilizes to the transmitter frequency before the transmitter pulse is turned off. That stabilized frequency must be maintained over the inter-pulse period at least for a length of time corresponding to the maximum range of 20 NM.

The input to the Automatic Frequency Control is from the AFC mixer which combines the magnetron rf sample with the local oscill. or signal to produce the difference frequency, or RFC IF error which is fed to the wide band IF amplifier and limited (see Figure II.2-2). This is followed by a 2-stage power amplifier which also provides IF pulse for BIT target to drive the high and low pass filters which make up the frequency discriminator which is centered within the IF pass band. The outputs of the high and low pass filter/detector combinations are summed in the loop integrator/filter. This is followed by a level changing amplifier with a gain of two. The output of this amplifier is used to drive the local oscillator.

At the beginning of each successive transmission of the magnetron, an error exists between the actual frequency of the local oscillator, established for the previous maggie transmission, and the local oscillator frequency required for the present transmission. This frequency error generates an actual error voltage at the output of the o.. criminator which drives the local oscillator in a direction tending to bring the error to zero.

The actual error voltage is not normally viewable. It can however be seen by means of a 2-input differential oscilloscope attached to the outputs of the high and low pass filter outputs.

This error lasts for about 200 nanoseconds as the AFC loop is correcting itself. The fast time constant of loop filter/integrator which permits the loop to correct with the main bang, also permits it to decay rapidly after the main band, and so it is necessary to sample the output of the Integrator immediately after it has corrected and settled and hold the new value during the period between pulses.

The sample and hold which loops around the filter/integrator performs this function. The S/H is actuated by a video pulse which is obtained from the wide band IF and limiter amplifier. The detected video pulse issued to trigger a one shot which provides the sampling pulse for the sample hold. This same pulse is fed out as a BIT trigger to turn on the test target in the post IF amplifier.

In addition to requiring a new agile magnetron, the frequency agility modification also required a new local oscillator and the above-described AFC circuits. The new local oscillator had to have a tuning range compatible with the agile magnetron. A unit with the same physical dimensions as the present LO was installed in the same location. The receiver module which is shown in Figure II.2-1 contains the AFC circuits. With the addition of frequency agility an additional circuit board was required in the receiver module. To accomodate this, the height of the module was increased approximately 1/2 inch. This allowed the installation of the new AFC circuits which required printed circuit boards to replace the existing single AFC board. The additional height of the receiver module, however, did not require an increase in the overall receiver-transmitter LRU envelope.

BIT

The AFC failure-indicating-circuits look for 3 things. The first two constitute a window detector to determine if the AFC output control voltage to the local oscillator is within its dynamic range. The third determines if the agile motor is running by determining if the control voltage is crossing a reference voltage and how often it is crossing this voltage. These signals are OR'd so that if any one is improper, an AFC fail is indicated.

III. RANGE RATE IMPROVEMENT MODIFICATIONS

The AN/APQ-153 range-tracker was originally designed for the high closing and opening rates and accelerations in air-to-air combat. The shuttle rendezvous range and range rate error requirements are $3\sigma_R = 1$ ft and $3\sigma_{\dot{R}} = 1$ ft/sec, respectively. Analysis showed that the range rate smoothing bandwidth reduction of about 10 was required to obtain these magnitudes of errors. Sufficient changes were made in the analog range-tracker to approach these values. With these changes including a simple single pole RC filter (RC = 1 second) on the range rate output point, the system "noise" excursion over a 30 second observation on an oscilloscope did not exceed $\pm$ 1 ft/sec.

III.1 Range Tracking Modification Kit

Range Tracker Modification Kit boards were delivered, installed, and tested by Emerson Electric engineer, Jim Gebhart, and accepted by NASA/Houston personnel in June. The following list indicates the modifications made to the Range Tracking boards to obtain the desired range rate accuracy improvement:

I. Circuit Card A1A14 (NASA Board 656984)

- a. Replace AR3 (ES3204-02) with LM108A (ES5309-01) see note 1.
- b. Replace R35, was 14.7K 1%, now 32.4K 1%.
- c. Replace R22, was 29.4K 1%, now 2.32K 1%.
- d. Replace C6, was (ES3182-01) now 4 (ES3399-27F) connected in parallel.
- e. Replace R2, was 681 1%, now 20.5K 1%.
- f. Replace R18, was 24.3K 1%, now 294K 1%.

II. Circuit Card A1A13 (NASA Board 656983)

- a. Replace AR1 (ES3203-04) with LM108H (ES5309-01) see note 1.
- b. Replace AR2 (ES3203-04) with LM108H (ES5309-01) see note 1.
- c. Replace R89, was 7.87K 1%, now 49.9K 1%.

III. Processor Wire List Changes (656960, Sheet 2)

a. Remove wire from A1XA13-8 to A1XA14-45.

b. Add wire from A1XA14-33 to A1XA14-45.

Note: LM108 op-amps are pin-for-pin replacements for 741's. However, each LM108 needs a 100 pF (M39014/01-1379) between pin 8 and ground for frequency compensation.

The basic performance of the AN/APQ-153 range rate circuitry was originally optimized for velocities of 3,000 ft/sec closing and 1,000 ft/sec opening. However, the rendezvous parameters are much closer to 300 ft/sec opening to 100 ft/sec closing. The scale factor of the range rate output was increased a factor of -10 changing the 5 millivolts per ft/sec to -50 millivolts per ft/sec. The noise level was correspondingly reduced by changing the transfer function to the range rate output, and reducing the effective noise bandwidth in the process.

Referring to Figure III.1-1 the basic AN/APQ-153 tracking loop, the range tracker functional diagram, and the NASA modifications in *italic type*, are both shown.

Simplified block diagrams of both the basic and NASA mod range tracker are indicated in Figure III.1-2. The loop transfer functions and smoothed range rates out become:

	Basic	NASA Mod
Open Loop Transfer Function	$(-111)\left(\frac{1+.209S}{S^2}\right)$	$(8.88)\left(\frac{1+.496S}{S^2}\right)$
Smoothed Range Rate Out	$-\frac{5}{(1+.064S)}\dot{R}_o$	$\frac{50}{(1+.496S)(1+.064S)}\dot{R}_o$

Thus, the acceleration constant is reduced from 111 to 8.88 and another pole smoothing is introduced into the range-rate output along with a scale factor of 50 instead of -5 (a factor of -10).

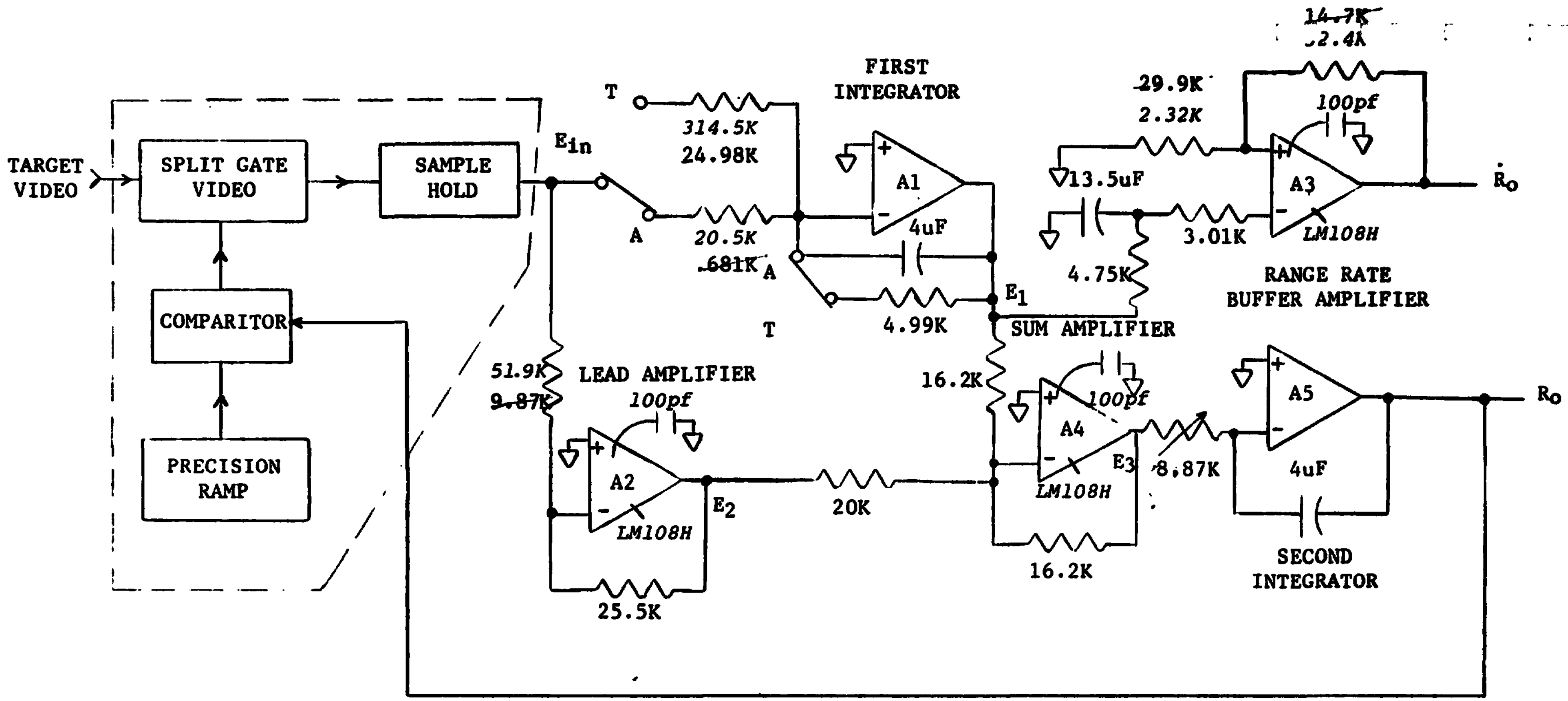


FIGURE III.1-1

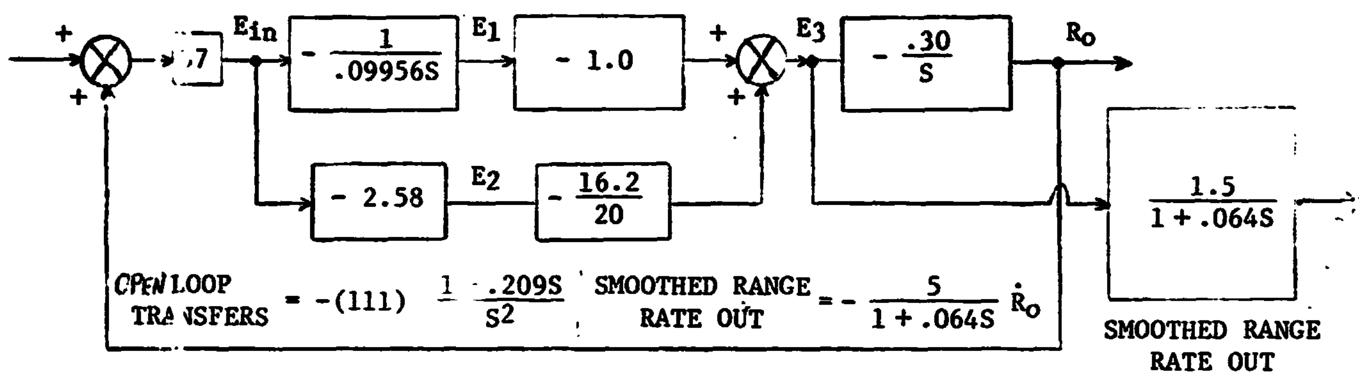
BASIC AN/APQ-153 RANGE TRACKER FUNCTIONAL DIAGRAM *(NASA MODIFICATIONS IN ITALIC TYPE)*

	Block Location	Card	Components
A1	First Integrator	A1A14	AR1, AR2, Q17, Q24, Q25
A2	Lead Amplifier	A1A13	AR1
A3	Range Rate Buffer Amplifier	A1A14	AR3, Q14, Q18, Q19
A4	Sum Amplifier	A1A13	AR2
A5	Second Integrator	A1A14	AR4, AR5, Q15, Q20, Q21

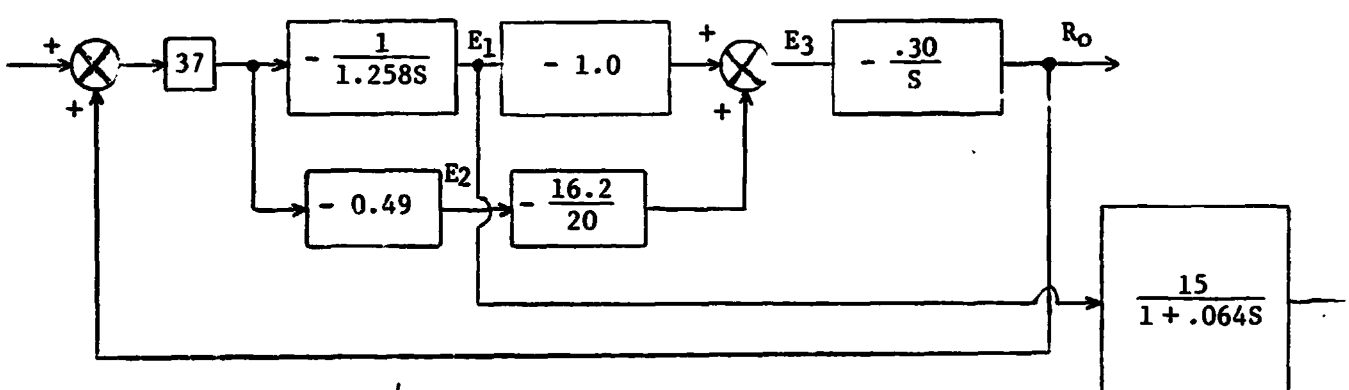
FIGURE III.1-2

RANGE TRACKER SIMPLIFIED BLOCK DIAGRAMS

A. BASIC



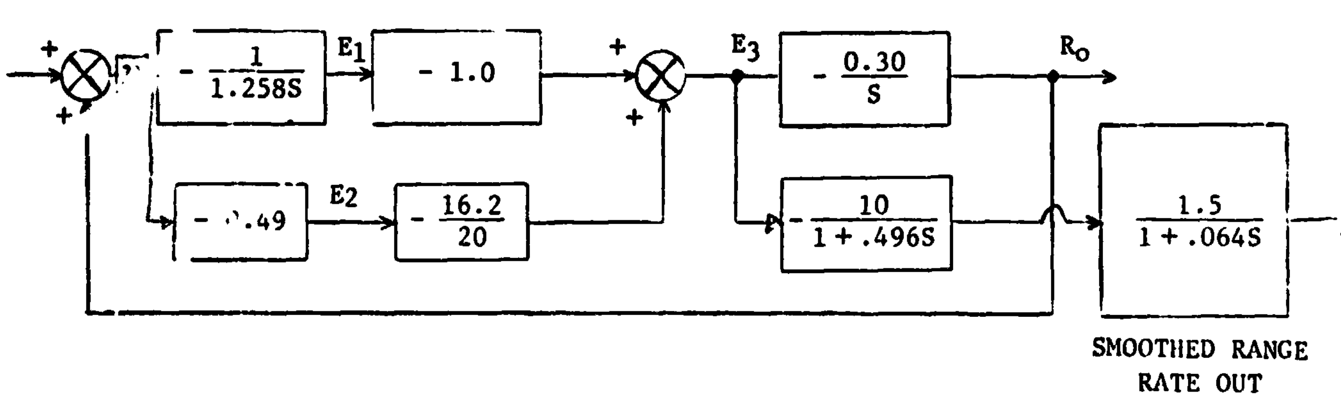
B. NASA MOD.



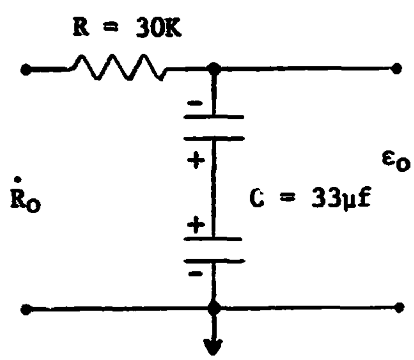
OPEN LOOP TRANSFER $= -8.88 \frac{1+1496S}{S^2}$; SMOOTHED RANGE RATE OUT $= \frac{50}{(1+.496S)(1+.064S)} \dot{R}_o$

SMOOTHED RANGE RATE OUT

C. NASA MOD. (Redrawn to be Analogous to BASIC)



With Al Cunningham present, Jim Gebhart demonstrated the actual range-rate noise level at the range-rate output point of the Range Tracker. The maximum excursion was ± 3 feet per second over a 30 second observation period on an oscilloscope presentation. Adding a simple RC filter as shown below, the output noise swing was reduced to ± 1 foot per second over a 30 second observation period. This final bandwidth may be close to that of the interface A/D converter.



$$\frac{\varepsilon_o}{\dot{R}_o} = \frac{1}{1 + RCS} = \frac{1}{1 + S}$$

RC = 1.0 seconds

The marked-up drawings are included to document the changes made. These drawings are listed as follows and are included in Appendix B:

1st and 2nd Integrators	656984
Pulse Gen, TRR, Gate Position	656983
Radar Processor (Wiring)	656960 (Sheet 2)

III.2 Range Rate Improvement Analysis

The block diagram of the basic AN/APQ-153 range tracking loop shown in Figures III.1-1 and III.1-2 is put into a general K parameter form below:

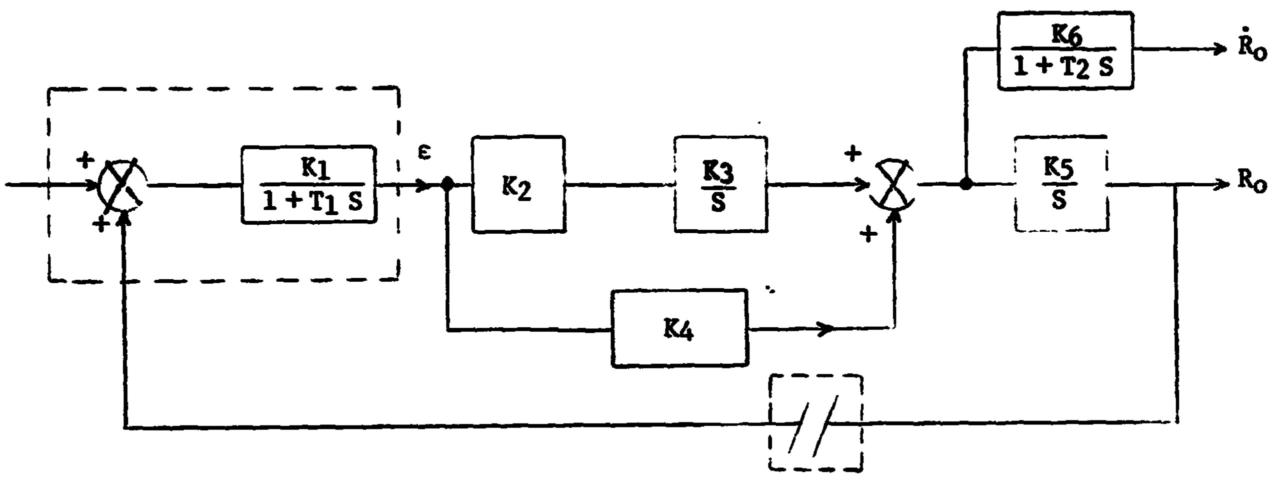


FIGURE III.2-1

The transfer functions in terms of the above parameters with $(1+T_1 S)^{-1} = (1+.005S)^{-1} \approx 1$ becomes:

$$\frac{R_o(S)}{R_i(S)} = H(S) = \frac{as+b}{S^2+as+b} \qquad (1)$$

$$\frac{\dot{R}_o(S)}{R_i(S)} = H_T(S) = \left(\frac{K6}{1+T2\,S}\right)\left(\frac{S}{K5}\right) H(S) = \left(\frac{K6}{K5}\right)\left(\frac{S}{1+T2\,S}\right)\left(\frac{as+b}{S^2+as+b}\right) \qquad (2)$$

$$\frac{\dot{R}_p(S)}{R_i(S)} = \left(\frac{ds}{S^2+as+b}\right) \qquad (3)$$

$$\left.\begin{aligned} a &= K_1K_4K_5 \\ b &= K_1K_2K_3K_5 \quad \text{- open loop gain} \\ d &= K_1K_2K_3 \quad \text{- open loop gain to tap for } \dot{R}_p(t) \end{aligned}\right\} \qquad (4)$$

The noise bandwidth (β_n) (not to be confused with the usual servo bandwidth) is defined in terms of the transfer function H(S) as follows:

If $H(w) = H(S)|_{S=jw}$ and $|H_m(w)|$ is the maximum amplitude of H(W) then the noise bandwidth becomes:

$$\beta_n = \frac{1}{2\pi}\left[\frac{\int_0^{\infty} |H(w)|^2\, dw}{|H_m(w)|^2}\right] \qquad (5)$$

and for the AN/APQ-153 general parameters previously defined, the specific $H(w)^2$ becomes:

$$|H(w)|^2 = \frac{1 + \left(\frac{b}{aw}\right)^2}{\left[1 + \left(\frac{b}{aw}\right)^2\right] + \left(\frac{w^2 - 2b}{a^2}\right)} \qquad (6)$$

and for $C = K_6/K_5$

$$\left|H_T(w)\right|^2 = \left[\frac{c^2\, w^2}{1 + (T_2 w)^2}\right] \left[\frac{1 + \left(\frac{b}{aw}\right)^2}{\left[1 + \left(\frac{b}{aw}\right)^2\right] + \left(\frac{w^2 - 2b}{a^2}\right)}\right] \qquad (7)$$

The range equivalent thermal noise error σ_N has been derived from extensions of Barton's treatment* for the split gate tracker as in the AN/APQ-153.

$$\sigma_N = \frac{\sqrt{\tau_g}\ C}{4\sqrt{\beta_R}\sqrt{\frac{f}{\beta_n}}\sqrt{\frac{S}{N}}} \qquad (8)$$

where it is assumed that:

$$\tau_g > \tau \qquad \text{and} \qquad \tau \cdot \beta_R \gg 1$$

where

- τ_g = Total split gate width ≈ 2 x pulse width (.85 μs)
- τ = Pulse length (0.425 μs)
- β_R = Receiver bandwidth (3 MHz)
- f = Pulse repetition frequency (2500 per second)
- $\frac{S}{N}$ = Signal-to-noise power ratio at end of IF
- C = Velocity of light (feet/second)
- β_n = The noise bandwidth as defined earlier

Using the basic AN/APQ-153 nominal parameters the $\frac{S}{N}$ ratio in db at 4 nm is 31.46. For σ to be 1/3 ft at this signal-to-noise ratio, the noise bandwidth β_n as determined from the above must be 0.5 Hz.

Inserting the basic AN/APQ-153 parameters equations (6) and (7) become:

*Barton, D.K. "Radar System Analysis" Chapter 11, Prentice-Hall, New Jersey, 1964.

BASIC

$$|H(w)|^2 = \frac{1 + \left(\frac{4.79}{w}\right)^2}{\left[1 + \frac{4.79}{w}\right]^2 + \frac{\left[w^2 - 14.42\right]}{545}} \tag{9}$$

$$|H_T w|^2 = \frac{(5w)^2}{(1 + .0086\ w^2)} \ |H(w)|^2 \tag{10}$$

These two are plotted versus w in Figures III.2-2 and III.2-3. The numerical integration as required in (5) to obtain β_n was done on the DEC 10 computer. The corresponding σ was obtained using (8) with S/N = 31.46. Thus the basic AN/APQ-153 has:

For R_o β_n = 4.36 Hz and σ_{R_o} = 3.85 ft

For $\dot{R}_o$ β_n = 5.68 Hz and $\sigma_{\dot{R}_o}$ = 4.4 ft/sec

Thus, the NASA Mod system needs to have a noise bandwidth of 0.5 Hz as compared to the basic noise bandwidths of 4.36 and 5.68 Hz, a factor of about 10 in noise-bandwidth reduction.

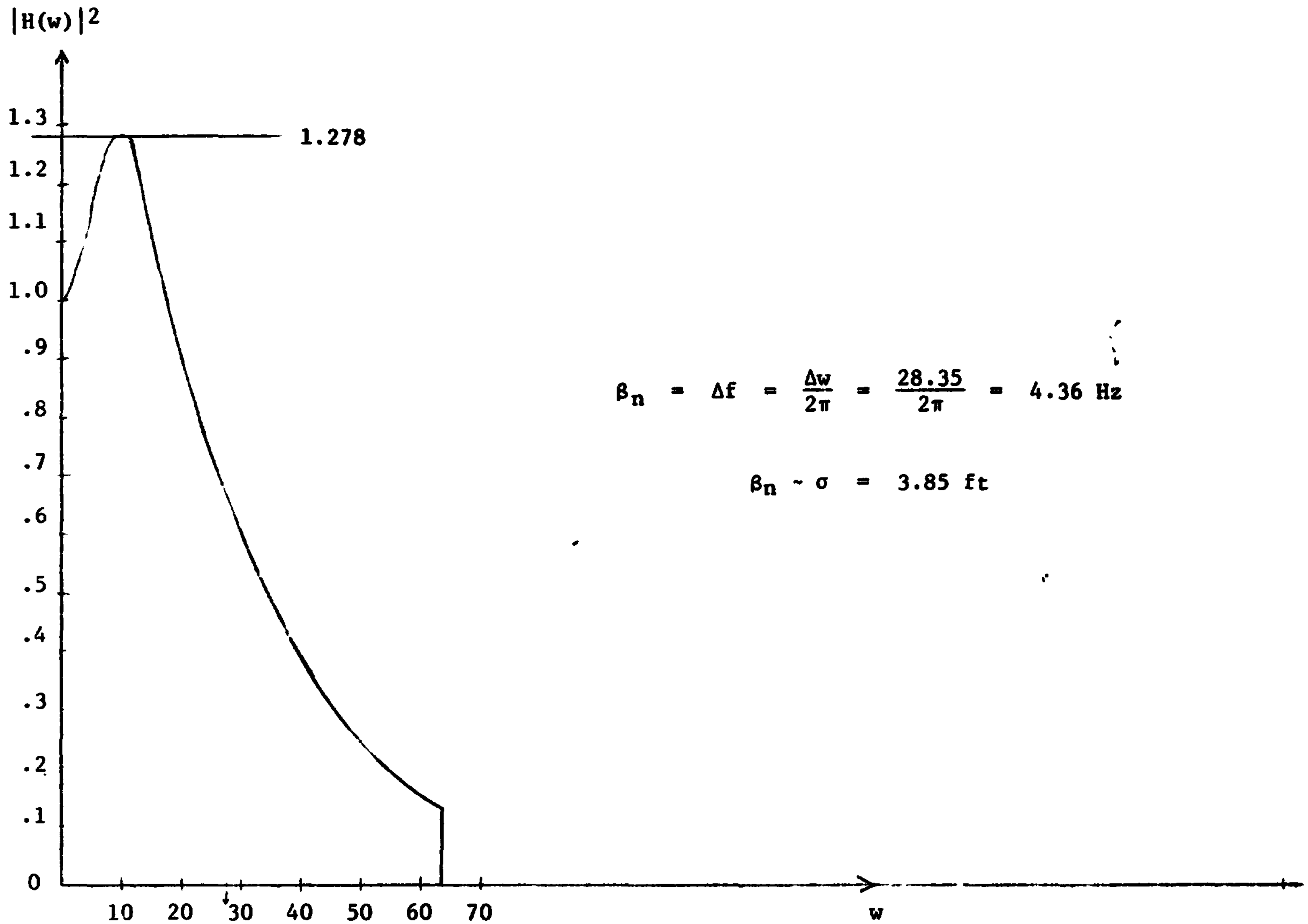
Now, there are many combinations of a and b to obtain β_n = 0.5 Hz. For complex conjugate poles of H(w) ($x \pm iy$) the family of a and b for $\dot{R}_o$ becomes:

b	111	75	50	25	10	5	3	1	15	.25
a	2.26	2.22	2.21	2.0	1.7	1.3	1.1	.70	.50	.34
$\phi = \tan^{-1} \frac{y}{x}$	83.7°	82°	80°	78°	74°	73°	71°	69°	69°	69°
x	1.13	1.13	1.13	1.0	.85	.65	.55	.35	.25	.17
y	10.29	8.36	6.70	4.89	3.04	2.13	1.64	.936	.661	.470

For combinations of a and b which yield H(w) with negative <u>real poles</u>, the following table gives the corresponding noise bandwidth β_n.

FIGURE III.2-2

$|H(w)|^2$ vs w

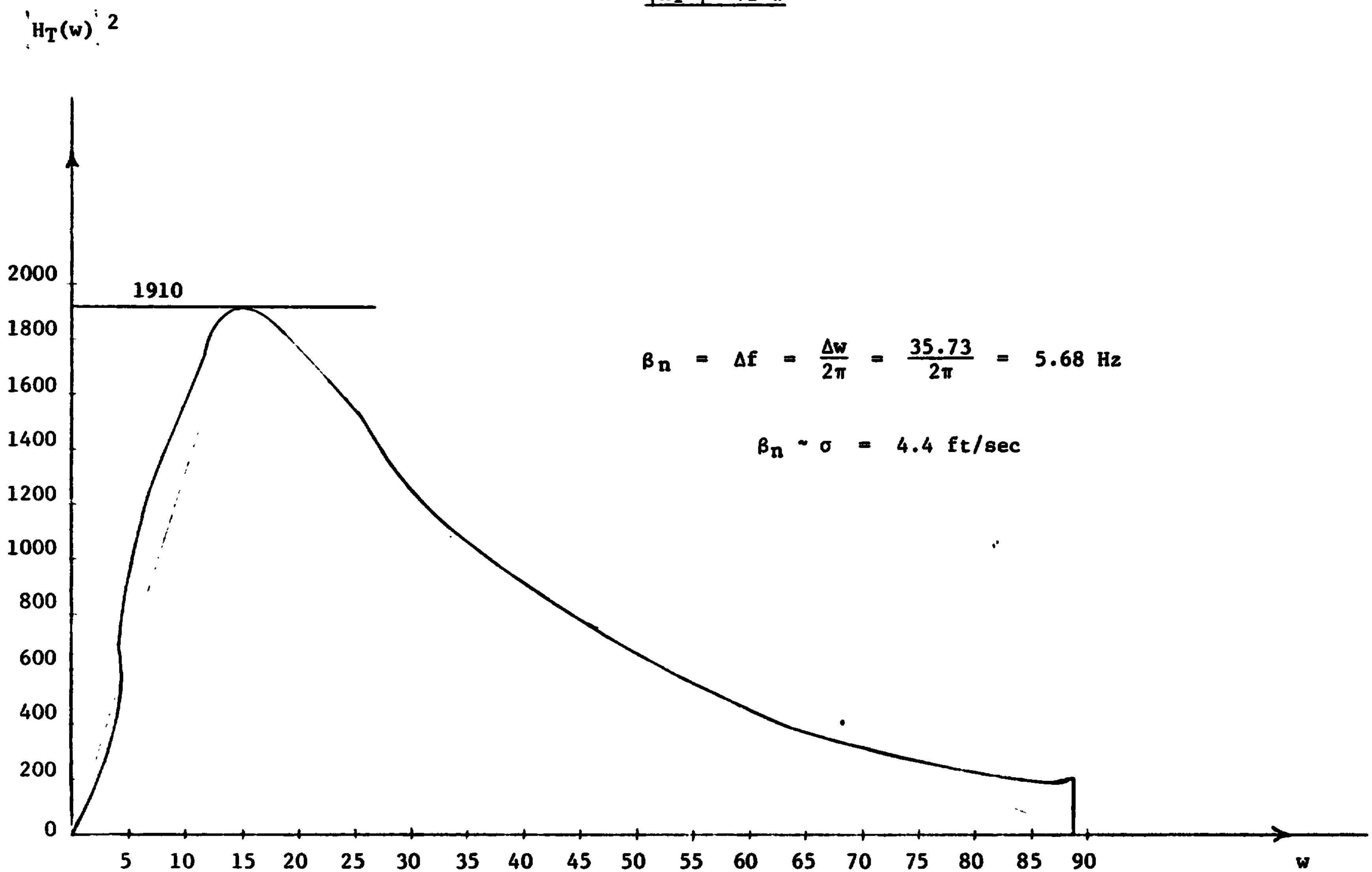


$$\beta_n = \Delta f = \frac{\Delta w}{2\pi} = \frac{28.35}{2\pi} = 4.36 \text{ Hz}$$

$$\beta_n \sim \sigma = 3.85 \text{ ft}$$

FIGURE III.2-3

$|H_{Tw}|^2$ vs w



Values of β_n for $|H(w)|^2$

A Function of Real Negative Poles

b	a	β_n
111	23	4.66
50	14.33	3.58
10	6.333	1.58
~ 8.88	~ 4.44	~ 1.35
2	3	.75
1	2.01	.50
1	2.05	.51
1	2.12	.53
1	2.5	.625

Comparing the Range Tracker Simplified Block Diagrams in the Range Tracker Mod. Kit section, Figure III.1-2, with the parametric form in this section, Figure III.2-1 the K parameters become:

	Basic	NASA Mod.
K_1	37	37
K_2 K_3	10	0.8
K_4	2.09	0.4
K_5	0.3	0.3
$a = K_1 K_4 K_5$	23.2	4.44
$b = K_1 K_2 K_3 K_5$	111	8.88
$d = K_1 K_2 K_3$	370	29.6
β_n (for R_o)	4.66 Hz	1.35 Hz
K_6	1.5	15
τ_2	.064 seconds	.500 seconds ~ 1.12 with $\dot{R}_o$ output RC filter

IV. RADAR TO COMPUTER INTERFACE DESIGN

Emerson agreed to assist in developing an interface design compatible with the AN/APQ-153. The following describes the interface design and includes a schematic diagram and a parts list. The NASA "Technical Description of Digital Interface for AN/APQ-153 Radar is included:

The AN/APQ-153 Digital Interface uses a modular data acquisition system (DAS) (Datel Systems Inc. P/N DAS-16-M12B1C3B)*. This module only requires power and input/output signal conditioning as shown on schematic diagram ESK 1002*. Briefly the major parameters of the DAS system are:

1. Eight (8) differential input channels.
2. ± 5V bipolar input range.
3. Offset binary coding, i.e., - 5.000V = octal 0000 and + 4.9925V = octal 7777.
4. 12 bit output resolution including sign.
5. Simple RESET, CONVERT, and BUSY control lines with automatic channel sequencing.
6. ± .025% of F.S. system accuracy.

Schematic ESK 1002* shows the signal conditioning circuits of each channel between the input connector J1 and the DAS J1 connection. Each channel is described below:

Channel 1

Channel 1 has the dual velocity signal conditioning circuits. Switch S2A and S2B select low (± 250 ft/sec) or high (± 1,000 ft/sec) ranges of velocity. This assumes that ± 1,000 ft/sec is equivalent to ± 5V input signal. Individual gain and offset adjustments are provided for the inverting amplifier A1. A 1 Hz 3-pole low pass filter (A3) is provided between the amplifier and the DAS Channel 1 input to filter 3 and 6 Hz con scan noise. Channel 1, as well as all other channels, are provided with input signal overvoltage protection consisting of CR1, CR2, CR3, CR4, R32, and R9. FD-300 low leakage diodes are used in these limiter circuits. Since the channel inverts the signal and the digital output is negative logic. It is

*See Appendix B.

intended that the interface cable or computer interface invert or complement the velocity data as required. All other channels also use inverted signal inputs so that all output data words will be consistently negative logic for reinversion as required.

Channel 2

Channel 2 has the dual range signal conditioning circuits. Switch S3A and S3B select low range (6,000 ft) or high range (60,000 ft). This assumes that 0 to 60,000 ft is equivalent to 0 to 60 VDC input signal. Individual gain and offset adjustments are provided for the inverting amplifier A2. The offset adjustment offsets the amplifier A2 to + 5.0 VDC for a 0 ft (0V) input signal. At maximum range either low or high the amplifier output is -5 VDC. Thus the range signal is digitized using the full 12 bits of resolution.

Channels 3 thru 7

Channels 3 thru 7 are assigned as follows:

Channel 3	Az
Channel 4	Az Rate
Channel 5	El
Channel 6	El Rate
Channel 7	Logic Signal

These channel inputs are direct except for input protection circuitry. As per telecon with NASA personnel, direct inputs of these parameter voltages within $\pm$ 5 VDC is acceptable. It is assumed that computer software will calculate parameter values from the input voltage v.s. parameter value calibrated values.

Channel 8

This channel has not been connected and the output word is a "don't care" value.

The channel sequency will be as indicated above unless otherwise desired. A different sequence can be easily incorporated. Channels may be sequenced at a rate to 50 KHz, if necessary, for signal averaging.

An internal power supply option has been provided (for 400 Hz operation) if desired. Power switching and fusing has been provided.

Output and input drivers and receivers are dual rail logic of the National DM8830 and DM8820A types. Two least significant bits are wired to zero. These and the 12 bits of the DAS give the 14 bit desired data word.

Interconnecting cables are not included in the P/L although mating connectors for testing are included.

IV.1 Technical Description of Digital Interface

1.0 SCOPE

This description is for an add-on A/D converter and Digital Interface for the AN/APQ-153 modified by Emerson Electric for NASA-JEC under contract NAS-9-13675 and NAS-9-14760.

2.0 PERFORMANCE CHARACTERISTICS

2.1 Parameter Output Format

a. Natural binary with MSB = Polarity.

b. 13 bits plus sign per word.

c. 1 word per parameter.

d. 8 parameters per sequence.

2.2 Parameter Designation

a. Range.

b. Range rate.

c. Azimuth angle.

d. Azimuth angle rate.

e. Elevation angle.

f. Elevation angle rate.

g. Lock-on indicator.

h. Blank word.

2.3 Computer Handshake Details

a. Request signal:

Positive Polarity
2.4 - 5.0 V level

b. End of conversion signal:

Positive logic
2.4 - 5.0 V E.O.C.

c. Computer will supply master reset signal, then strobe in sequence for 8 parameters.

d. Standard 8820 and 8830 line transmitters and receivers will be used.

2.4 Output Signal Levels

Positive logic, TTL compatible.

2.5 Data Line Drive Requirements

a. 50 ft maximum, twisted shielded pairs.

2.6 Data Rate

a. Less than 5 request per second.

2.7 Parameter Scaling

a. Range, full scale
Selectable, 0 - 6,000 ft, or 0 - 60,000 ft.

b. Range rate, full scale
Selectable, 0 - 250 ft/sec or 0 - 1,000 ft/sec, bi-polar.

c. Angle, $\pm$ 45 full scale.

d. Angle rate, $\pm$ 20 /sec full scale.

3.0 POWER

Power for unit shall be either supplied from radar or from 400 Hz supply.

4.0 PHYSICAL CHARACTERISTICS

4.1 Size

19 inch rackmount, 5-1/4" high, 18 inch maximum, depth.

4.2 Panel Color

Light gray.

4.3 Identification

a. Nameplate on back, name on front.

4.4 Cooling

a. Ambient air without fan in air conditioned laboratory.

4.5 Switches and Adjustments

a. Located on back of unit.

4.6 Interface Connectors Requirements

a. Located on back of unit.

b. MS-3116, MS3126, Bendix PT06 or JT06 or equivalents.

c. Input, output on separate connectors.

Additional technical notes are in Appendix B along with the entire interface schematic ESK 1002.

V. COMPARISON BETWEEN NON-COHERENT AND COHERENT RADARS

The Ku-Band Shuttle Missions yield radar requirements for the terminal phase, (< 8 nm) as follows:

Minimum Range	100 ft
Search Angle	90 x 90 III, 10 x 10 I and II
Range Accuracy (3σ)	1% (100 ft to 5 nm) 390 ft (5 to 30 nm) open (30 to 300 nm)
Range Rate Accuracy (3σ)	± 1 ft/sec random Range less than 30 NM
Angle Rate	4 mr/sec acquisition 5 degrees/sec track
Angle Rate Accuracy (3σ)	0.14 mr/sec R < 30 nm
Angle Accuracy (3σ)	10 mr R < 30 nm 60 mr bias

The radar operational requirements:

Above within 10 seconds following ΔV = 10 ft/sec

Range Acceleration = 0.5 ft/sec^2

Recovery after break lock within 2 seconds

	R < 10 nm	Closing 100 ft/sec Opening 50 ft/sec
Velocity limits	R > 10 nm	Closing and Opening 300 ft/sec

The non-coherent pulse radar design can be sketched to meet the requirements in range and range rate. The parameters are listed in the following Table V.1:

TABLE V.1

Ku-Band Non-Coherent Rendezvous Radar Parameters

Power:	80 KW Peak; 80 watts average: .001 duty cycle
Range:	7 Nautical Miles
Antenna Gain:	35.4 dB; Noise Figure = 5 dB; Losses = 5 dB
Pulse Width:	120 nanoseconds; IF Bandwidth = 20 MHz
Pulse Repetition Rage:	8000 Hz; Tracking Noise Bandwidth ≅ 1 Hz

Single Pulse Signal /Noise Ratio ≅ 10.2
Non-Coherent Integration Gain = 23.5 dB
Range Error (1σ) ≅ 0.4 feet
Range Rate Error (1σ) ≅ 0.26 feet/second (differentiated range)

The pulse width is chosen as 0.120 us. Frequency agile magnetrons (Varian associates) exist with this order of pulse width. The corresponding round trip time at the minimum range of 100 ft (.491757 feet/nanosecond) is 203.35 ns. Thus, the receiver has 83.35 ns to recover after transmission. A Ferrite diode limiter combined with a PRE TR tube can enable sufficient receiver protection and recovery to obtain a very high signal-to-noise ratio for the $\sigma_R = \frac{1}{3}$ ft and the $\sigma_{\dot{R}} = \frac{1}{3}$ ft/sec. The duty cycle of .001 is typical so that a PRF of 8000 is consistent. The maximum unambiguous range for the PRF is 61,469 feet or 10.11 nm. An 80 watt average power magnetron would then have an 80 KW peak pulse power. The Ku-band antenna gain (for the same dimensions as our present X-band AN/APQ-153 non-coherent pulse radar system) is about 35.4 dB. The predicted noise figure and losses are both 5 dB. The effective range tracking servo bandwidth can be on the order of 1 Hz.

The next step is to recall the basic definitions and determination of the single pulse (no integration of pulses) signal-to-noise ratio (S/N).

$$S = \frac{P_t G A_e \sigma}{(4\pi)^2 R^4} \qquad \text{(Skolnik*, page 20)} \qquad (1)$$

S = Signal power at receiver (watts)

P_t = Transmitted power (watts)

G = Antenna gain

A_e = Antenna effective aperture (meters^2)

σ = Radar cross section (meters^2)

$$N = k T_o B_n F_N \qquad \text{(Skolnik*, page 24)} \qquad (2)$$

N = Noise power in receiver output of IF (watts)

T_o = 290 K IRE standard

B_n = IF receiver bandwidth (cps)

F_n = Noise figure

k = Boltzman's constant = $1.38054 \times 10^{-23} \frac{\text{joules}}{°K}$

Effective Aperture $$A_e = \frac{\lambda^2 G}{4\pi} \quad \text{(meters}^2\text{) (Skolnik*, page 263)} \qquad (3)$$

λ = Wavelength (meters)

G = Antenna gain

*"Introduction to Radar Systems", Merrill I. Skolnik, McGraw-Hill, 1962.

$$L = \text{Loss factor} \tag{4}$$

Dividing (1) by (2) and substituting (3) and (4) the IF signal-to-noise power ratio becomes (5) (on a single pulse; no integration of pulses).

$$\frac{S}{N} = \frac{P_t\, G^2\, \lambda^2\, \sigma}{(4\pi)^3 (R^4)\ (k\ T_o\ B_n\ F_n)\ (L)} \tag{5}$$

The other parameters which are needed are these:

- R = Begin tracking range = 7 nm = 12,964 meters
- σ = Rendezvous vehicle effective radar cross section = 1 meter^2
- T_o = 290 K
- k = 1.38054 x 10^{-23} joules/OK
- λ = .021763 meters (at 13.775 GHz)
- B_R = Bandwidth of receiver IF (20 MHz)
- τ_g = Total split gate width = 2 x pulse width (.24 us)
- τ = Pulse width (.120 us)
- f = PRF (8000 Hz)
- B_n = The noise bandwidth (1Hz)
- $\frac{S}{N}$ = Signal-to-noise power ratio after integration gain

Recalling a prior equation [(8) in Range Improvement Analysis section]

$$\sigma_N = \frac{\sqrt{\tau_g}\ C}{4\sqrt{B_R}\sqrt{\frac{f}{B_n}}\sqrt{\left(\frac{S}{N}\right)}} \tag{6}$$

The results of exercising the above equations is the lower set of values in Table V.1 in which the error σ is nearly at design goals. The target induced errors are caused by glint or scintillation effects are considered separately in later paragraphs.

One constraint determining the lower limit on the range-rate bandwidth (or the upper limit on the non-coherent integration time) is the rate of change of range-rate due to target cg acceleration. During thrusting (or ΔV time) this may be on the order of 0.5 to 1 foot/second^2. However, this need not be a design goal.

In the remaining time, it may be on the order of 0.1 feet/second^2. The range rate measurement error is given a one sigma value of 0.333 feet/sec. Thus, the maximum integration time can be about 3-1/3 seconds. Consider target rotation:

$w = .01$ rad/sec

$r = 9$ meters

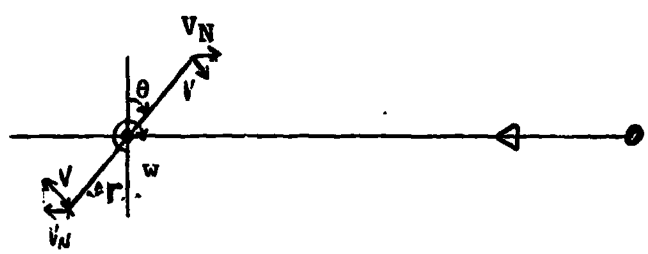


FIGURE V.1

$V_n = V\cos\theta = rw\cos(wt)$ $V_{n_{maximum}} = rw = .29527$ feet/sec

$\frac{dV_n}{dt} = rw^2 \sin(wt)$ $\left.\frac{dV_n}{dt}\right|_{maximum} = rw^2 = 0.0029527$ ft/sec^2

Thus, the range measurement error $\sigma = 0.333$ ft at 100 ft limits range integration time to about 1 second. As a conservative design goal, 1 second integration time for the range-rate measurement and 0.3 seconds for the range measurement shall be used.

The mechanization of the non-coherent pulse radar is grossly outlined in Figure V.2. The range tracking implementation may be as shown, but there are a few alternative schemes.

Range and Range Rate Tracking Instrumentation Alternatives

I. Digital Instrumentation General Constraints:

A. 20 to 50 nanoseconds early and late gating and/or sampling on the differentiated leading edge.

B. 5 nanosecond basic clock period using ECL technology.

II. All Digital Tracking Loop:

A. Alpha-Beta tracker algorithm and digital implementation:

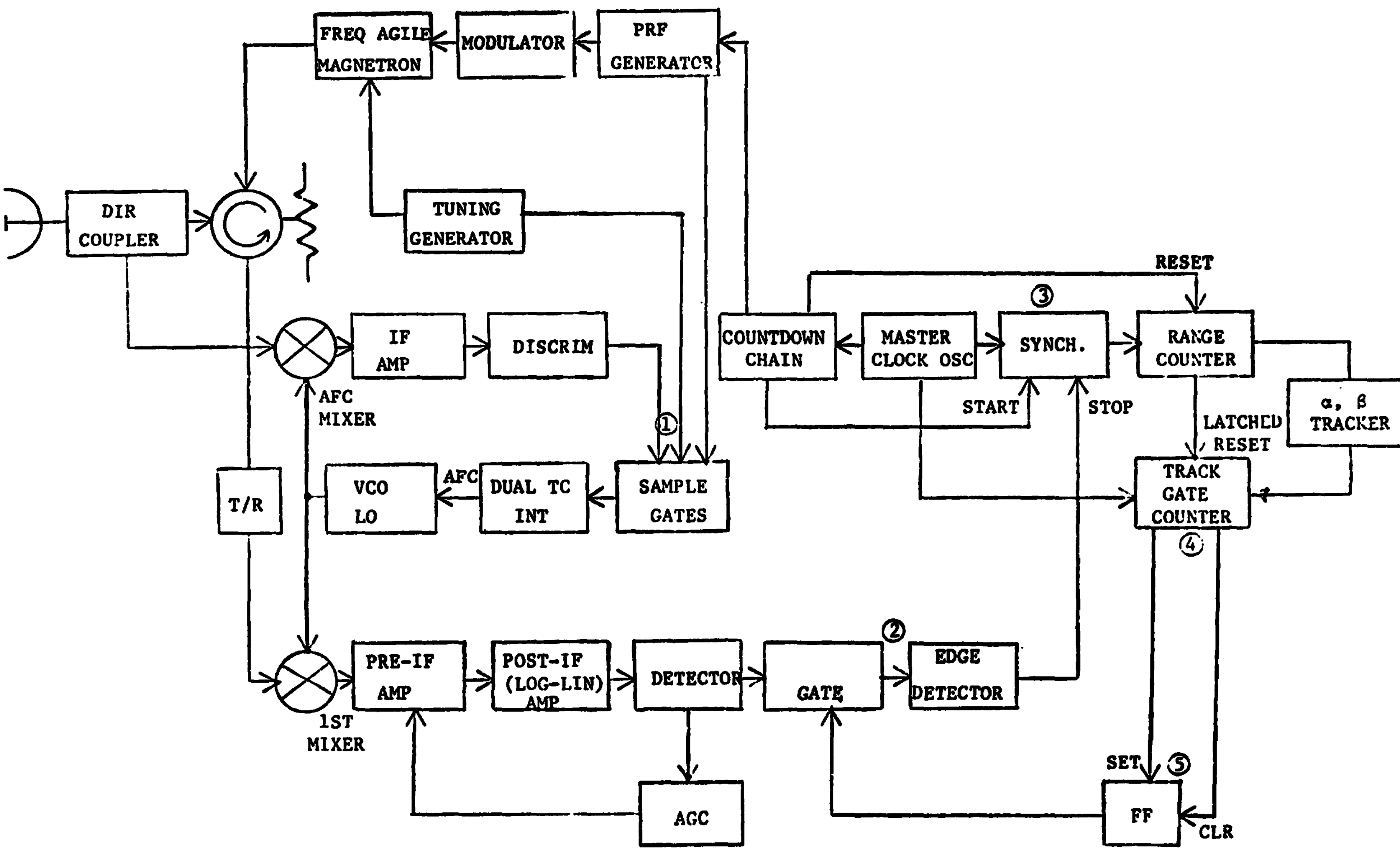
1. Type 2 servo; double integration in forward transfer.

2. Zero errors for constant position and velocity type inputs.

B. Vernier solution to positioning split-gates or sampling down to 0.1 nanoseconds.

FIGURE V.2

NON-COHERENT PULSE RADAR



III. Parallel Analog VCO Gating Loop and Digital-Time-Interval Measurement

A. Split gate range discriminator.

B. Integrator and compensation transfer.

C. Voltage controlled oscillator with split gate outputs.

D. Synchronizer gating of 200 MHz clock counting.

E. Averaging Digital Time Intervals (multiple of 5 ns) for improved ($\sqrt{N}$ factor) time and range accuracies.

The pulse doppler coherent radar design can also be designed to meet the range and range rate requirements. The parameters are listed in the following table:

TABLE V.2

Pulse Doppler Coherent Radar Parameters

Power:	400 watts peak; 8 watts average; duty cycle = .02
Range:	7 nautical miles
Antenna Gain:	35.4 dB; noise figure = 5 dB; losses = 5 dB
Pulse Width:	2500 nanoseconds; IF bandwidth = 1 MHz
Pulse Repetition Rate:	8000Hz; Tracking Bandwidth ≅ 8 Hz Coherent ≅ 1 Hz Non-Coherent

Single pulse signal/noise ratio ≅ 1.05

Coherent integration gain ≅ 30 dB + 9 dB non-coherent in doppler tracking.

Range rate error (1σ) ≅ 0.1 feet/second (at 7 nm) (excluding target motion induced errors)

Range error (1σ) ≅ 23.2 feet (at 7 nm) (if implemented like non-coherent; excluding target motion induced errors)

The pulse width must be chosen for the high duty cycle of the transmitter of 0.02. The average power is 8 watts with the peak then of 400 watts (this is extrapolated from our coherent pulse doppler development EC153). Then with a PRF of 8000Hz, the pulse width comes out to be 2.5 us, and the corresponding IF bandwidth is about 1 MHz.

A gross mechanization scheme is shown in bloc. diagram form in Figure V.3. As shown, there is needed a specific range tracking loop for determination of range, the range rate being determined by the doppler phase-locked loop.

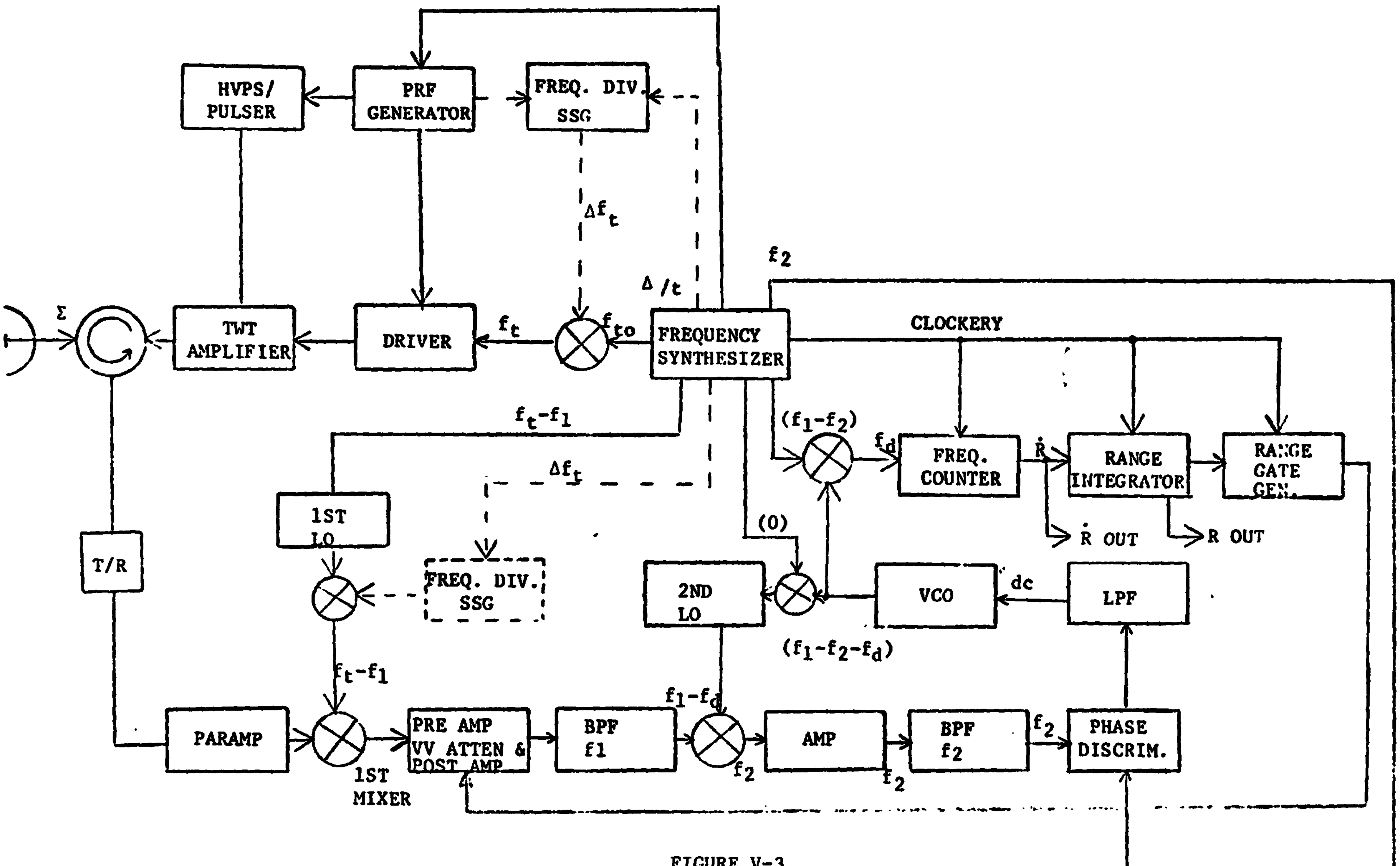


FIGURE V-3

COHERENT PULSE DOPPLER RADAR

The basic equations (1) thru (6) hold for the coherent system with a different set of parameter values:

B_R = 1 MHz

τ_g = 5.0 μs

τ = 2.5 μs

Coherent Integration Gain = 30 dB

Incoherent Integration Gain = 9 dB

P_t = 400 watts

$B_n \cong$ 1 Hz

Others are as in the non-coherent system. The results of exercising the equations is the lower set of values in Table V.2 in which the error σ's are better than design. The target induced errors that are caused by glint and scintillation and vehicle rotation are considered in the following paragraphs.

Close-In Range Problem with Target Generated Range Errors

Rendezvous Target Minimum Representation: Two point reflectors of equal amplitude 18 meters apart and rotating at 0.01 radians per second.

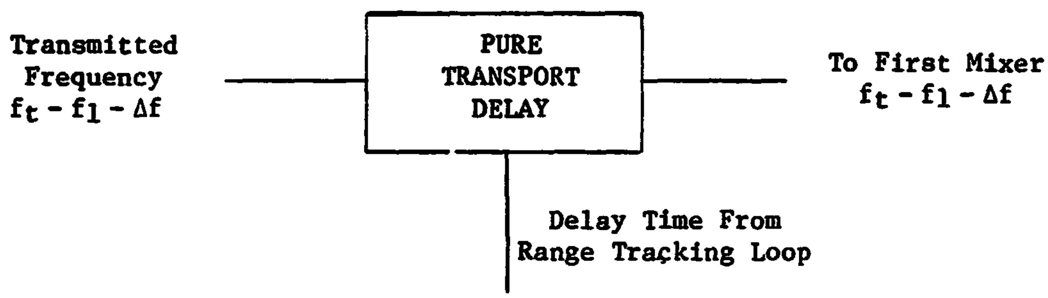
Rendezvous Target Maximum Representation: Complex reflections of unequal amplitude extending 18 meters and rotating at 0.01 radians per second.

For the 20 nanosecond leading edge tracking non-coherent system with frequency diversity, there are no in-front-of vehicle induced target motion errors.

For the 1000 nanosecond centroid velocity tracking coherent system (without frequency diversity) the NRL Cross and Evans "Target-Generated Range Errors" paper* illustrates how bad the errors can become if the pulse width is long compared to target length. Experimentally the range error RMS can be about one-fourth length or up to 15 feet. Using the extremely difficult frequency diversity with the coherent system, this could possible be reduced by a factor up to four to yield possibly 4 feet RMS range error. With a 1 second velocity smoothing the velocity RMS error would be on the order or 4 feet/second.

*"Target-Generated Range Errors" by D. C. Cross and J. E. Evans in IEEE 1975 International Radar Conference Record, pages 385 - 390.

Doppler - Velocity Coherent Phase-Locked Loop Tracking with Frequency Diversity



Δf is programmed frequency diversity. For example, the Δf can be varied from one pulse to the next, but holding the transmitted frequency constant during each PRF period. However, to maintain phase coherence in changing frequency while enabling the coherent phase-locked loop to remain locked-on, the transmitted frequency must be delayed by the round-trip time (obtained from the range tracking loop) before used in the first mixer. This is a very difficult instrumentation problem to realize adequately, and in any case requires extremely good range tracking to make it practical.

Comparison between Non-Coherent and Coherent Rendezvous Radars

	Non-Coherent	Coherent
Power	80 KW: 80 watts: .001	0.4 KW: 8 watts: .02
B_T	1 Hz	8 Hz Coherent 1 Hz Non-Coherent
I_g	23.5 dB	30 dB Coherent +9 dB Non-Coherent
T	τ = 120 ns τ_r = 50 ns	2500 ns 1000 ns
σ_R(at 7 nm) (at 100 ft)	0.4 ft < 0.1 ft	23.2 ft (if range implemented no <0.1 ft glint considered)
$\sigma_{\dot{R}}$(at 7 nm)	0.26 ft/sec	0.1 ft/sec (if no glint considered)
Target Induced Errors σ_R $\sigma_{\dot{R}}$	< .4 ft <0.3 ft/sec	$\geq$ 4 ft $\geq$ 4 ft/sec

APPENDIX A

STATEMENT OF WORK

FOR

RADAR PERFORMANCE IMPROVEMENT

1.0 PURPOSE

1.1 Objective

The objective of this Statement of Work (SOW) is to describe the effort required to provide three modification lists for evaluation on the AN/APQ-153 Fire Control Radar. The kits are to be designed to fit within the existing packaging constraints of the system.

1.2 End Product

The end products of this contractual effort shall be a frequency agility kit to permit JSC to evaluate system performance with and without agility, five modified circuit boards and bandwidth reduction to improve the range rate accuracy.

2.0 SCOPE

2.1 General

The Contractor shall provide the necessary resources to perform the fabrication and delivery of the frequency agility kit and to perform the analyses and modifications of the circuit boards as specified in Section 3.0 of this SOW.

3.0 TECHNICAL REQUIREMENTS

3.1 Frequency Agility

3.1.1 General

Addition of the frequency agility option shall improve signal-to-clutter ratio, provide ECCM, increase detection range, reduce STAE (Second Time Around Echo) and reduce target fade and glint. All this shall be accomplished with the present LRU/envelope; the only LRU impacted shall be the receiver-transmitter. The weight of the LRU shall increase by a maximum of approximately 3 lbs.

3.1.2 System Operation and Performance

The operational performance of this pulse radar shall be improved by the use of frequency agility where the transmitted frequency is changed on a pulse-to-pulse basis. Varying the transmit frequency to separate pulse frequencies for a series of pulses during the time the radar beam scans a target shall reduce the correlation between various undesired radar returns such as clutter. Targets shall appear more uniform to the pilot. The probability of detection shall also increase as shown in Figure 3.1 for a two square meter target. Frequency agility shall improve angle tracking performance for the angle track option as the accuracy of a tracking system to determine the deviation of the target axis from the antenna axis is affected by target glint and fading, refraction errors in radomes and variations in the propagation media. These sources of angular resolution error shall be averaged down by rapid variation of the transmission frequency. The peak-to-peak frequency excursion shall be 100 MHz at an agility rate of 85 Hz.

3.1.3 Hardware Description

Frequency agility shall be mechanized in the receiver-transmitter LRU as shown in Figure 3.2. The present 6543 magnetron shall be replaced with an agile magnetron which has the same high voltage and RF (Radio Frequency) interface with the modulator as the present magnetron.

Two techniques shall be considered for this application. The first technique is to dither a tuning application. The second technique is to drive an expanding ring at the agile rate to vary the cavity dimensions. In either case, a PM (permanent magnet) resolver shall be attached to the motor shaft to provide a readout voltage proportional to the transmitter frequency. This output shall be used in the coarse AFC loop. The frequency agility technique requires that on a pulse-to-pulse basis the transmitter frequency be separated by an amount greater than the receiver bandwidth (3 MHz). This requires the transmitter output to be frequency modulated. The frequency modulation and agile rate are determined to be 100 MHz and 85 Hz, respectively. Since the transmitter frequency is changed on a pulse-to-pulse basis, the AFC (Automatic Frequency Control) local oscillator (LO) must track the varying transmitter frequency. A block diagram of the frequency agility system is shown in Figure 3-3. The AFC loop is required to sample the transmitted RF frequency during the transmit pulse and then to generate a local oscillator frequency separated from the transmitter frequency by the system IF (Intermediate Frequency). As the transmitter frequency changes from pulse-to-pulse, the tracking local oscillator stabilizes to the transmitter frequency before the transmitter pulse is turned off. That stabilized frequency must be maintained over the interpulse period at least for a length of time corresponding to the maximum range of 20 NM. The AFC consists of a coarse and a fine tuning loop. The outer or coarse loop utilizes the magnetron tuning drive resolver output, which is proportional to frequency, as the feedback for the coarse loop. The local oscillator frequency is controlled using the resolver pickoff as the feedback to tune the LO each time the system sync pulse occurs. Since the system sync pulse occurs approximately 8 microseconds before the transmitted pulse, the coarse AFC loop has 8 microseconds to settle to within the coarse pickoff frequency. Upon the occurrence of the transmitted pulse, the AFC fine loop then samples the transmit frequency and closes the fine loop around the local oscillator to maintain the local oscillator within the IF separation. This frequency of the local oscillator is then held for a time corresponding to 20 NM range.

As the frequency agility modication requires a new LO, a unit with the same physical dimensions as the present LO and a tuning range compatible with the required new agile magnetron shall be installed in the same location. The receiver module which is shown in Figure 3.2 shall contain the AFC circuits. With the addition of frequency agility, an additional circuit board is required in the receiver module. To accommodate this, the height of the module shall increase approximately 1/2 inch. This allows the installation of the new AFC circuits which required two printed circuit boards to replace the existing single AFC board. The additional height of the receiver module shall not require an increase in t: overall receiver-transmitter LRU envelope.

3.2 Modification of Circuit Boards

3.2.1 General

The basic AN/APQ-153 is required to track targets with velocities of 3,000 feet/second closing a 1,000 feet/second opening. The operating velocity limit requirements for the rendezvous mission are not as large. Modification to the range tracker to operating velocity limits of 300 feet/second opening and 100 feet/second closing will decrease the tracker noise bandwidth. This in conjunction with expanded analog scale factors will provide an improved tracking capability that is closer to the requirements of the rendezvous radar.

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

PAGE 1 OF 41

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
18	6-1-76	N/A	

5. ISSUED BY CODE

NASA-Johnson Space Center
R&T Procurement Branch
Attn: M. A. Payne/BC73(35)
Houston, TX 77058

6. ADMINISTERED BY (If other than block 5) CODE

7. CONTRACTOR NAME AND ADDRESS (Street, city, county, state, and ZIP Code) CODE FACILITY CODE

Emerson Electric Co.
Electronics & Space Div.
8100 W. Florissant
St. Louis, MO 63136

8.
☐ AMENDMENT OF SOLICITATION NO. ______
DATED ______ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. NAS 9-14[illegible]
DATED 11-17-75 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ______ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

N/A

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ______
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Mutual agreement of the parties
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

ARTICLE II-DELIVERY is amended to read:

All items and/or documentation required to be furnished under this contract shall be delivered by July 31, 1976.

A. Paragraph 3.3. is added to the Statement of Work as follows:

3.3 Interface Design
The contractor shall assist in developing an interface design compatable with the Radar System. The design shall be arrived at through engineering discussions. A final design concept and drawings will be supplied as part of the end product of this contract.

These changes are effected at no cost to the Government.

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

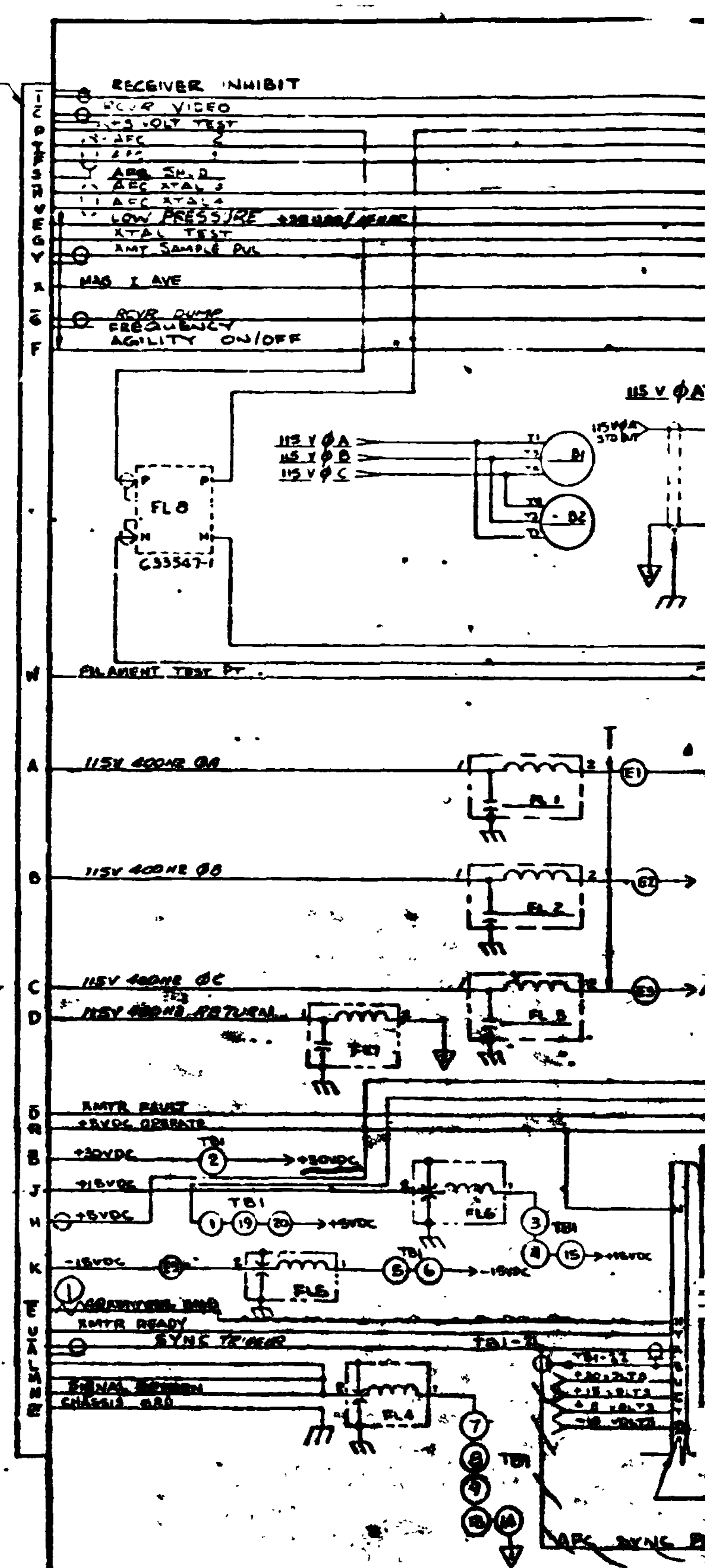
13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 3 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR	17. UNITED STATES OF AMERICA
BY [signature] (Signature of person authorized to sign)	BY ______ (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
E. W. Pellegrin Manager of Contracts	6/3/76	James W. Wilson	

APPENDIX B

MARKED-UP DRAWINGS AND OTHER RELEVANT TECHNICAL DETAILS



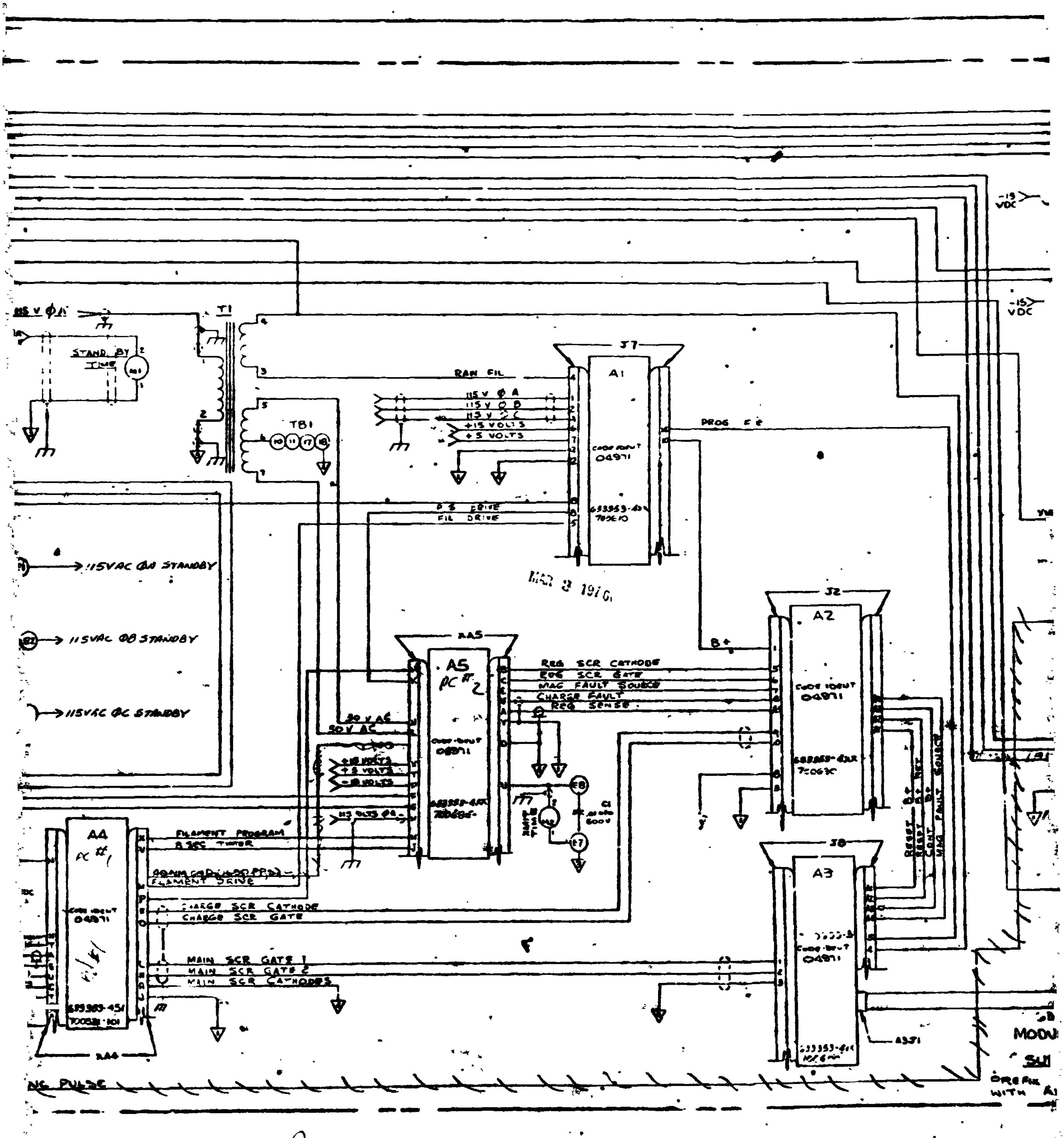
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

① 40NM PNG CMD is not necessary for ... opr.

② required R/T wire mods for ... opr.

③ SIGNAL WIRES MARKED IN GREEN ARE NOT NEEDED WITH 633980-1 POST AMP/AFC ASSY.

FOLDOUT FRAME 1



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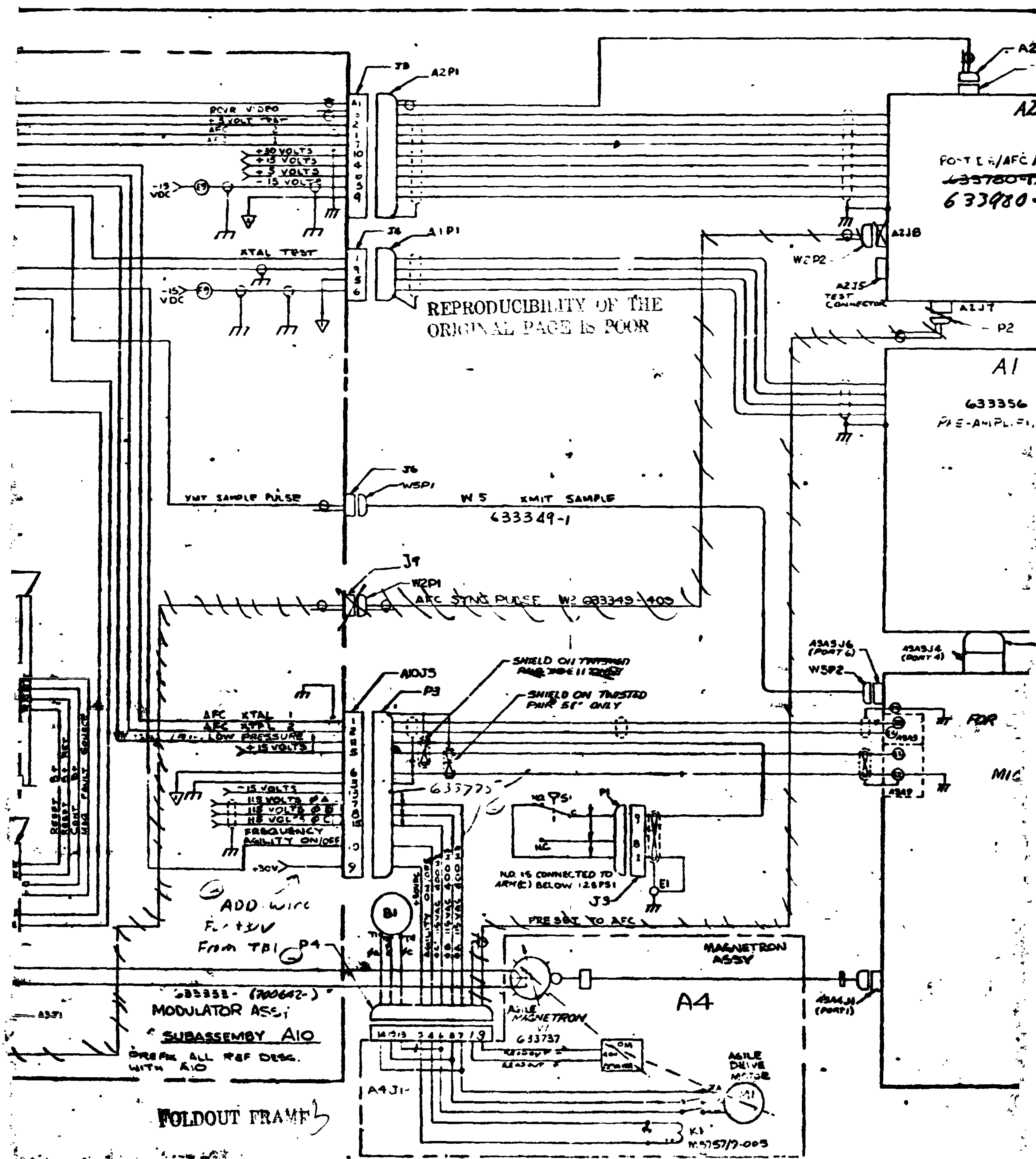

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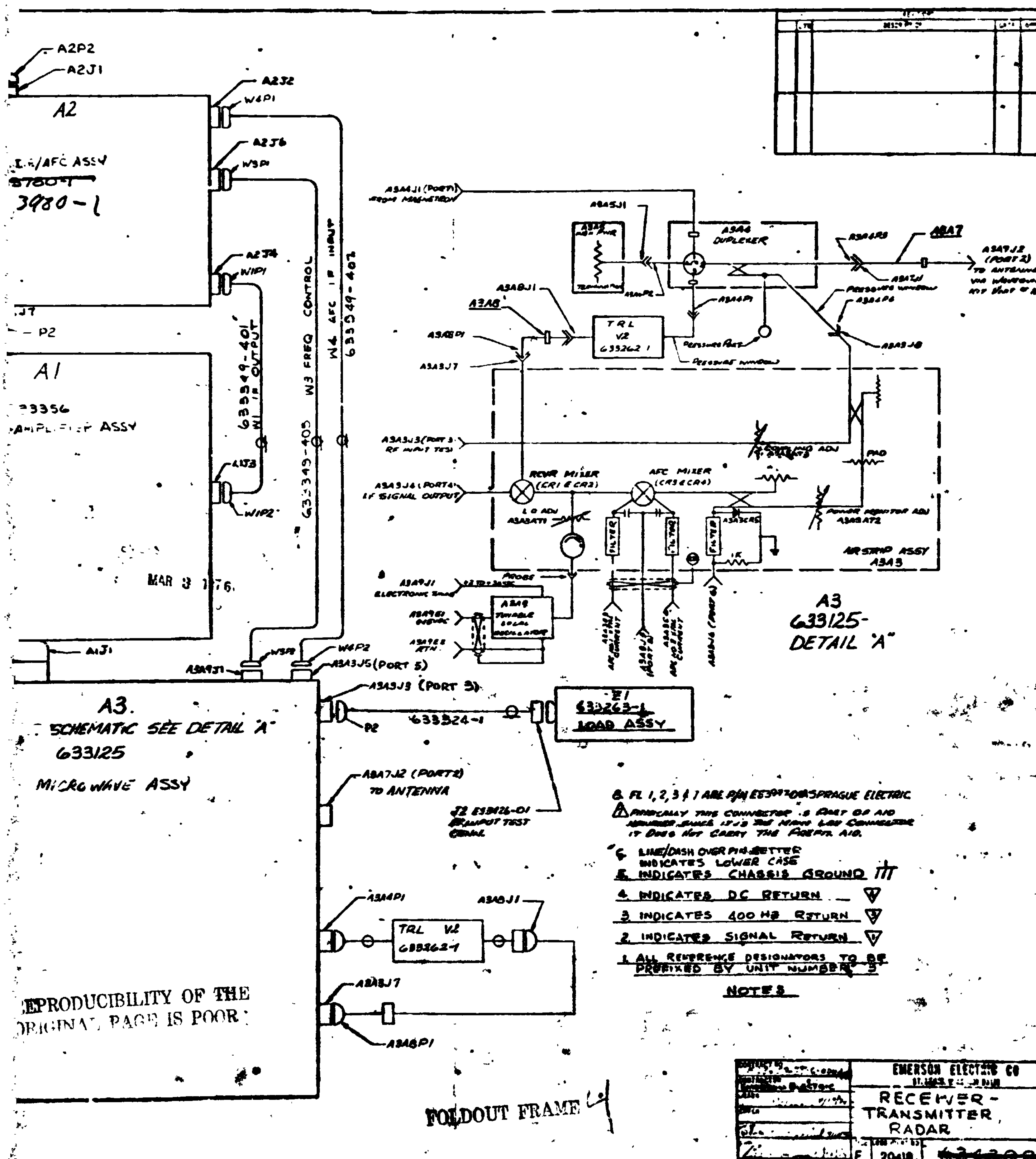
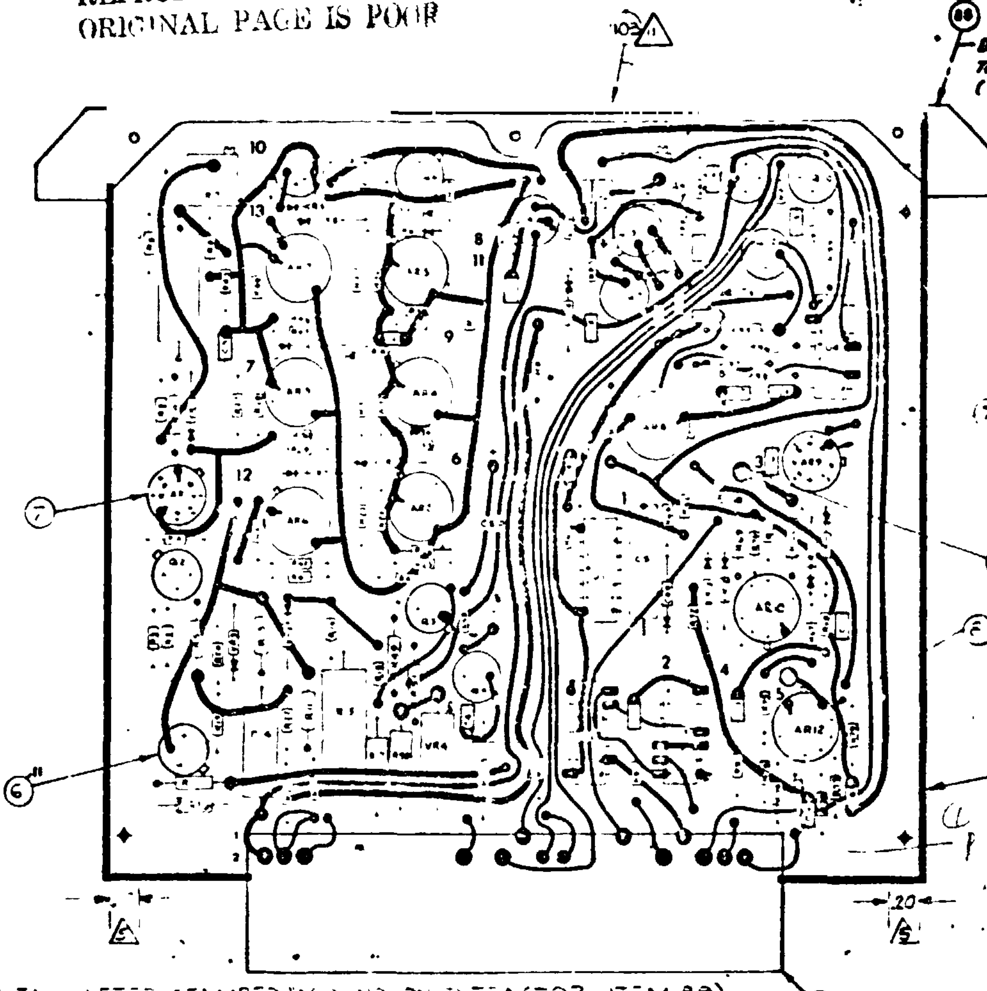


MAR 3 1976

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

FOLDOUT FRAME 4



11 INSTALL AFTER STAMPED "ASSY NO" ON EXTRACTOR (ITEM 86)

10 STAKE ITEM [illegible] ... GENERAL METHOD OF APPLICATION SHALL BE PER [illegible]

9 [illegible] VARNISH [illegible] WITH [illegible] ALLOW TO DRY BEFORE ASSEMBLY.

8 THIS SYMBOL IDENTIFIES THE NUMBER ONE PIN

7 THIS DRAWING IS DETAILED ONLY TO THE DEGREE NECESSARY TO ILLUSTRATE RELATIVE LOCATION OF COMPONENTS TO BE ASSEMBLED AND IS NOT INTENDED TO ILLUSTRATE TRUE SCALE OUTLINE RELATIONSHIP

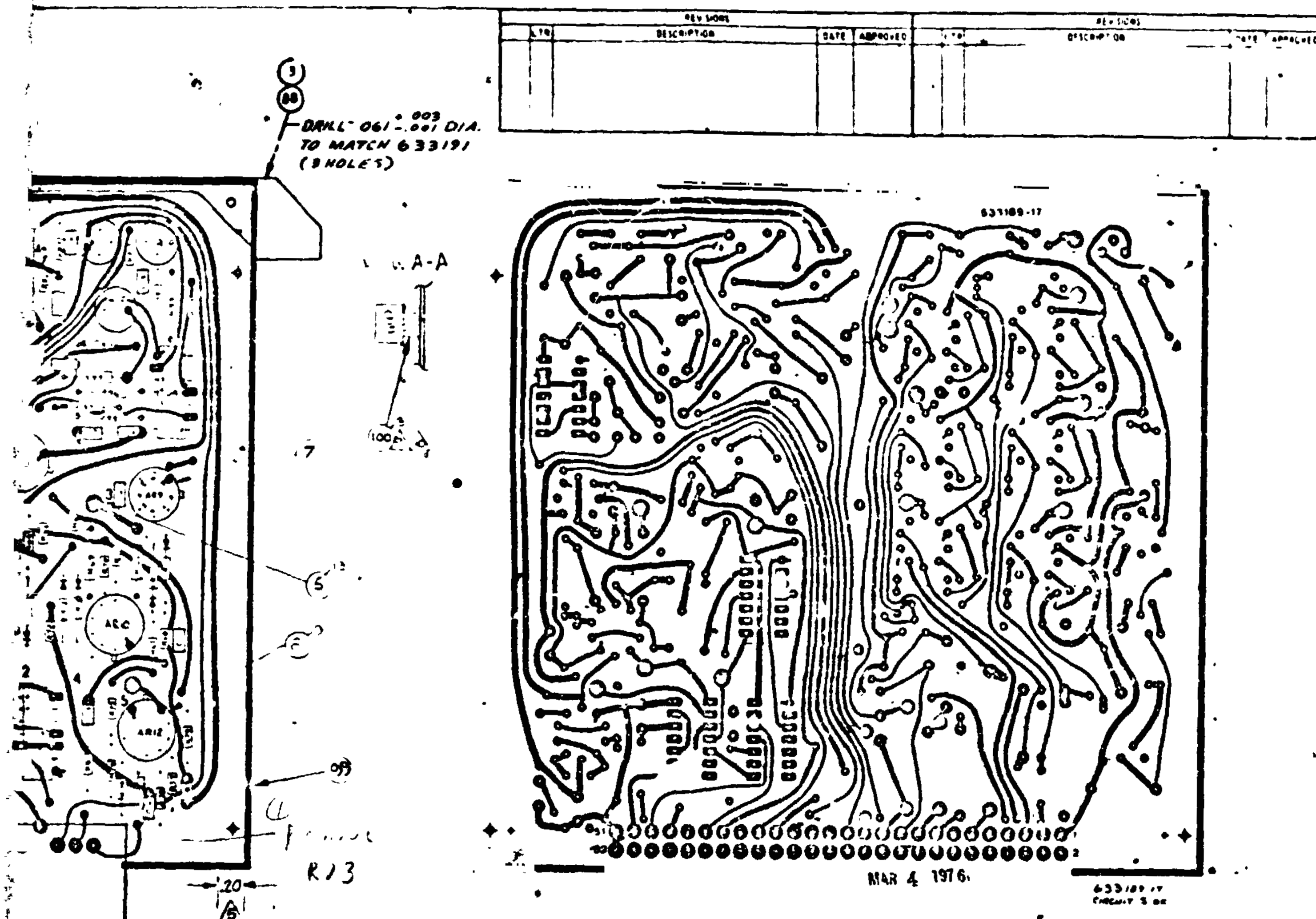
12 SEE SHEET 2 (SCHEMATIC) FO[R] ... ING WIRING

① MOD TO INT... WITH AGILE A...

FABRICATE PER D9016. SEE PARAGRAPH 5 D9016 FOR NOTES 1 THROUGH 6

NOTES

FOLDOUT FRAME 1



FOR PARTS LIST INFORMATION SEE CORRESPONDING NUMBER PL BOOKFORM DRAWING

FOR REFERENCE DESIGNATION & PARTS LIST ITEM NUMBER RELATIONSHIP SEE CORRESPONDING NUMBER RD BOOKFORM DRAWING

① MOD TO INTERFACE WITH AGILE AFC 3-9-76 JKU

SEE SHEET 2 (SCHEMATIC) FOR INTERCONNECTING WIRING

THROUGH 6

SHEET FUNCTION	SHT	REV
SCHEMATIC	2	
ASSY	1	

EMERSON ELECTRIC CO
ST LOUIS MISSOURI 63136

CIRCUIT CARD ASSEMBLY—
POWER SUPPLY BIT

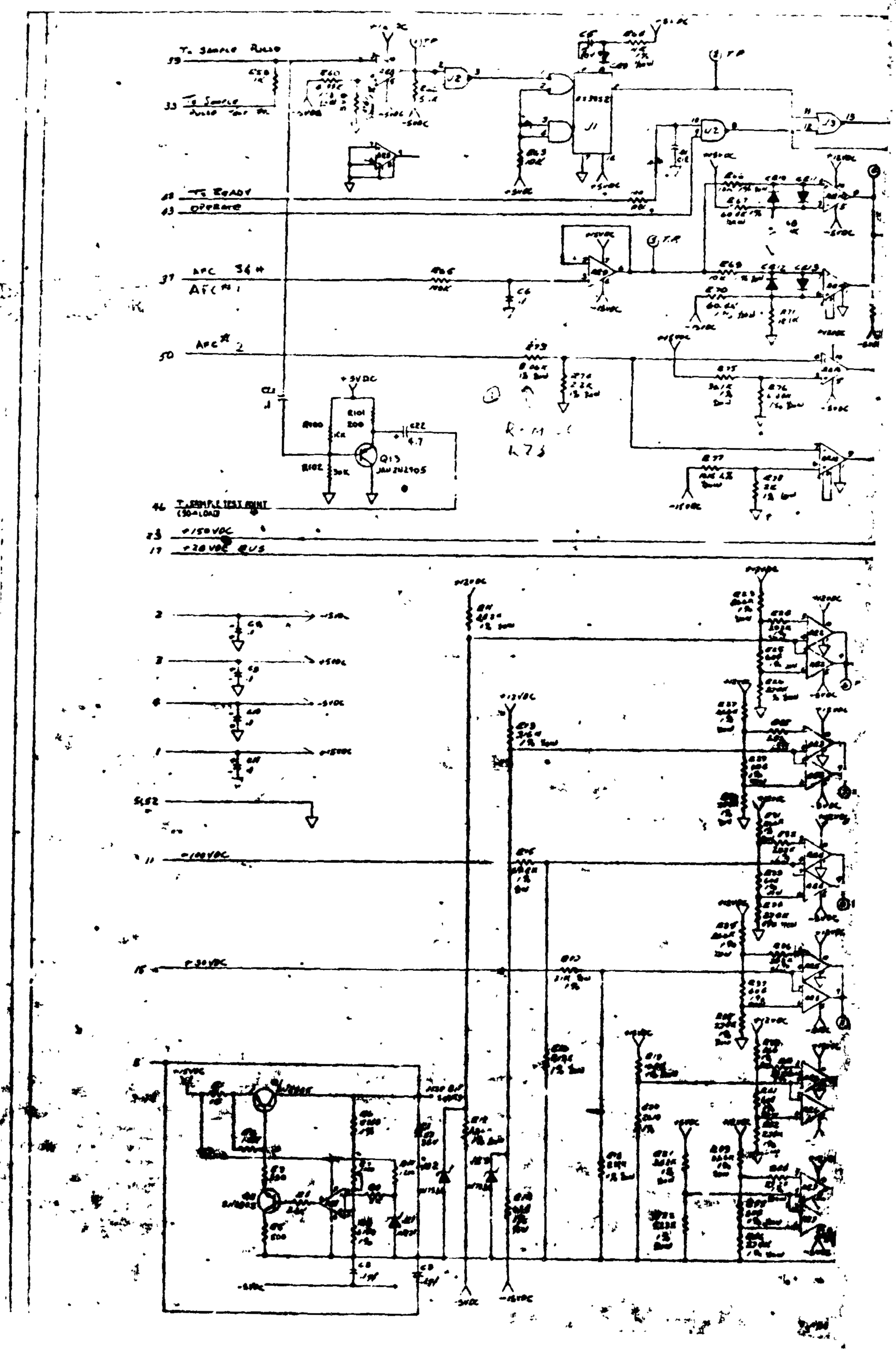
SIZE	CODE IDENT NO	
D	20418	656973

SCALE 2:1

656973

FOLDOUT FRAME 2

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR



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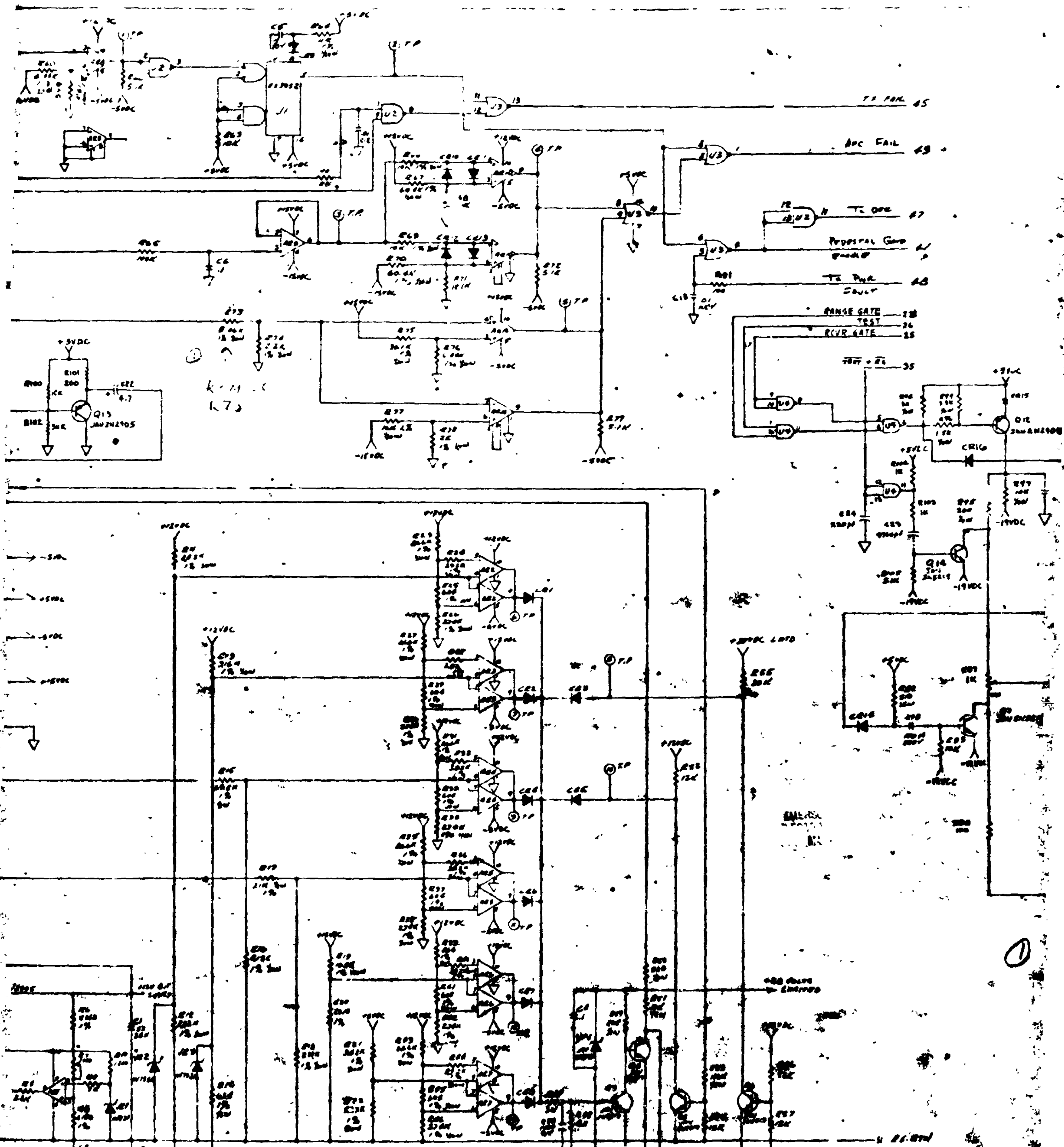

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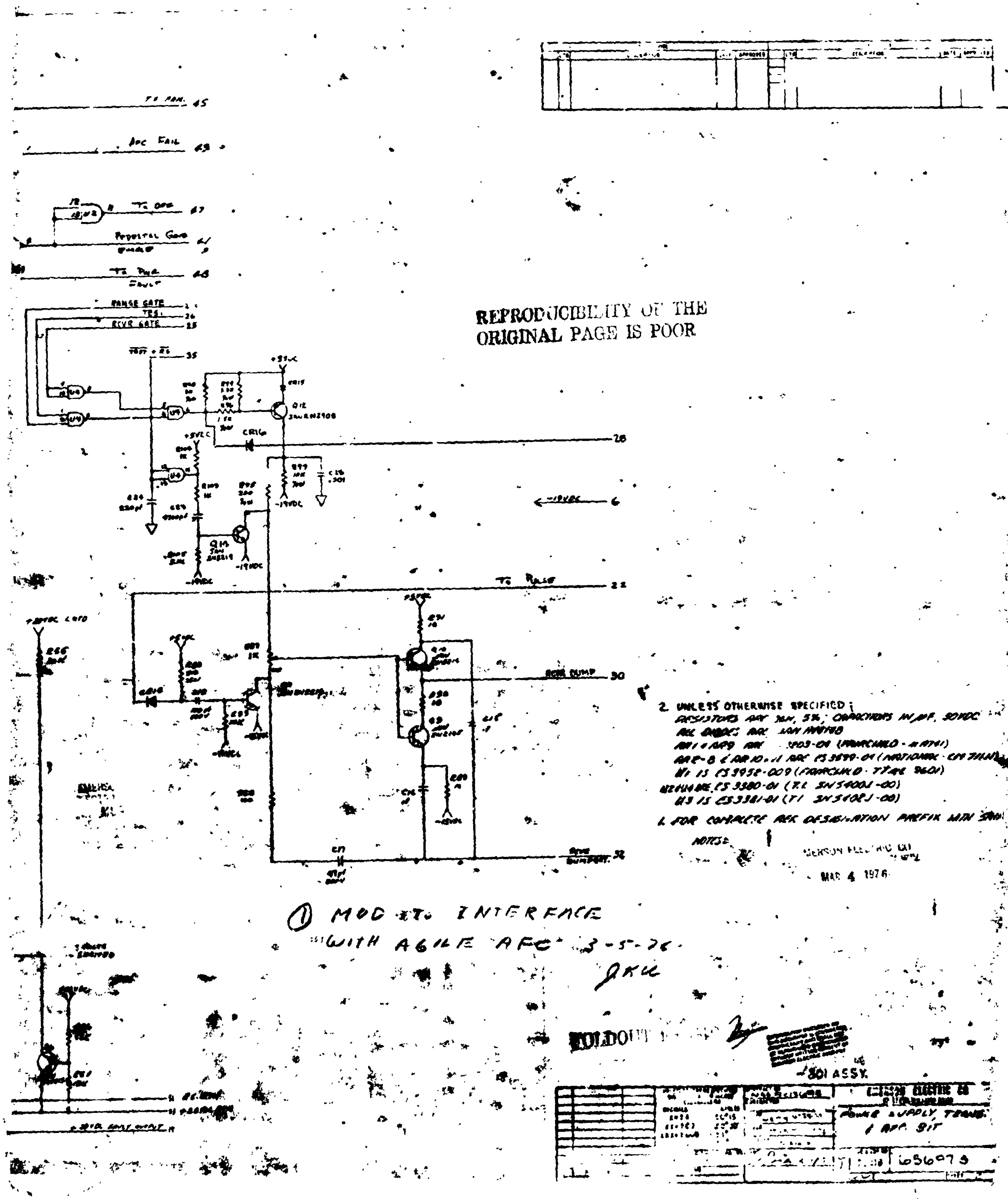
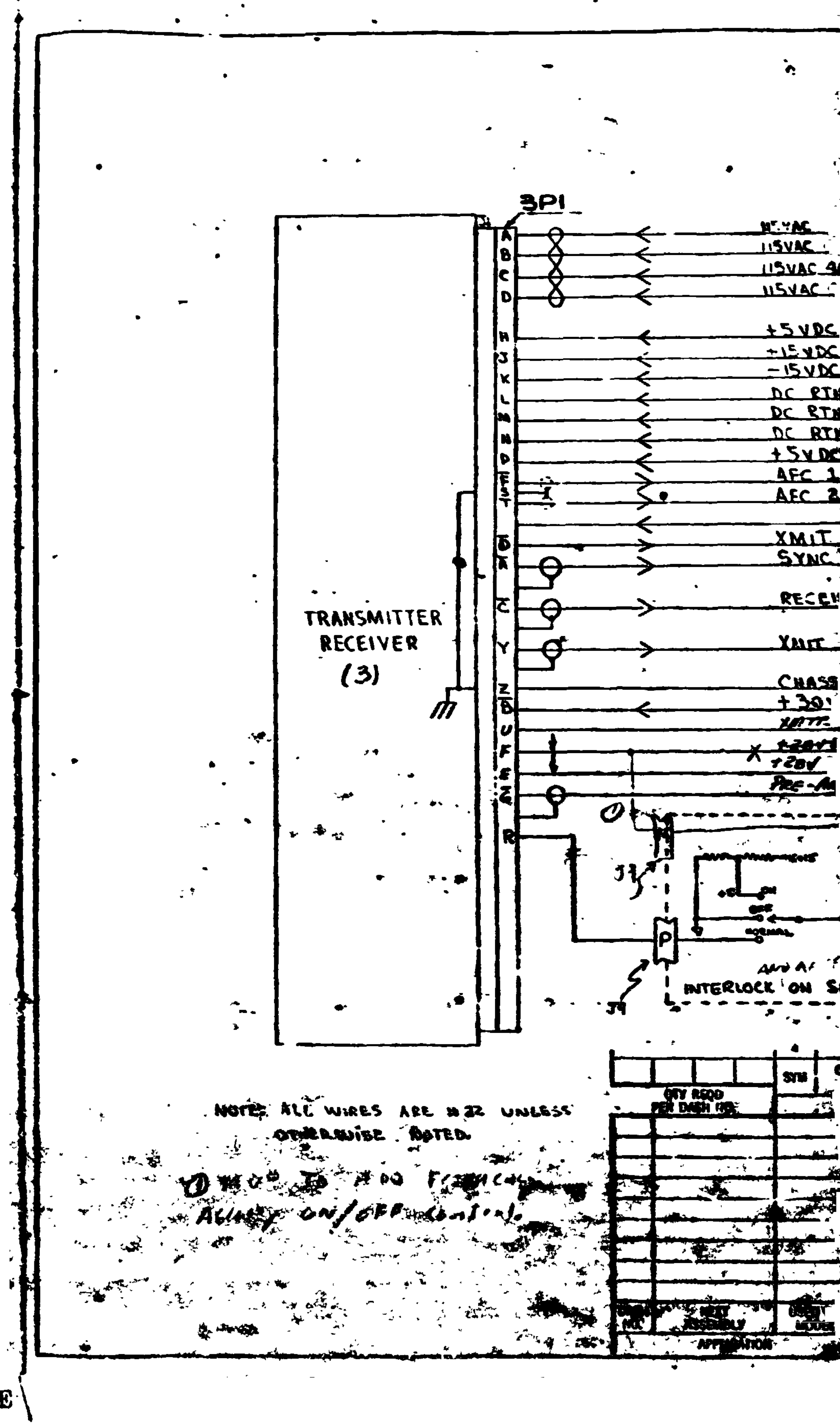

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
2. UNLESS OTHERWISE SPECIFIED:
ENERSON ELECTRIC CO
MAR 4 1976
① MOD TO INTERFACE WITH AGILE AFC 3-5-76
JKW
FOLDOUT FRAME
301 ASSY.
POWER SUPPLY, TRANS. & AFC BIT



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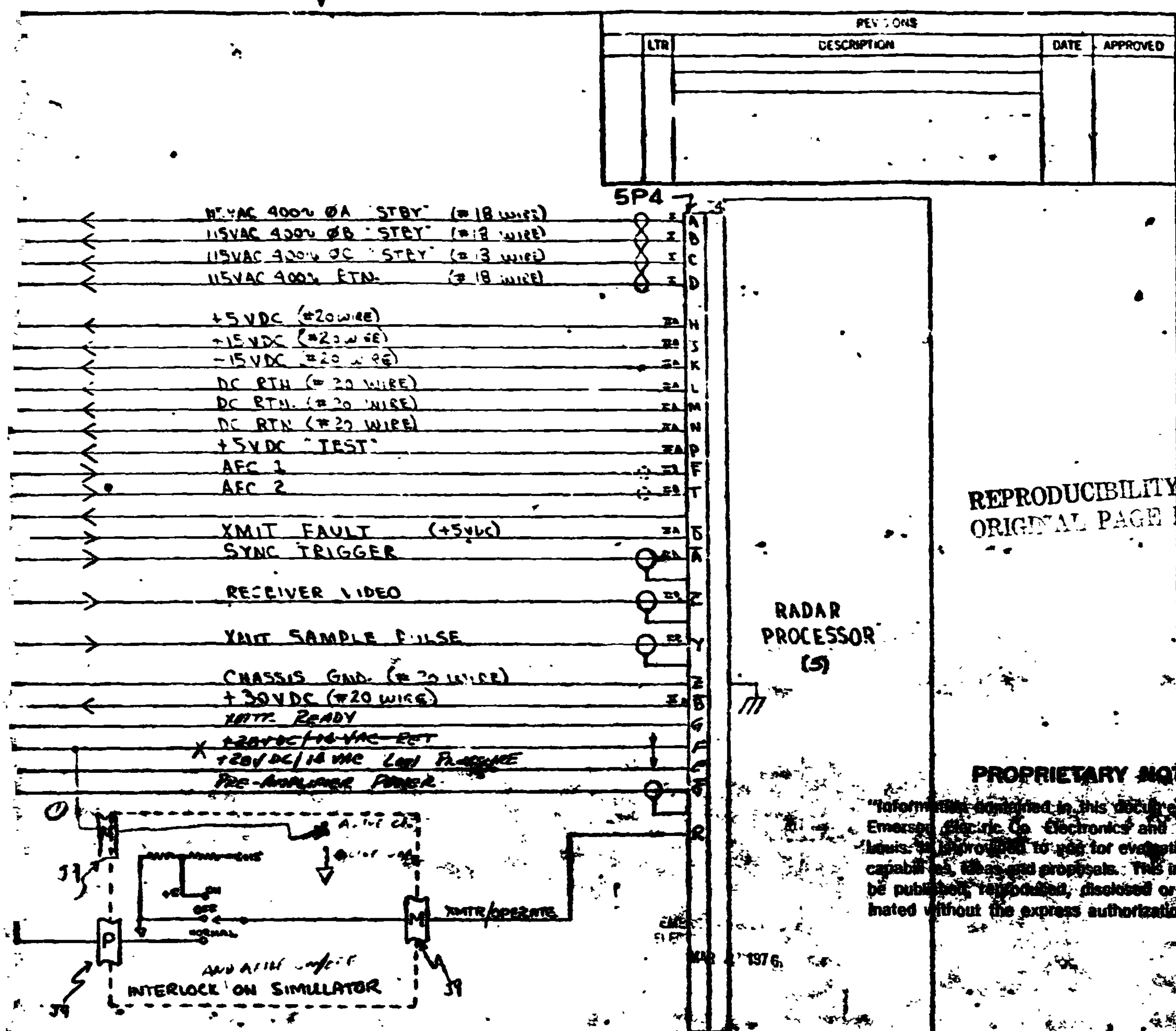


QTY REQD PER DASH NO.	SYM	CODE IDENT	PART OR IDENTIFYING NO.	ITEM NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL OR NOTE	SPECIFICATIONS

LIST OF MATERIALS OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON DECIMALS ANGLES ±0° 30'

CONTRACT NO.

CONTRACTOR

DRAWN 3-5-76

CHECKED

EMERSON ELECTRIC CO.
ST. LOUIS, MISSOURI 63136

SYSTEM WIRING SCHEMATIC
RADAR PROCESSOR TO
TRANSMITTER RECEIVER

656901

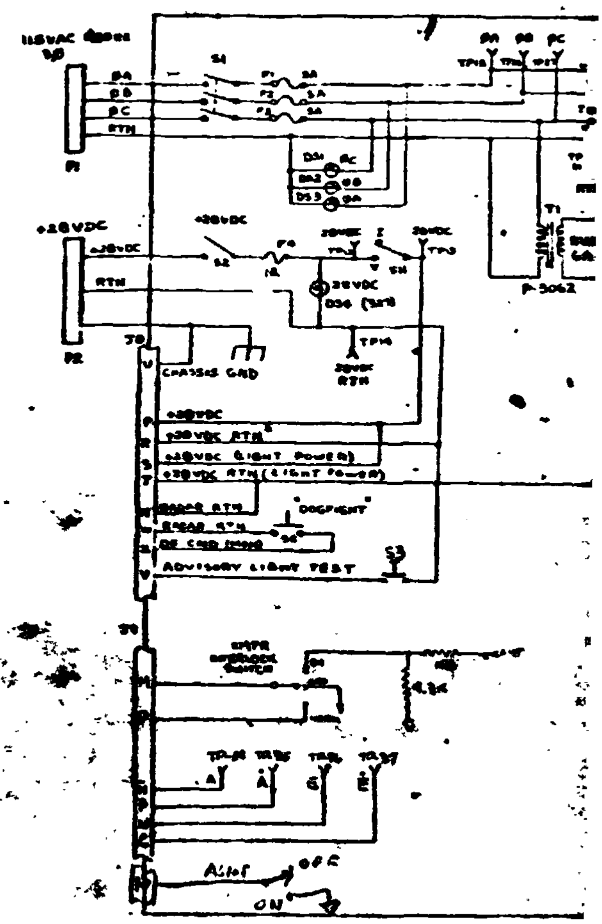
DASH NO. | NEXT ASSEMBLY | USED ON MODEL

APPLICATION

REL NO.

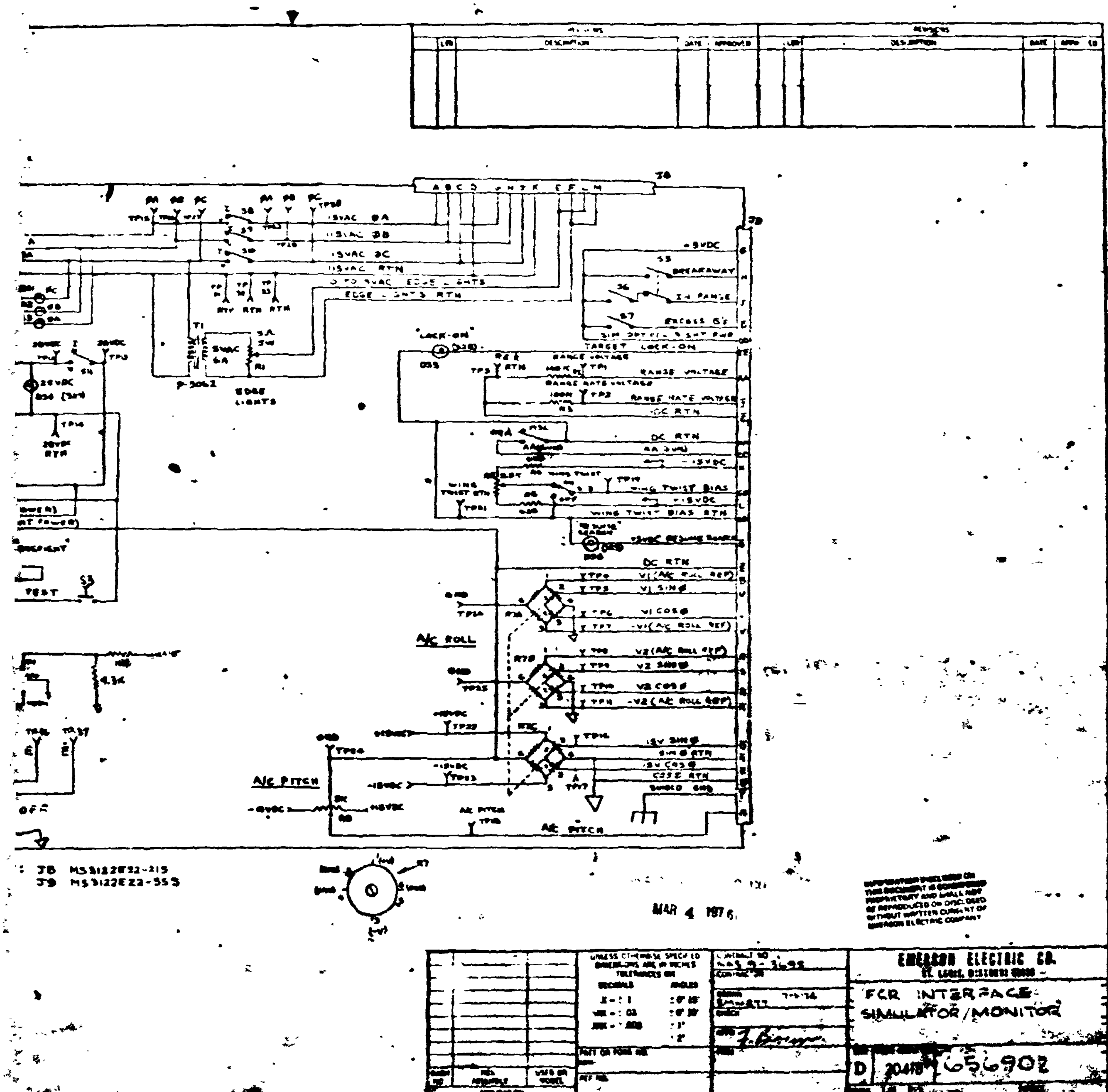
SHEET 3

FOLDOUT FRAME 2



NOTE: J8 MS3122E22-21S
J9 MS3122E22-55S

FOLDOUT FRAME



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REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

FOLDOUT FRAME

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

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	SYM	CODE IDENT	PART OR IDENTIFYING NO.	ITEM NO	NOMENCLATURE OR DESCRIPTION	MATERIAL OR NOTE	SPECIFICATIONS
QTY REQD PER DASH NO							

LIST OF MATERIALS OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON

DECIMALS	ANGLES
.X = ±.1	± 0° 15'
.XX = ± .03	± 0° 30'
.XXX = ± .008	± 1°
	± 2°

CONTRACT NO. [illegible] 0001

CONTRACTOR

DRAWN

CHECK [illegible] 4-13-76

APPD

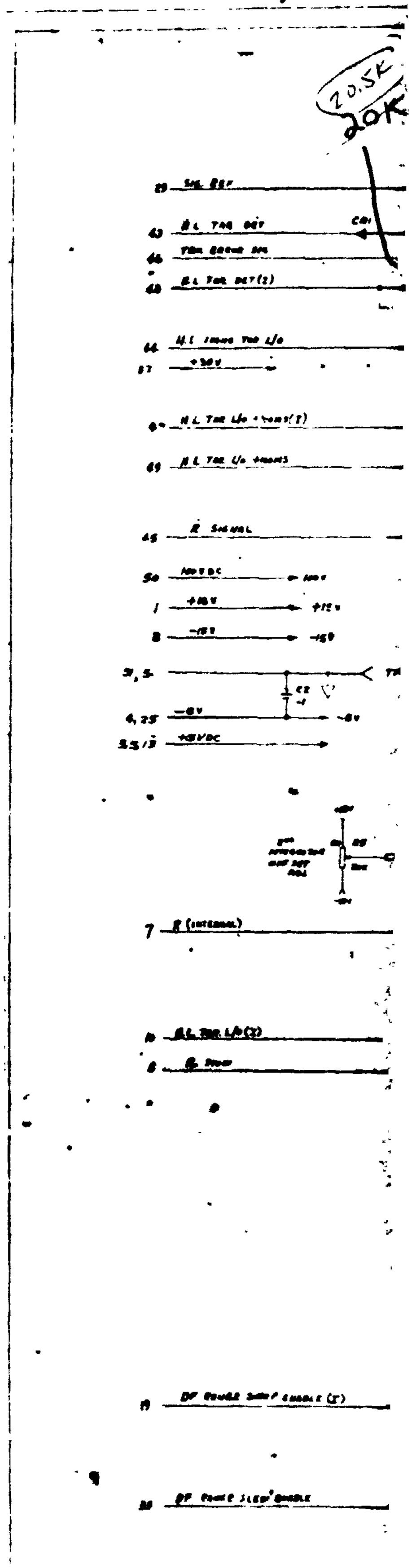
PROJ

EMERSON ELECTRIC CO.
ST. LOUIS, MISSOURI 63136

SIZE C | CODE IDENT NO. 20418

SCALE | SHEET 2

FOLDOUT FRAME 2



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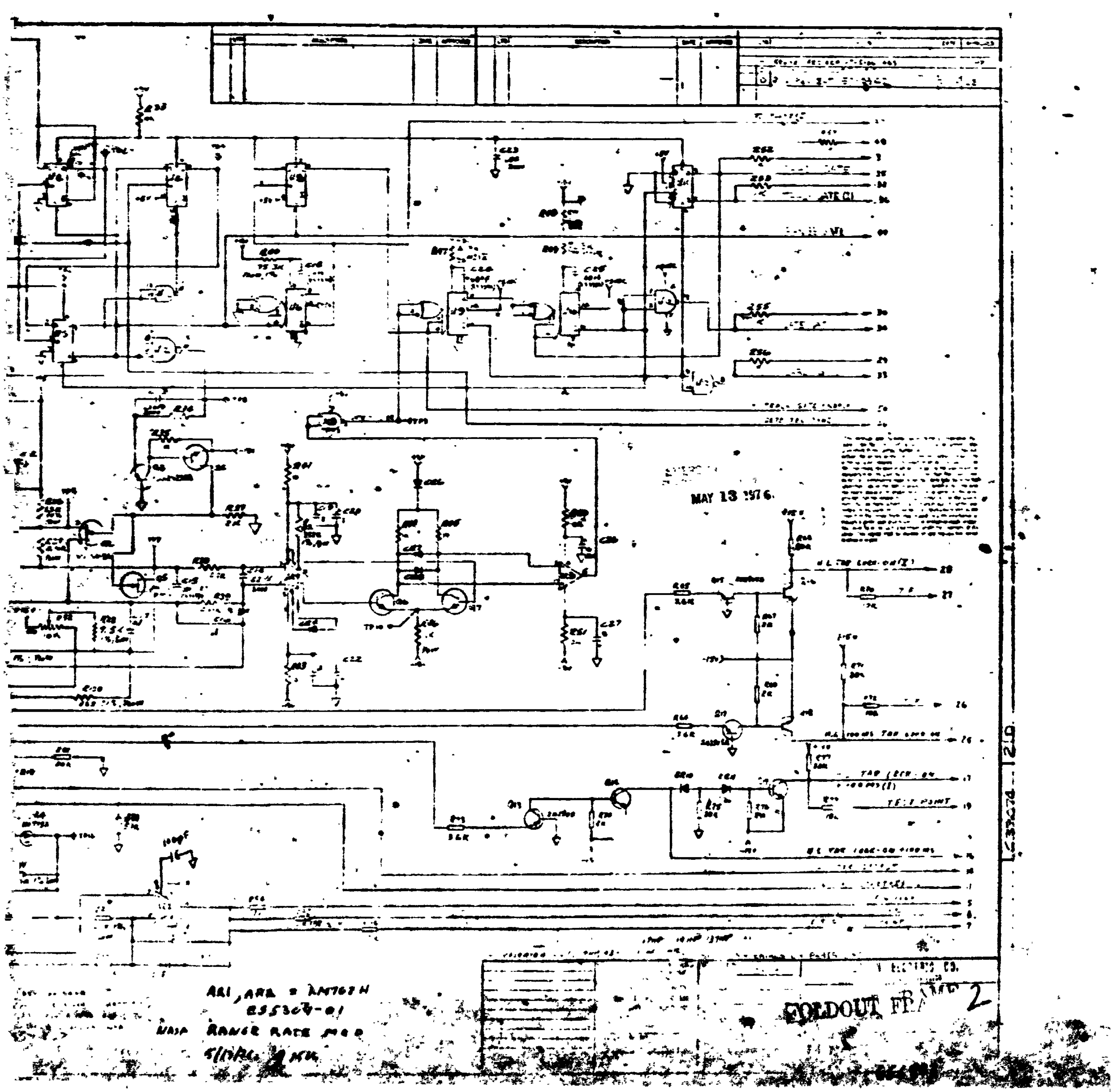
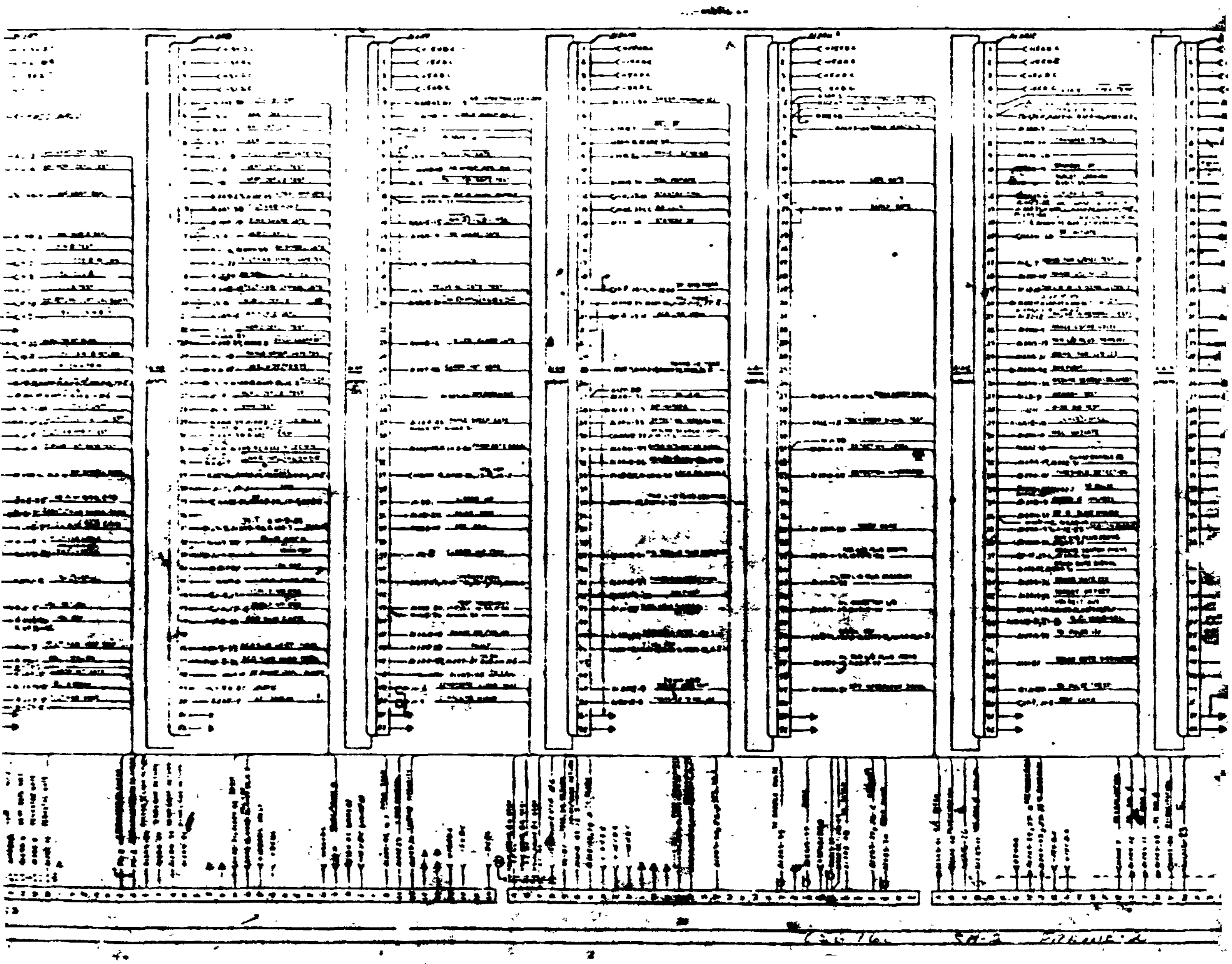

MAY 13 1976
FOLDOUT FRAME 2



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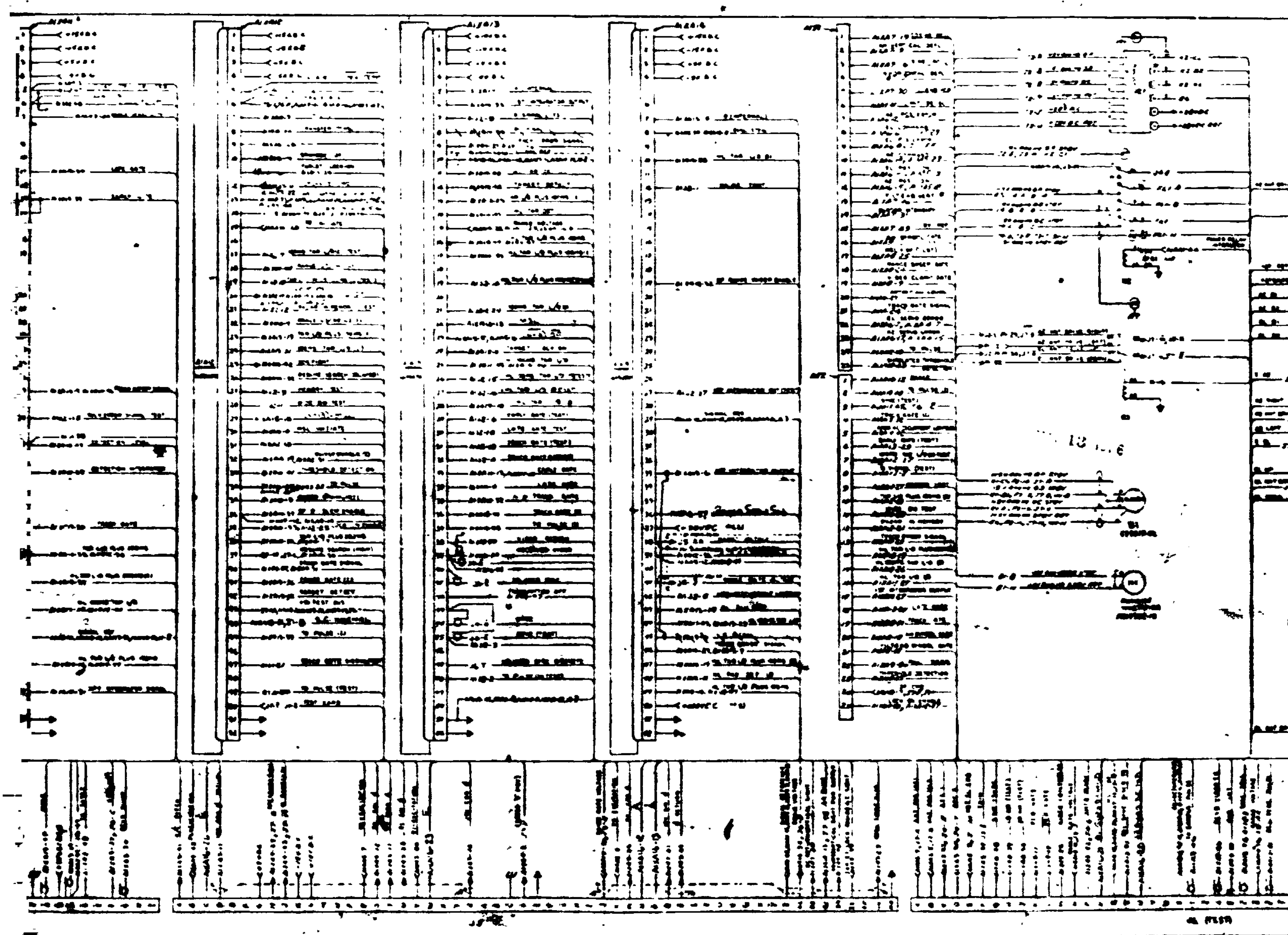


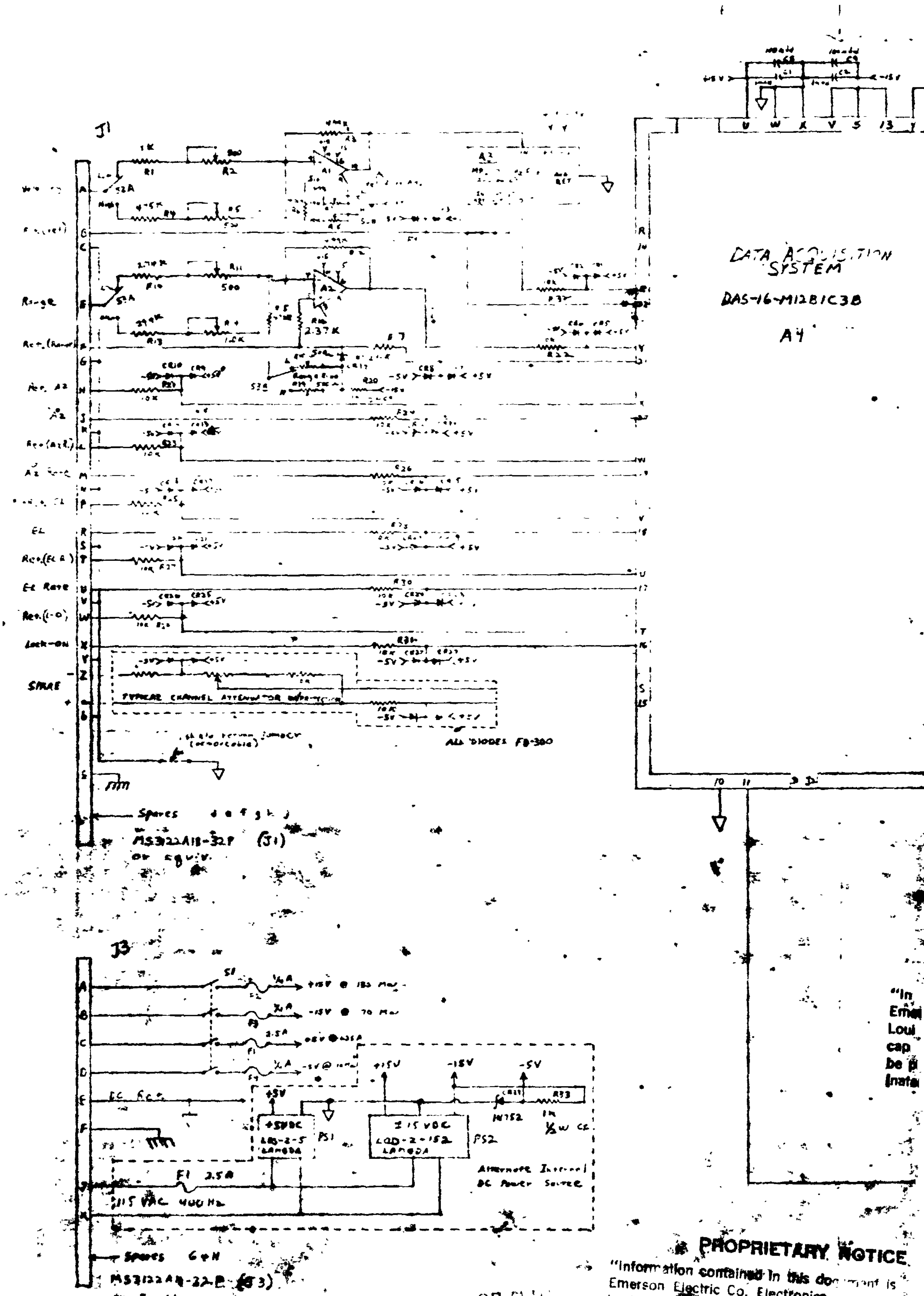
NASA RANGE RATE MOD · RADAR PROCESS[illegible]

5/13/76 JKU

656960

SHEET 2

FOLDOUT FRAME 2



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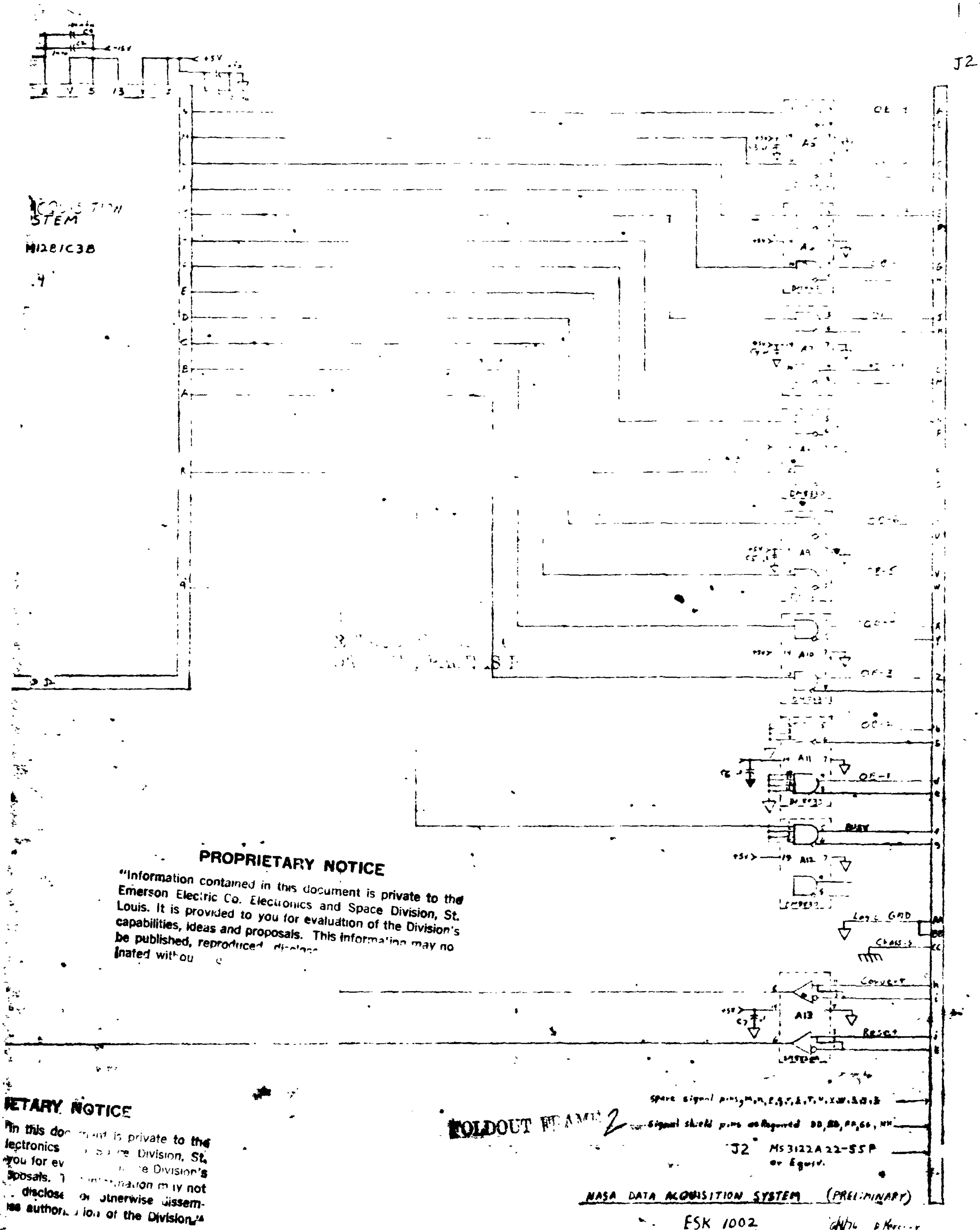

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NASA DATA ACQUISITION SYSTEM

DESIGN ACTIVITY
EMERSON ELECTRIC CO.
ELECTRONICS & SPACE DIVISION
ST. LOUIS, MO. 63136

CODE IDENT		SHEET	REV
20418	PL ESK1002	1 of 4	

QTY REQD PER DASH NO. -1	SYMBOL	CODE IDENT	PART OR IDENTIFYING NO.	ITEM NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL OR NOTES	SPECIFICATION
1			DAS-16-M1231C3B	1	Data Acquisition System	Datel	A4
2			2VK22D/1-3	2	Connector	Viking (Datel)	A4J1, A4J2
1			MP230-6	3	Filter, Active 1 Hz	Analogic	A3
8			SN75183	4	I.C.	Alt. DM8830 Nat. T.I.	A5-A12
1			SN75182	5	I.C.	Alt., DM8820A Nat. T.I.	A13
32			FD300	6	Diode	Fairchild	CR1-CR32
5			89XR500	7	Potentiometer	Beckman	R2,R5,R11, R12,R19
14			RNC60H1002FM	8	Resistor	10K 1% 50PPM 1/8W	R4,R17 R21-R32
1			RNC60J1001FM	9	Resistor	1.00K 1% 25PPm 1/8W	R1
1			RNC60J4751FM	10	Resistor	4.75K 1% 25PPM 1/8W	R4
1			RNC60J2741FM	11	Resistor	2.74K 1% 25PPM 1/8W	R10
1			RNC60J2942FM	12	Resistor	29.4K 1% 25PPM 1/8W	R13
5			M39014/01-1433	13	Capacitor	.1ufd cer.	C3-C7
3			M39014/02-1403	14	Capacitor	1ufd cer. 50V	C1, C2
3			M39006/09-6081	15	Capacitor	+20% 100utd elec. 25V	C8, C9
2			MST-205N	16	Switch	Alco	S2, S3
1			MST-405N	17	Switch Pwr	Alco	S1
2			uA741	18	AMP		A1, A2

ESD Form 1735-1 Feb 65

DESIGN ACTIVITY EMERSON ELECTRIC CO. ELECTRONICS & SPACE DIVISION ST. LOUIS, MO. 63136	20418 CODE IDENT	PL ESK1002 SHEET 2 of 4	REV

QTY REQD PER DASH NO.				SYMBOL	CODE IDENT	PART OR IDENTIFYING NO.	ITEM NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL OR NOTES	SPECIFICATION
			1			89 X R1K	19	Potentiometer	Beckman	R14
			2			89 X R10K	20	Potentiometer	Beckman	R7, R8
			2			RNC60J4991FM	21	Resistor		R3, R12
			1			RNC60J4011FM	22	Resistor		R6
			1			RNC60J4751FM	23	Resistor		R15
			1			RNC60H2371FM	24	Resistor		R16
			1			RCR20G102JR	25	Resistor		R20, R33
			2			IN752A	26	Voltage Regulator		CR33, CR34
							27			
							28			
							29			
							30			
							31			
							32			
							33			
							34			
							35			
							36			

DESIGN ACTIVITY EMERSON ELECTRIC CO. ELECTRONICS & SPACE DIVISION ST. LOUIS, MO. 63136	20418 CODE IDENT	PL ESK1002 SHEET 3 of 4	REV

QTY RECD PER DASH NO.					SYMBOL	CODE IDENT	PART OR IDENTIFYING NO.	ITEM NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL OR NOTES	SPECIFICATION
				1			PA3103GY	37	19"X5¼" Panel	Bud Light Grey Textured	
				1			AC428	38	Chassis Base	13"X17"X4" Bud	
				1			BPA-1598	39	Plate, Chassis	13"X17" Bud	
				1			MS3122A22-55P	40	Connector	Interface I/O	J2
				1			MS3122A18-32P	41	Connector	Input, Analog	J1
				1			MS3122A12-10P	42	Connector	Pwr Input	J3
			1				MS3126F22-55S	43	Connector	Interface I/O Test Cable	
			1				MS3126F18-32S	44	Connector	Input, Analog Test Cable	
			1				MS3126F12-10S	45	Connector	Pwr, Input Test Cable	
			1				AN3057-24	46	Cable Clamp	Test Cable Interface Clamp	
			1				AN3057-16	47	Cable Clamp	Input Analog test Cable Clamp	
			1				AN3057-10	48	Cable Clamp	PWR, Input Test Cable Clamp	
		1					LOS-Z-5	49	Power Supply	LAMBDA	PS1
		1					LOD-Z-152	50	Power Supply	LAMBDA	PS2
				2			099063	51	Fuseholders	Littlefuse	
				3			312.250	52	Fuse 3AG ¼A	Littlefuse	F2-F4
				1			31202.5	53	Fuse 3AG 2½A	Littlefuse	F1
				1			169P84-062EP	54	Perf Board	Vector	

DESIGN ACTIVITY
EMERSON ELECTRIC CO.
ELECTRONICS & SPACE DIVISION
ST. LOUIS, MO. 63136

20418	PL ESK1002	
CODE IDENT	SHEET 4 of 4	REV

QTY REQD PER DASH NO.					SYMBOL	CODE IDENT	PART OR IDENTIFYING NO.	ITEM NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL OR NOTES	SPECIFICATION
				11			ME-2B-14-W-T-B	55	Sockets 14 pin	Scanbe	
				100			R32	56	Sockets, Push in	Vector	
				100			T49	57	Terminal Push in	Vector	
				A/R			N/A	58	Hdw Set		

DATEL SYSTEMS, INC.

MODULAR 16 CHANNEL DATA ACQUISITION SYSTEM

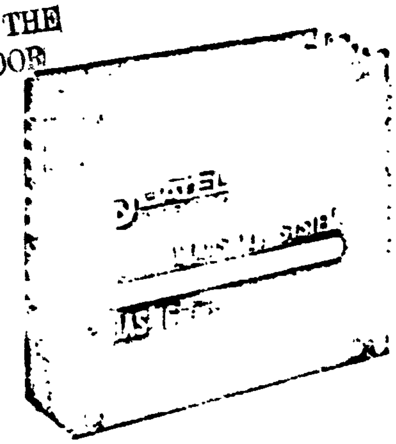
MODEL DAS-16 SERIES

FEATURES

- **Small Size . . . . 1.5" x 4.5" x 5.0"**
- **Complete . Simply Apply D.C. Power**
- **Two Modes of Operation . . Random or Sequential**
- **High Input Impedance . . . 100M ohm**
- **Low Power Consumption . . . . . Less than 7 Watts**
- **Fast Throughput Rate Up to 100 KHz.**
- **High Resolution Up to 12 Binary Bits**
- **Variety of Output Formats . . . . . Binary or BCD**

TYPICAL APPLICATIONS

- ☐ Air Pollution Data Gathering and Analysis
- ☐ Automatic Testing of Components
- ☐ Meteorological Data Gathering
- ☐ Biomedical Data Gathering and Monitoring
- ☐ Geophysical Testing
- ☐ Chemical Process Analysis and Control
- ☐ Telemetry Data Reduction
- ☐ Oceanographic Data Logging



FIRST SYSTEM IN A MODULE PRICED FROM $245. EA.

GENERAL DESCRIPTION

Datel Systems' Model DAS-16 is a new approach to the Data Acquisition System, a "Complete Data Acquisition module", occupying only 34 cubic inches and weighing less than 18 oz. Through the use of MOS and Monolithic circuits and unique packaging techniques, Datel has significantly reduced the size over competitive systems, at the same time reducing cost.

System DAS - 16 was designed primarily to interface directly with most mini-computers available on the market today. For real time data logging, System DAS - 16 can be interfaced to printers, paper tape punches, solid state or core memory and magnetic tape recorders.

DAS - 16 contains an eight or sixteen channel Multiplexer, Sample & Hold amplifier, Analog to Digital converter, System Sequencer which includes all necessary control and interface logic and a solid state readout, displaying multiplexer address and the analog to digital output value.

Random and Sequential addressing is employed to enhance system flexibility. Mode selection is determined by external control signals. Individual channels may be sampled at rates consistent with their particular bandwidth.

DAS-16 is available with input ranges of 0to+5V, 0 to +10V, ± 5V, or ± 10V at an input impedance of 100 megohms. Overall accuracy is ± 0.05% with a temperature coefficient of ± 40 ppm/°C. DAS - 16 will operate over an operating temperature range of 0° to +70°C. Gain and offset adjustments are provided, however long term stability is excellent, so it will seldom be necessary to readjust the external gain and offset trims once the initial adjustments are made.

Output coding can be Binary or BCD with word lengths of 8, 10, 12 Binary bits or 3 digit BCD. System throughput rates are available up to 100 KHz (8 Binary bits), 60 KHz (10 Binary bits), and 50 KHz (12 Binary bits).

WHO WILL USE DAS - 16

Applications include measuring, studying, and computing data in analog form. This includes variables like pressure, temperature, force, position, velocity, and voltage that are continuous.

An engineer wants to utilize DAS-16 for converting analog data to digital codes for three reasons:

1.) He wants to do some computer analysis, and computers require numerical form such as binary digital codes for input.

2.) He wants to do some telemetering or transmission of the data.

3.) He wants to store multi-channel data for a long period without degrading it, and the output of DAS - 16 can be stored in cores, tape memories or most other storage media.

MODES OF OPERATION

The input analog signals may be multiplexed for digitizing in a sequential or random manner. Mode selection is determined by control signals and by hard-wire jumpers (sequential mode for channel short cycle).

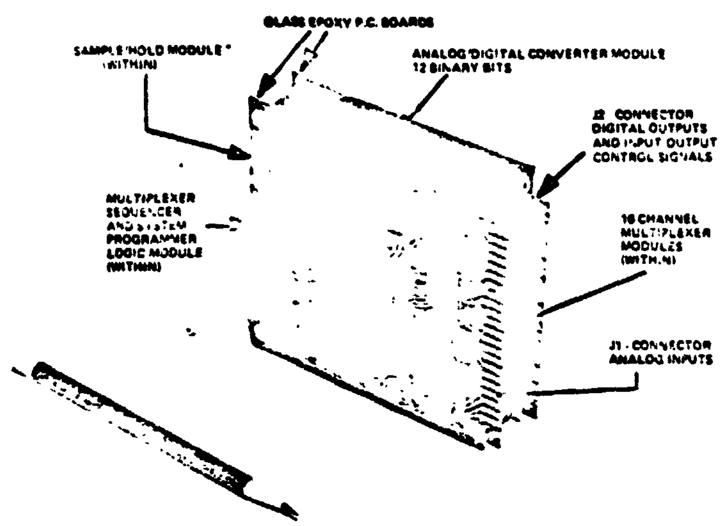
Sequential Mode

In the "Sequential Mode", analog multiplexing is controlled by an internal binary counter. When the "Busy" signal of the analog to digital converter goes false the sequential counter is advanced to the next channel. A 5 μsec delay is necessary before converting, this allows for Multiplexer and Sample/Hold settling time. The last channel to be sequenced is determined by hard wiring, the short cycle inputs to the sequencer counter outputs. If the full 16 channels are to be utilized the short cycle feature need not be used.

Random Mode

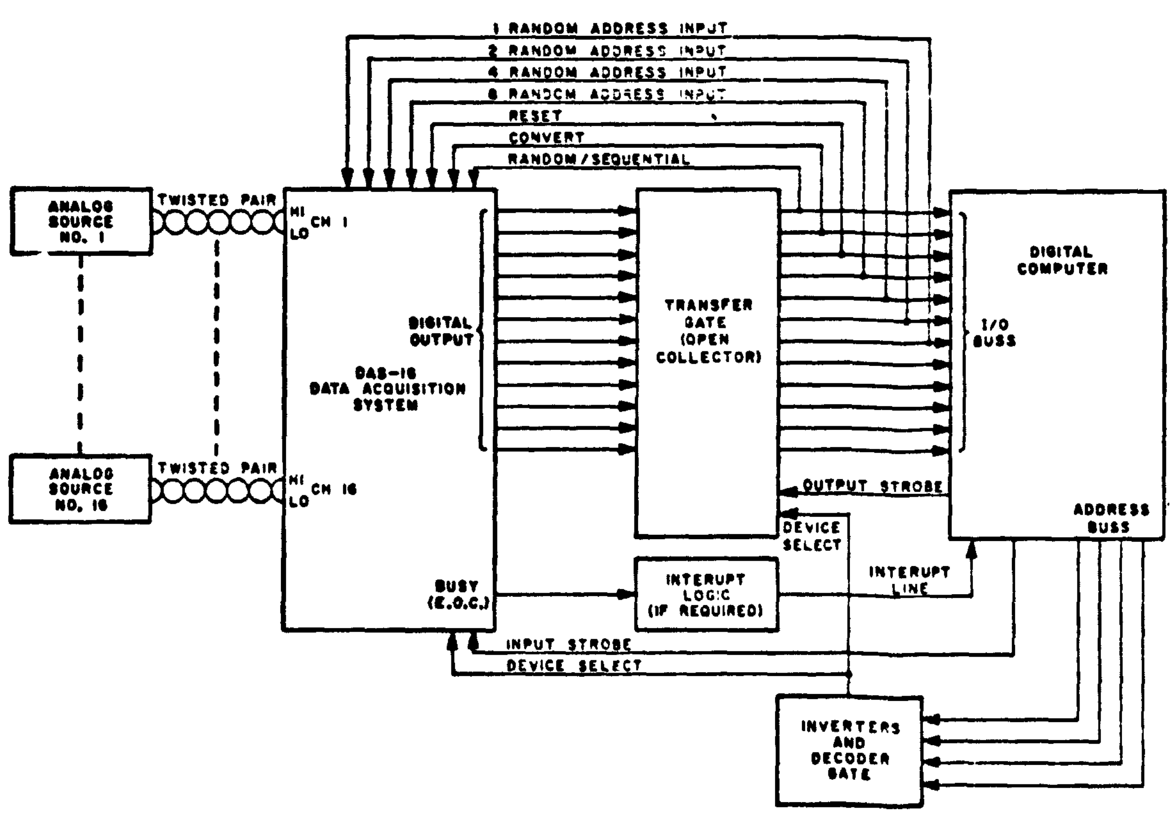
In the "Random Mode" any of the 16 channels may be addressed in any order.

When the "Device Select" signal is true and a "Strobe" is generated with the appropriate binary code on the channel address inputs, a channel will be selected. As in the case in sequential mode, a delay of 5 μsec is necessary before giving a "Convert" command. This is to allow for settling time of the Multiplexer and Sample/Hold. When the Busy signal goes to False a new channel may be selected.

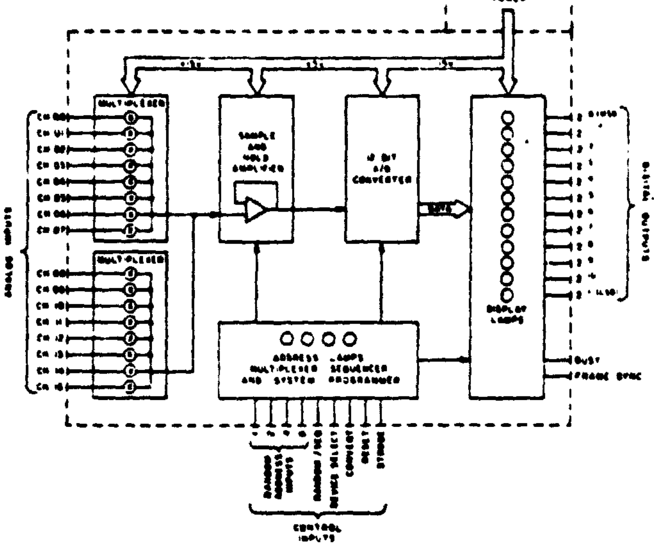


DATA ACQUISITION SYSTEM
MODEL DAS-16-L12B2D4B

TYPICAL SYSTEM CONFIGURATION



BLOCK DIAGRAM



MULTIPLEXER

It contains 16 MOS-FET switches with associated driver circuits, each having a current limiter pull-up FET to provide minimum propagation delay, also, included is all the necessary decoding logic for channel selection.

SAMPLE AND HOLD

Basic elements are a high input impedance non-inverting amplifier, a sample and hold FET switch/holding capacitor and a high gain output amplifier.

ANALOG TO DI TAL CONVERTER

The A/D contains a programmer/output register, a precision D/A Converter, high-speed voltage comparator and an operational temperature compensated voltage reference source. A modified successive approximation technique is employed which allows for encoding speeds of 750 nsec/bit.

SYSTEM PROGRAMMER

It contains a sequential and random addressable register or counter, interface logic for strobing random or sequential operation, and all necessary logic to be addressed by the output of a mini-computer.

DISPLAY

Both input channels and A/D output value are displayed by sixteen gallium phosphide red light-emitting diodes.

L SERIES: LOWEST COST

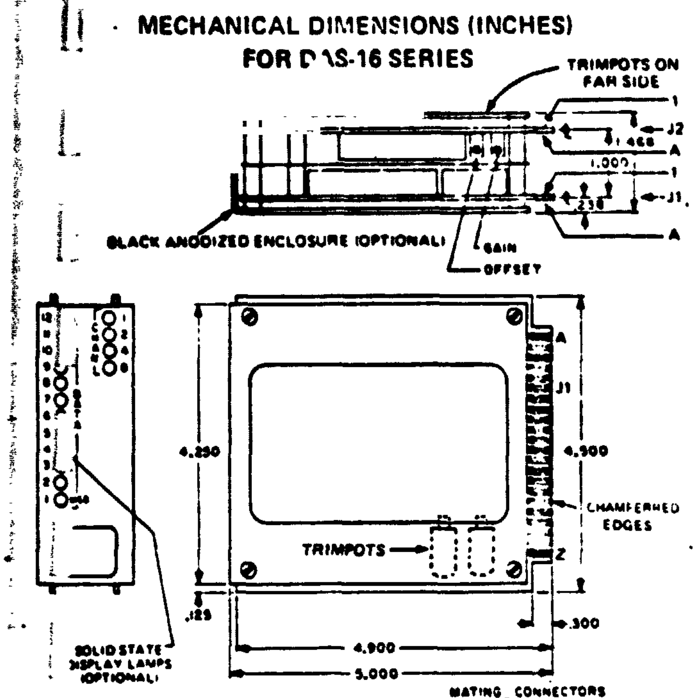
MODEL	DAS-16-L8B	DAS-16-L10B	DAS-16-L12B	DAS-16-L8D	DAS-16-L12D
SYSTEM OUTPUT RESOLUTION (DTL/TTL COMPATIBLE)	8 Binary Bits	10 Binary Bits	12 Binary Bits	2 Digits BCD	3 Digits BCD
NUMBER OF ANALOG INPUTS	8(16 opt.)	8(16 opt.)	8(16 opt.)	8(16 opt.)	8(16 opt.)
AVAILABLE INPUT VOLTAGE RANGES (1)	+5V, +10V ±5V ±10V (1) Same on All Models				
CHANNEL INPUT IMPEDANCE "ON" CONDITION	100 Megohms	100 Megohms	100 Megohms	100 Megohms	100 Megohms
CHANNEL INPUT IMPEDANCE "OFF" CONDITION	100 Megohms	100 Megohms	100 Megohms	100 Megohms	100 Megohms
CHANNEL INPUT ACQUISITION TIME	5 μsec to ±0.025%	5 μsec to ±0.025%	5 μsec to ±0.025%	5 μsec to ±0.025%	5 μsec to ±0.025%
SYSTEM APERTURE TIME	50 nsec	50 nsec	50 nsec	50 nsec	50 nsec
SYSTEM ACCURACY	±0.05% of FS	±0.05% of FS	±0.05% of FS	±0.05% of FS	±0.05% of FS
LINEARITY	± 1/2 LSB	± 1/2 LSB	± 1/2 LSB	± 1/2 LSB	± 1/2 LSB
SYSTEM THROUGHPUT RATE	50KHz (20 μsec)	30KHz (33 μsec)	25KHz (40 μsec)	50KHz (20 μsec)	25KHz (40 μsec)
TEMPERATURE COEFFICIENT	±40 ppm/°C	±40 ppm/°C	±40 ppm/°C	±40 ppm/°C	±40 ppm/°C
SYSTEM CONTROL INPUTS (DTL/TTL COMPATIBLE)	Random Address Input Sequential Input Device Select Convert, Reset, Strobe — SAME ON ALL MODELS				
SYSTEM DIGITAL OUTPUTS	Up to 12 Parallel Lines, Serial Output End of Conversion Multiplexer Short Cycle Frame Sync — SAME ON ALL MODELS				
SYSTEM OUTPUT DISPLAY (OPTIONAL)	Up to 12 LIGHT EMITTING Diodes for "A/D" Output Up to 4 LIGHT EMITTING Diodes for Channel Address — SAME ON ALL MODELS				
OPERATING TEMPERATURE RANGE	0° to +70°C	0° to +70°C	0° to +70°C	0° to +70°C	0° to +70°C
STORAGE TEMPERATURE RANGE	-55°C to +85°C	-55°C to +85°C	55°C to +85°C	-55°C to +85°C	-55°C to +85°C
POWER REQUIREMENTS	+5±.25VDC @ 800 ma +15±.5VDC @ 110 ma -15±.5VDC @ 70 ma (1) — SAME ON ALL MODELS				
CASE SIZE	1.5"W x 4.5"L x 5.0"D — SAME ON ALL MODELS				

M SERIES: HIGHEST SPEED AND ACCURACY

MODEL	DAS-16-M8B	DAS-16-M10B	DAS-16-M12B	DAS-16-M8D	DAS-16-M12D
SYSTEM OUTPUT RESOLUTION (DTL/TTL COMPATIBLE)	8 Binary Bits	10 Binary Bits	12 Binary Bits	2 Digits BCD	3 Digits BCD
NUMBER OF ANALOG INPUTS	8(16 opt.)	8(16 opt.)	8(16 opt.)	8(16 opt.)	8(16 opt.)
AVAILABLE INPUT VOLTAGE RANGES (1)	+5V, +10V ±5V, ±10V (1) Same on All Models				
CHANNEL INPUT IMPEDANCE "ON" CONDITION	100 Megohms	100 Megohms	100 Megohms	100 Megohms	100 Megohms
CHANNEL INPUT IMPEDANCE "OFF" CONDITION	100 Megohms	100 Megohms	100 Megohms	100 Megohms	100 Megohms
CHANNEL INPUT ACQUISITION TIME	5 μsec to ±0.025%	5 μsec to ±0.025%	5 μsec to ±0.025%	5 μsec to ±0.025%	5 μsec to ±0.025%
SYSTEM APERTURE TIME	50 nsec	50 nsec	50 nsec	50 nsec	50 nsec
SYSTEM ACCURACY	±0.025% of FS	±0.025% of FS	±0.025% of FS	±0.025% of FS	±0.025% of FS
LINEARITY	±1/2 LSB	±1/2 LSB	±1/2 LSB	±1/2 LSB	±1/2 LSB
SYSTEM THROUGHPUT RATE	100 KHz (10 μsec)	60KHz (16.6 μsec)	50KHz (20 μsec)	100KHz (10 μsec)	50KHz (20 μsec)
TEMPERATURE COEFFICIENT	±40 ppm/°C	±40 ppm/°C	±40 ppm/°C	±40 ppm/°C	±40 ppm/°C
SYSTEM CONTROL INPUTS (DTL/TTL COMPATIBLE)	Random Address Input, Sequential Input, Device Select, Convert, Reset, Strobe — SAME ON ALL MODELS				
SYSTEM DIGITAL OUTPUTS	Up to 12 Parallel Lines, Serial Output, End of Conversion, Multiplexer Short Cycle, Frame Sync — SAME ON ALL MODELS				
SYSTEM OUTPUT DISPLAY (OPTIONAL)	Up to 12 LIGHT EMITTING Diodes for "A D" Output Up to 4 LIGHT EMITTING Diodes for Channel Address — SAME ON ALL MODELS				
OPERATING TEMPERATURE RANGE	0° to +70°C	0° to +70°C	0° to +70°C	0° to +70°C	0° to +70°C
STORAGE TEMPERATURE RANGE	-55°C to +85°C	55°C to +85°C	-55°C to +85°C	-55°C to +85°C	-55°C to +85°C
POWER REQUIREMENTS	+5±.25VDC @ 800 ma +15±.5VDC @ 120 ma -15±.5VDC @ 70 ma (1) — SAME ON ALL MODELS				
CASE SIZE	1.5"W x 4.5"L x 5.0"D — SAME ON ALL MODELS				

NOTE (1) 20±.5VDC @ 16 ma POWER SUPPLY REQUIRED FOR ±10V INPUT VOLTAGE RANGE

MECHANICAL DIMENSIONS (INCHES) FOR DAS-16 SERIES



INSTALLATION DIMENSIONS

OUTPUT CODING FOR DAS-16 SERIES

±5V FS	Analog Input Range (± 10V, FS)	Offset Binary	2's Complement
4.9925	+ 9.995	111111111111	011111111111
	+ 8.750	111100000000	011100000000
	+ 7.500	111000000000	011000000000
	+ 5.000	110000000000	010000000000
0.0000	0.000	100000000000	000000000000
	− 5.000	010000000000	110000000000
	− 7.500	001000000000	101000000000
	− 8.750	000100000000	100100000000
	− 9.995	000000000001	100000000001
−5.000	−10.000	000000000000	100000000000

Analog Input Range (0 to +10V, FS)	Straight Binary	Analog Input Range (0 to +10V, FS)	BCD (8-4-2-1)
+ 9.9975	111111111111	+ 9.990	100110011001
+ 8.7500	111000000000	+ 8.750	100001110101
+ 7.5000	110000000000	+ 7.500	011101010000
+ 5.0000	100000000000	+ 5.000	010100000000
+ 2.5000	010000000000	+ 2.500	001001010000
+ 1.2500	001000000000	+ 1.250	000100100101
0.0000	000000000000	0.000	000000000000

INPUT/OUTPUT CONNECTIONS

CONNECTOR FUNCTIONS ARE ARRANGED IN VERTICAL EDGEBOARD VIEW

CONNECTOR J1

PIN	FUNCTION	PIN	FUNCTION
A	CH 16 HI ANALOG INPUT	1	CH 16 LO ANALOG INPUT
B	CH 15 HI ANALOG INPUT	2	CH 15 LO ANALOG INPUT
C	CH 14 HI ANALOG INPUT	3	CH 14 LO ANALOG INPUT
D	CH 13 HI ANALOG INPUT	4	CH 13 LO ANALOG INPUT
E	CH 12 HI ANALOG INPUT	5	CH 12 LO ANALOG INPUT
F	CH 11 HI ANALOG INPUT	6	CH 11 LO ANALOG INPUT
H	CH 10 HI ANALOG INPUT	7	CH 10 LO ANALOG INPUT
J	CH 9 HI ANALOG INPUT	8	CH 9 LO ANALOG INPUT
K	AUX. LO ANALOG INPUT	9	AUX. LO ANALOG INPUT
L	DEVICE SELECT	10	RANDOM / SEQUENTIAL
M	STROBE	11	RESET
N	2 RANDOM ADDRESS INPUT	12	4 RANDOM ADDRESS INPUT
P	1 RANDOM ADDRESS INPUT	13	8 RANDOM ADDRESS INPUT
R	AUX. LO ANALOG INPUT	14	AUX. LO ANALOG INPUT
S	CH 8 HI ANALOG INPUT	15	CH 8 LO ANALOG INPUT
T	CH 7 HI ANALOG INPUT	16	CH 7 LO ANALOG INPUT
U	CH 6 HI ANALOG INPUT	17	CH 6 LO ANALOG INPUT
V	CH 5 HI ANALOG INPUT	18	CH 5 LO ANALOG INPUT
W	CH 4 HI ANALOG INPUT	19	CH 4 LO ANALOG INPUT
X	CH 3 HI ANALOG INPUT	20	CH 3 LO ANALOG INPUT
Y	CH 2 HI ANALOG INPUT	21	CH 2 LO ANALOG INPUT
Z	CH 1 HI ANALOG INPUT	22	CH 1 LO ANALOG INPUT

-20V USED ONLY FOR -10VFS INPUT RANGE)

CONNECTOR J2

PIN	FUNCTION	PIN	FUNCTION
A	12 DIGITAL OUTPUT (LSB)	1	5 SEQUENCER OUTPUT
B	11 DIGITAL OUTPUT	2	4 SEQUENCER OUTPUT
C	10 DIGITAL OUTPUT	3	[illegible] OUTPUT
D	9 DIGITAL OUTPUT	4	[illegible] SEQUENCER OUTPUT
E	8 DIGITAL OUTPUT	5	[illegible]
F	7 DIGITAL OUTPUT	6	NO CONNECTION
H	6 DIGITAL OUTPUT	7	NO CONNECTION
J	5 DIGITAL OUTPUT	8	NO CONNECTION
K	4 DIGITAL OUTPUT	9	CONVERT
L	3 DIGITAL OUTPUT	10	NO CONNECTION
M	2 DIGITAL OUTPUT	11	NO CONNECTION
N	1 DIGITAL OUTPUT (MSB)	12	NO CONNECTION
P	SERIAL OUTPUT	13	+5VDC [illegible]
R	BUSY	14	FRAME SYNC
S	-5VDC OR -20VDC	15	[illegible] SEQUENCER OUTPUT
T	ADC INPUT (TEST POINT)	16	2 SEQUENCER OUTPUT
U	+15VDC	17	8 SEQUENCER OUTPUT
V	-15VDC	18	[illegible] SEQUENCER OUTPUT
W	GROUND	19	[illegible] SHORT CYCLE INPUT
X	GROUND	20	[illegible] SHORT CYCLE INPUT
Y	+5VDC	21	4 SHORT CYCLE INPUT
Z	+5VDC	22	3 SHORT CYCLE INPUT

(LEAVE J2-13 OPEN WHEN J2-S IS CONNECTED TO -20V (-10VFS INPUT RANGE IN USE)

PRICE LIST

(SINGLE QUANTITY)

Model	Price
DAS-16-L8B	− $245.
DAS-16-L10B	− $295
DAS-16-L12B	− $445.
DAS-16-L8D	− $245.
DAS-16-L12D	− $445.
DAS-16-M8B	− $345
DAS-16-M10B	− $395
DAS-16-M12B	− $545
DAS-16-M8D	− $345.
DAS-16-M12D	− $545.

Eight input channels standard, for an additional eight add $100 to List Price

(2) Add $10[illegible] for optional Black Anodized Aluminum enclosure and Solid State Display Lamps

ORDERING INFORMATION

DAS−16−M or DAS−16−L _ − _ _ _

NUMBER OF BITS AND CODING
- 8B = 8 BINARY BITS
- 10B = 10 BINARY BITS
- 12B = 12 BINARY BITS
- 8D = 2 DIGIT BCD (8-4-2-1)
- 12D = 3 DIGIT BCD (8-4-2-1)

INPUT CHANNELS
- 1 = 8 CHANNELS
- 2 = 16 CHANNELS

F.S. ANALOG INPUT
- A = 0V TO +5V
- B = 0V TO +10V
- C = ±5V
- D = ±10V

BLACK ANODIZED ALUMINUM ENCLOSURE AND SOLID STATE DISPLAY LAMPS
- A = WITH
- B = WITHOUT

OUTPUT FORMAT
- 1 = STRAIGHT BINARY (UNIPOLAR INPUT)
- 2 = BCD (UNIPOLAR [illegible])
- 3 = OFFSET BINARY ([illegible] INPUT)
- 4 = 2's COMPLEMENT ([illegible] INPUT)

CONNECTORS: VIKING 2VK22D/1-3, 2 REQUIRED . . $3.95

PRICES AND SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

DATEL SYSTEMS, INC. 1020 TURNPIKE STREET, CANTON, MASS 02021 TEL. (617) 828-8000 (714) 835-2751 (408) 733-2424 (213) 933-7256 TWX 710-348-0135 TELEX 924461

9/75 BULLETIN Q16CL05500

DESCRIPTION

The Analogic MP230 is a low-pass three-pole active filter that is especially designed for high-precision signal-filtering applications where exceptional low-frequency passband performance, miniaturization, and low cost are important system requirements. It includes a dual FET front end, an op amp output, and associated passive components; all packaged in a compact low-profile fully-shielded module. See Figures 1 and 2. By excluding the active components from its dc path, the MP230 accurately processes sensitive input signals where extremely low offset voltages and low output noise are critical.

PERFORMANCE

By incorporating the three poles of the filter in a Butterworth configuration, the MP230 yields maximally flat passband characteristics and rapid attenuation of 60dB per decade above the 3-dB cutoff frequency. See Figure 3. Seven user-selectable cutoff frequencies from 0.5 to 100Hz are available. Characterized by low offset voltage (2μV) and low output noise (1.4μV p-p), the MP230 processes an input voltage range of ±10 volts with a gain of nearly unity at dc. The input impedance of the filter is equal to the series resistance of the MP230 (dependent upon selected f3dB) and the load impedance. For optimum filtering, high impedance loads are recommended. A shield terminal separates the connection between the filter output terminal and the load input terminal, thereby eliminating board leakage effects on the dc gain. The MP230, powered by ±15 volts dc, operates over the temperature range of 0 to +70°C.

IMPLEMENTATION

Although intended primarily for use with the Analogic MP221 Chopper Amplifier (see Figure 4), the MP230 Filter will function ideally in any user's integrating A/D conversion system or OEM building-block application that requires low-pass signal filtering in the presence of low offsets and low noise. These applications include low level buffers, measurement preamplifiers, load cells, thermocouples, and strain gages. Packaged in a 2.0 by 1.0 by 0.39 inch Modupac™ case for maximum component density and mechanical protection, the MP230 is usually soldered to a user's PC card. Gold-plated pins enhance solderability and conductivity. An advanced shielding technique assures MP230 operation in hostile electrical environments and allows optimal physical positioning without danger of mutual interference problems.

FEATURES

- Low Offset Voltage
  <2μV
- Low Noise
  <1.4μV p-p
- Wide Input Voltage Range
  ±10 Volts
- Nearly Unity Gain
- Maximally Flat Passband
- Range of 3-dB Cutoff Frequencies
- Rapid Attenuation Above Cutoff
  Frequency: 60 dB/Decade

APPLICATIONS

- Instrumentation
  - Load Cells
  - Thermocouples
  - Strain Gages
- Measurement Preamplifiers
- Low Level Buffers

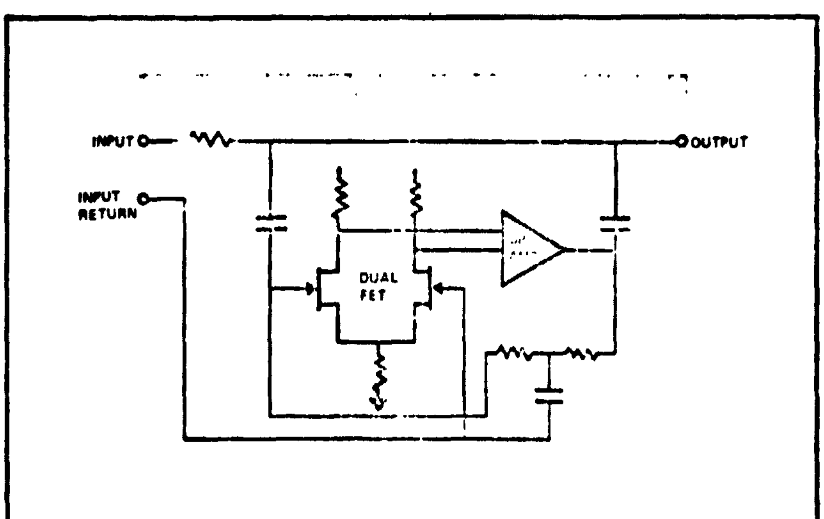


Figure 1. MP230 Simplified Schematic Drawing

ANALOGIC . . . The Digitizers

ANALOG INPUT

Voltage Range	±10 Volts
Impedance	R-filter + R-load (kΩ)
Offset Voltage	2μV maximum

ANALOG OUTPUT

Voltage Range	±10 Volts
Impedance	R-filter + R-load (kΩ); dependent upon f_{3dB}, as follows:

f_{3dB} (Hz) =	100	33	10	3.3	2	1	0.5
R-filter (kΩ) =	16	16	16	25	42	42	42

Noise	1.4μV p-p $\times\sqrt{f_{3dB}}$

GAIN CHARACTERISTICS

Gain at DC	1 − ±0.01%, as R-load (kΩ) approaches ∞ in R-load/R-filter + R-load
3dB Attenuation Frequency (f_{3dB})	100, 33, 10, 3.3, 2, 1, or 0.5 Hz; consult factory
Stopband Attenuation	60dB/decade

POWER

+15Vdc	2mA
−15Vdc	2mA

ENVIRONMENTAL & PHYSICAL

Operating Temperature	0 to +70°C
Non-Operating Temperature	−25°C to +85°C
Dimensions	2" x 1" x 0.39" Modupac™ (50.80 x 25.40 x 9.91mm)

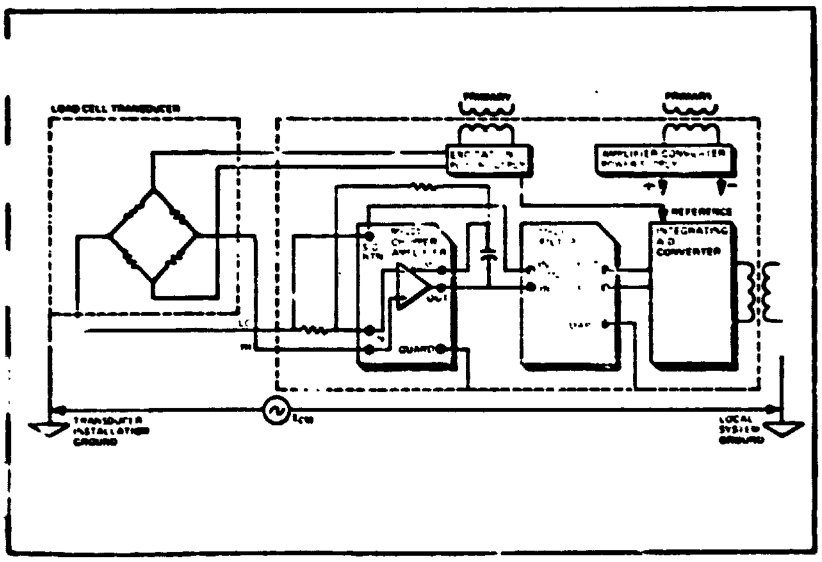


Figure 4. Low Level Amplification and Filtering with Guarded System in Presence of High Common Mode Voltages

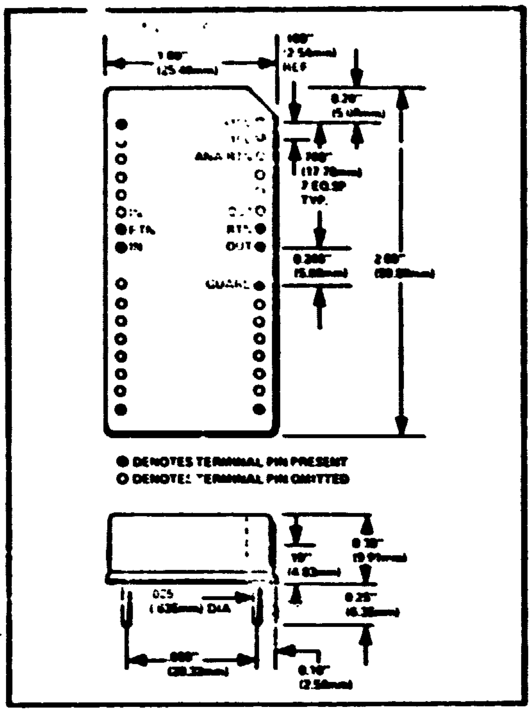


Figure 2. MP230 Outline Dimensions and Pin Connections

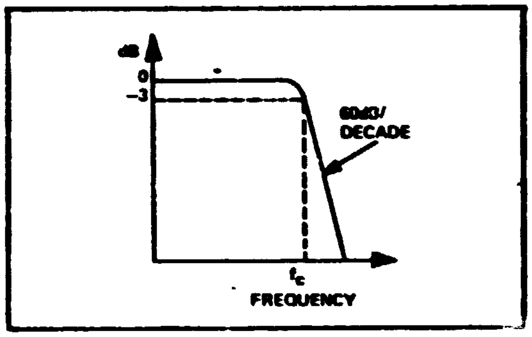


Figure 3. MP230 Passband Characteristic

ORDERING GUIDE

Simply Specify Configuration

For	Enter
Modupac	MP230
Card-Mounted MP	AN230

For 3-dB Attenuation Frequency	Enter
100Hz	1
33Hz	2
10Hz	3
3.3Hz	4
2Hz	5*
1Hz	6
0.5Hz	7

*Standard filter stocked.

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