X-711-74-219
PREPRINT

NASA TM X- 70 724

THE DESIGN, TESTING AND OPERATION OF THE IUE DATA PROCESSING UNIT POWER SUPPLY

JOSEPH A. GILLIS, Jr.

JULY 1974

GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

(NASA-TM-X-70724) THE DESIGN, TESTING AND OPERATION OF THE IUE DATA PROCESSING UNIT POWER SUPPLY (NASA) 34 p HC $4.75 N74-31657
CSCL 09B Unclas
G3/09 46711

X-711-74-219

THE DESIGN, TESTING AND OPERATION

OF THE

IUE DATA PROCESSING UNIT POWER SUPPLY

Joseph A. Gillis, Jr.

July 1974

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

THE DESIGN, TESTING AND OPERATION
OF THE
IUE DATA PROCESSING UNIT POWER SUPPLY

Joseph A. Gillis, Jr.

FOREWORD

The purpose of this document is to describe the design and operation of the power supply for the IUE Data Processing unit. It is anticipated that many units will eventually be made for IUE and other spacecraft to follow since the data processing system as a whole is hopefully to be a standard design. For this reason information is provided to assist in power supply part selection and testing procedures. This will help ensure that units turned out by any contractor will be essentially carbon copies of those originally produced by the designer for the prototype unit flown on the IMP-J spacecraft.

CONTENTS

APPENDIXES

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

TABLES

THE DESIGN, TESTING AND OPERATION
OF THE
IUE DATA PROCESSING UNIT POWER SUPPLY

INTRODUCTION

The basic techniques of dc to dc conversion by purely electronic means have long been known and used. The unit described herein makes use of some of the best features of these basic techniques which have been tried and proven in flight hardware on recent spacecraft. This, coupled with the use of some of the latest and most reliable components available, has produced a design which hopefully will prove reliable in the long run, and lend itself to ready reproduction as needed for future spacecraft.

While the idea of a so called "standard design" is a desirable goal from the point of view of cost and time savings, certain precautions should be taken to allow for changes which may be required. These changes could come about for several reasons, among them:

a. Certain parts could become obsolete and/or no longer available.

b. The load requirements on future spacecraft could increase substantially over that required of the first units.

c. The spacecraft interface specifications could change to the extent a basic design change could be required to meet them.

All these factors can be generally anticipated from past experience, but the specific modifications possibly required of future units can only be guessed at. In light of this, certain features have been designed into the unit to facilitate making changes while having a minimal effect on the overall electrical and mechanical design. These will be pointed out in the discussion of the circuit design.

DESIGN SPECIFICATIONS

Below are listed the specifications the power supply must be designed to meet.

Input Voltage: +28 volts 2%

Output voltages and loads

Output Volts	Output Current	Regulation
+7.75 volts	200-600 ma.	±5 mv.

Output Volts	Output Current	Regulation
-8.0 volts	40 ma.	±3%
-18 volts	1 ma.	±3%

Temperature Range: -20° C to +50° C

Output Voltage Ripples: 10 mv or less on all lines

Input Current Ripple: 5 ma or less

Efficiency: 70% minimum at maximum load
60% minimum at minimum load

Power Oscillator Frequency: 19 KHz ±3% (subject to slight change from spacecraft to spacecraft)

Package size and connector: The package outside dimensions and connector are shown in Figure 1.

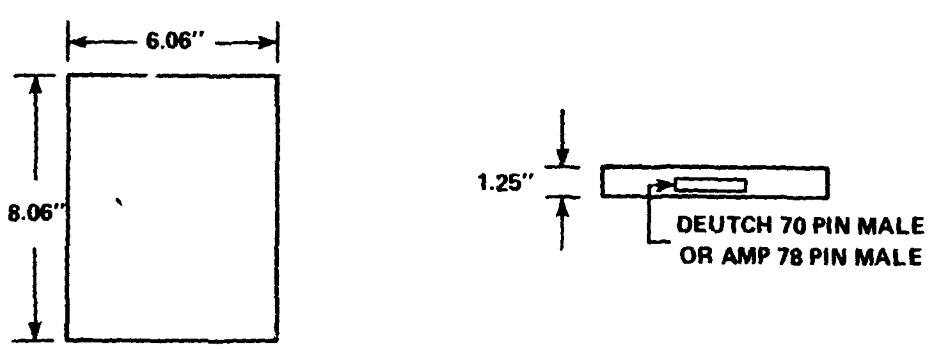


Figure 1. Data Processing Unit Power Supply Outside Dimensions

The input is to be dc isolated from the outputs, and the inputs and outputs are to be dc isolated from the frame.

Input Current Surge: The input current surge at turn on will be limited in peak value, duration and rate of change as shown in Figure 2.

RFI and EMC Control: The power supply shall be subjected to and meet the radio frequency interference and electromagnetic compatibility requirements as outlined in Appendix C.

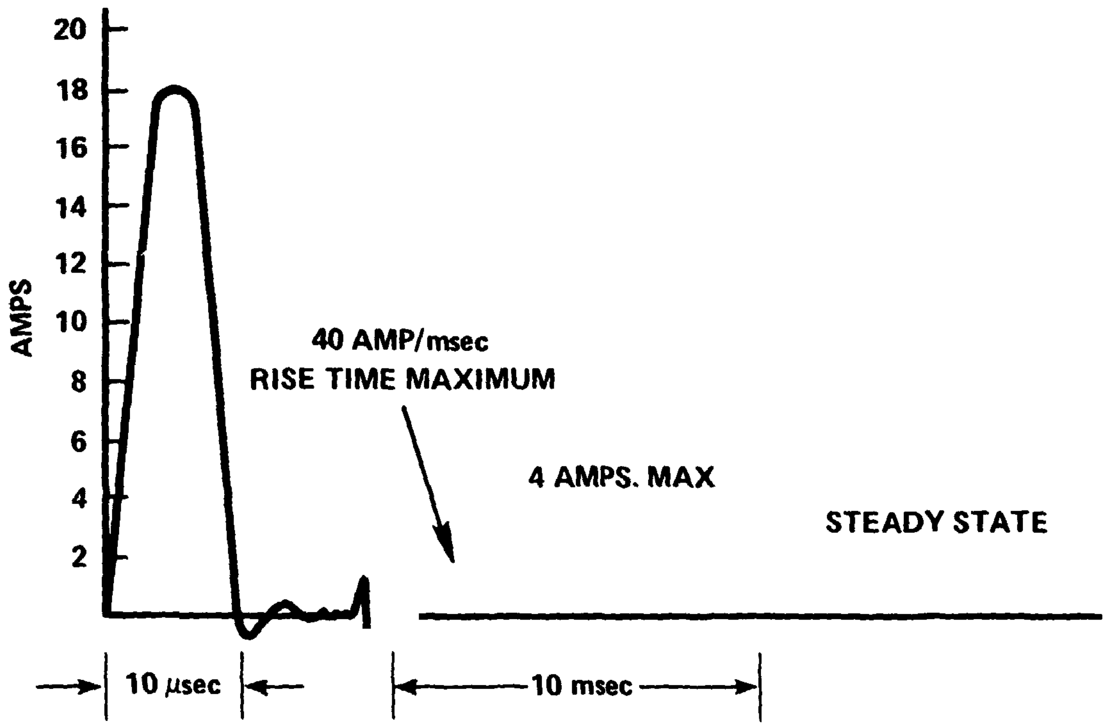


Figure 2. Maximum Limits on the Input Current Transient Surge Parameters

GENERAL DESIGN APPROACH

A block diagram of the overall circuit is shown in Figure 3. As can be seen from the block diagram, the power supply consists of three main parts, two regulators and the power oscillator. The input and output regulator are essentially in series. While it is generally poor practice to have two regulators in series from a reliability and efficiency point of view, it is done in this case because several advantages are gained therefrom. First it is obvious an output regulator must be used on the 7.75 volt output. Given this fact it remains to be determined whether other regulation is needed or desirable. The other two outputs would probably just barely meet the specified ±3% with the input varying ±2% and the temperature varying -20° C to +50° C with no further regulation. If the specified loads were to change somewhat during operation, or be different to begin with, these outputs would probably go out of specification. Another area where further regulation would be helpful is in maintaining the power oscillator frequency within limits. Most power oscillator designs are such that their frequency of operation is directly proportional to the voltage supplied to them. Thus, the frequency would change ±2% with the input voltage. The other 1% tolerance would easily be used up with the temperature variation and, since a self oscillating power converter

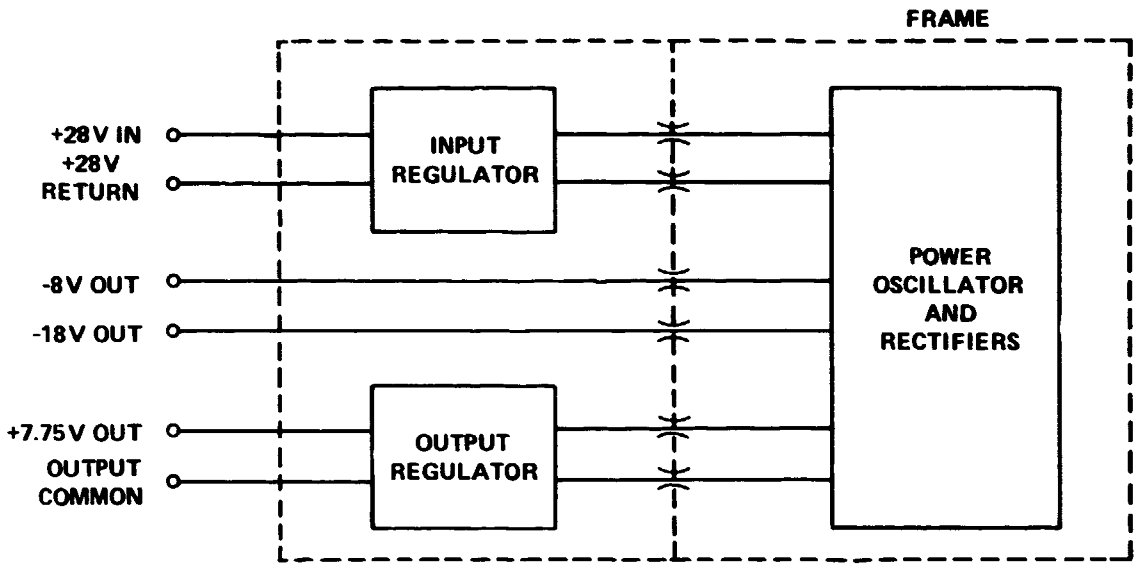


Figure 3. Block Diagram of the IUE Data Processing Unit Power Supply

was decided upon, with load change. For these and other reasons, the use of an input regulator was decided upon, with the following benefits gained:

1. Ensures the -8 volt and -18 volt outputs remain well within their specified limits.

2. Greatly eases the problem of maintaining the power oscillator frequency within specified limits.

3. Offers an easy way to limit the inrush current to the main LC input filter.

4. Helps isolate the power supply from perturbations occurring on the main bus during EMC testing (see Appendix C) and during actual operation in the spacecraft.

5. Contributes to the overall regulation of the +7.75 volt output.

As indicated in the block diagram, the AC portion of the circuit is completely isolated from the DC portion. This tends to make much more effective use of the feedthru LC filters and contributes to an exceptionally quiet design with very low radiated and conducted noise.

SPECIFIC DESIGN APPROACH

Input Regulator

The input regulator is a simple series dissapative type shown in the overall schematic of Figure 4. Q1, a heat sunk 2N2854-2 acts as a single stage pass element controlled by the differential amplifier Q2, a dual transistor type 2N3350. Q1 is operated with about .7 volts across it at nominal input voltage, and at 28 volts in -2% it is just entering saturation. CR1 supplies the reference voltage. This device is run at about 1.6 milliamperes, well below its rated current. In addition to saving on power, this gives the regulator a negative temperature coefficient which tends to offset the positive coefficient of the two unregulated outputs and the power oscillator frequency. Total power dissipation of the input regulator is approximately 300 milliwatts at nominal load, or about 6% of the total input power. For this decrease in efficiency below that which would be attained were no regulator used, the advantages delineated in the previous section are acquired. During turn on, the inrush current to the main filter L1-C3 is limited by the beta of Q1 and the maximum current available through R4. Inrush current spikes of high magnitude but very short duration can still occur during turn on through the capacitor of feedthru filter LC1 to chassis ground which is common to the input return external to the power supply. This current spike represents a very small amount of charge transfer and is within the IUE specification. A pass element in the positive input end of the regulator, via the return line, would preclude this minor problem. However, this would require a PNP device to maintain the single stage simplicity, and none with the desired characteristics, particularly high gain, were available. The DC output impedance of the regulator is approximately 1.65 ohms, which is considerably higher than that of the main bus. However, this tends to decrease the frequency change with load, and the regulator does reduce the ±2% change in input voltage to less than ±.2%. In practice, R7 and R8 are adjusted so that the regulator output voltage is 27.3 volts at an E_{in} of 28 volts and nominal load (I_{in} approximately 172 milliamperes). The total value of this resistance will be in the vicinity of 12 k ohms.

Power Oscillator

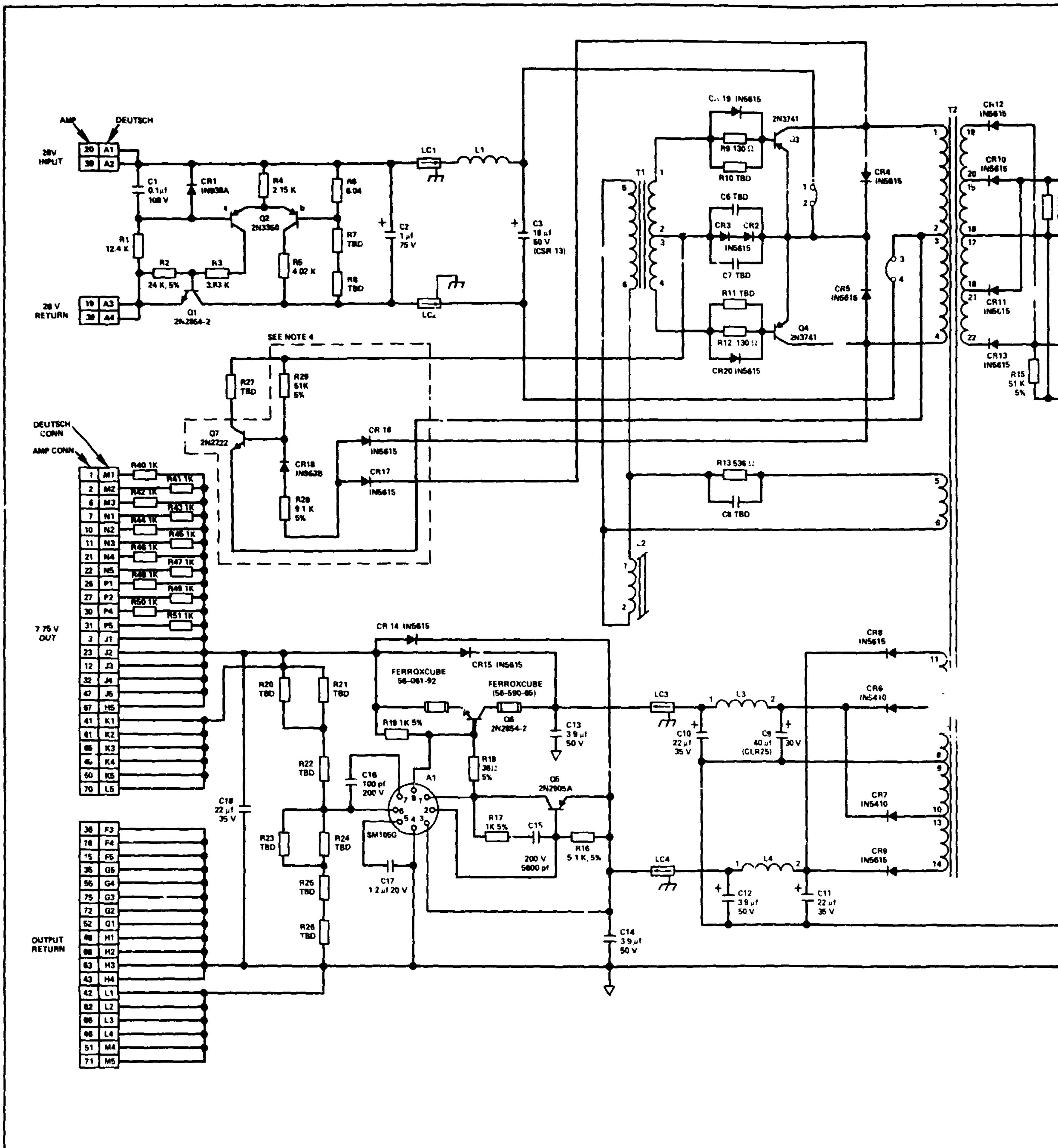
The power oscillator used is a three core magnetic oscillator, a slightly modified version of that known as the Jensen square wave oscillator. The circuit is shown as part of the complete schematic of Figure 4, and consists of Q3, Q4, CR2-CR5, CR19, CR20, R9-R13, C6-C8, T1, T2 and L2. Saturating inductor L2 has been added across the primary of T1, which normally would be the saturating, frequency determining element in the circuit. L2 can be easily trimmed to adjust the operating frequency, or can be modified to accommodate a different operating frequency from one spacecraft to the next. This can be done with minimal effect on T1 and the rest of the circuit. L2 has about 20% fewer turns than does the T1 primary, and uses the same type core, to ensure it being the controlling device. Terminals 5 and 6 of transformer T2 feeds back 20 volts peak to the drive transformer T1 and L2. R13 is adjusted such that about 15.7 volts peak appear across terminals 1 and 2 of L2 and 5 and 6 of T1.* Capacitor C8 across R13 is either not used, or quite small (100 pf or less) and may be handy to make minor adjustments to the operating frequency. The output windings of T1 supply 4 volts peak to drive Q3 and Q4. R9 and R12 are adjusted such that the ratio of collector current to base current at maximum load is approximately 12 to 1. Their value has been typically 130 ohms. CR2 and CR3 are part of the starting circuit. The layout allows for two diodes in series here although only one is used in the prototype units. Two diodes allow for a higher voltage across C6 and C7, which may be useful if transistors with longer storage times are used for Q3 and Q4 in place of Motorola 2N3741's. CR19 and CR20 may also be used, if necessary, to decrease the storage time during switching. R10 and R11 facilitate balancing the two sides of the oscillator. Main transformer T2 is a ferrite torroid designed to use approximately one sixth of its flux capacity.

A starting boost circuit was designed and incorporated in the layout. This consists of R27-R29, CR16-CR18, and Q7. The prototype units, and those of the foreseeable future, do not use this entire circuit. Only R27 (10k ohm, 1/2 watt carbon), with a jumper wire from Q7's collector to emitter, was used. This presently seems quite adequate for starting at all temperatures and loads specified. In future units, if load requirements or different switching transistors give starting problems, and R27 must be reduced to say 5k ohm or less, then the entire circuit may be used to reduce dissipation. The circuit simply disconnects R27 once the power oscillator comes up to full operation. Another contingency feature built into the power oscillator is its ability to operate with either PNP or NPN devices for Q3 and Q4. The input voltage can be reversed at the jumpers shown in Figure 4 (terminals 1-4). In the event NPN devices should be used in some future units, the following steps would be required;

a. Reverse CR2-CR5, CR16-CR20

*Circuit Considerations for dc to dc Conversion Above 10 kHz. G. Ernest Rodriguez, X-716-66-375.

FOLDOUT FRAME |



FOLDOUT FRAME 2

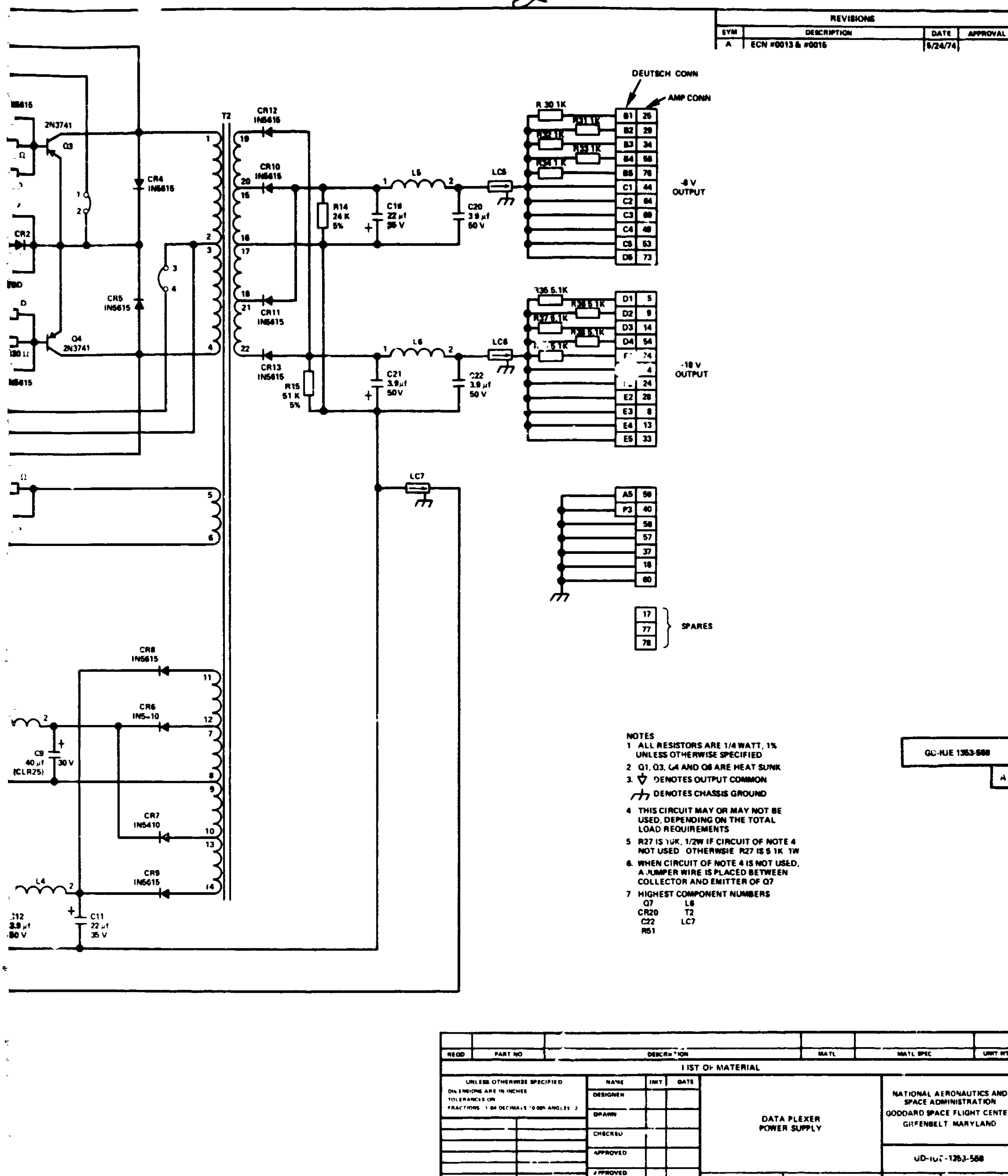


Figure 4. Circuit Schematic

b. Replace Q7 with a PNP device

c. Connect terminals 1 to 3 and 4 to 2

No layout changes would be needed.

Output Regulator

The output regulator is shown as part of the overall circuit diagram in Figure 4. It consists of R16-R26, C13-C18, CR14 and CR15, Q5 and Q6, and A1. A1 is an SM105G integrated circuit regulator procured to a Goddard high reliability specification. The 105 device was decided upon due to its excellent load and line regulation characteristics. Q5 and Q6 are added to boost the load capability to in excess of one ampere. Q6 is selected for medium to high gain (h_{FE} of 100 to 130), and low saturation resistance at collector currents of one ampere and less. This allows Q6 to be operated at a low voltage drop (about .7 volts at nominal load) for efficiency and reliability, and still be well within its class A operating region. For this purpose, Q6 has a lower, separate voltage source than that used to supply its driver, Q5, and the SM105G. The voltage appearing at the collector of Q6 is approximately 8.4 volts at nominal load. That appearing at the emitter of Q5 and pin 3 of A1 is approximately 13 volts. This allows A1 to operate with a voltage differential between input and output (pin 3 to pin 8) of about 4.5 volts, well within the SM105G specification (3 volts minimum).

R18 limits the maximum collector current of Q5 to about 10 milliamperes by using the SM105G's built in current limiting feature. This protects Q5, and therefore A1, against temporary short circuits at the regulator output. In the event of a short, the maximum output current will be the current gain of Q6 times the current through R18. The current limit characteristic of A1 has a negative temperature coefficient. This is counteracted by the positive temperature coefficient of Q6's current gain, so that for changing ambient temperatures, the current limit will remain roughly constant. In the event of a short circuit, the output current will go to about 1.2 amperes. Dissipation in Q6 at this time will go to about 10 watts and although Q6 is well heat sunk, its temperature, and therefore its gain, collector current and dissipation will rise rapidly. Therefore, this protection scheme is good for short intervals only, on the order of one minute or less. However, this should prove adequate for the intended purpose, i.e., to protect against momentary accidental shorts on the 7.75 volt output during bench testing and integration. During a short circuit, Q5 maximum dissipation will be about 1?0 milliwatts and constant. During actual operation in the spacecraft, the 7.75 volt output is distributed to many different loads. However, all non-essential loads are current limited by having a 1000 ohm resistor in series with their inputs.

The current limit feature of R18 and A1 also protect against drops in the input voltage. Without this limiting, Q5 will try to supply the entire load current if the input voltage drops to the point slightly below that where Q6 becomes saturated. Under this condition Q5 can dissipate excessive power which could result in failure. One drawback to the SM105G regulator is its reference voltage. It is extremely low (1.8 volts) and, compared to other discrete reference voltage zeners available, perhaps not as stable with time. The long term stability of this reference is specified by the manufacturer as .1% typical and 1% maximum. Experience with these devices seems to indicate this to be conservative estimates. When these devices are first turned on, their reference may change several millivolts, causing the output to change 4.5 times that much. Typically, however, after several days operation they tend to steady down, and continued operation after that over a period of several months seems to indicate their stability to be considerably better than .1%. The reference voltage does have a slight positive temperature coefficient, which is counteracted in the design by using silicon sensistors somewhere in the lower half of the feedback voltage divider (R23-R26). This gives the feedback voltage at terminal 6 of A1 a positive temperature coefficient to match that of the reference. The sensistor value used was anywhere between 18 ohms to 45 ohms. Diodes CR14 and CR15 ensure the output cannot be more positive than the regulator input, a possible failure mode for both the transistors and the SM105G.

In order to gain maximum benefit from the regulating capability of the SM105G, care had to be exercised in the layout of the regulator. The 7.75 volt output and return must be sensed as close to the connector as possible. From the sense point on, heavy loads should have separate current paths than light loads so as to maintain regulation as high as possible by keeping line drops low.

The -18 volts and -8 volts are developed from simple full wave rectifiers as shown in Figure 4.

PERFORMANCE DATA

Output voltage curves for varying temperature, and the two extreme cases of line and load are shown in Figure 5. Frequency curves for varying temperature, load and line are shown in Figure 6, Circuit efficiency is typically as follows:

Maximum load: 74%

Minimum load: 68%

Figures 7, 8 and 9 show Q3 and Q4 collector currents. This waveform is probably the most significant of any in indicating the overall operation of the circuit. As

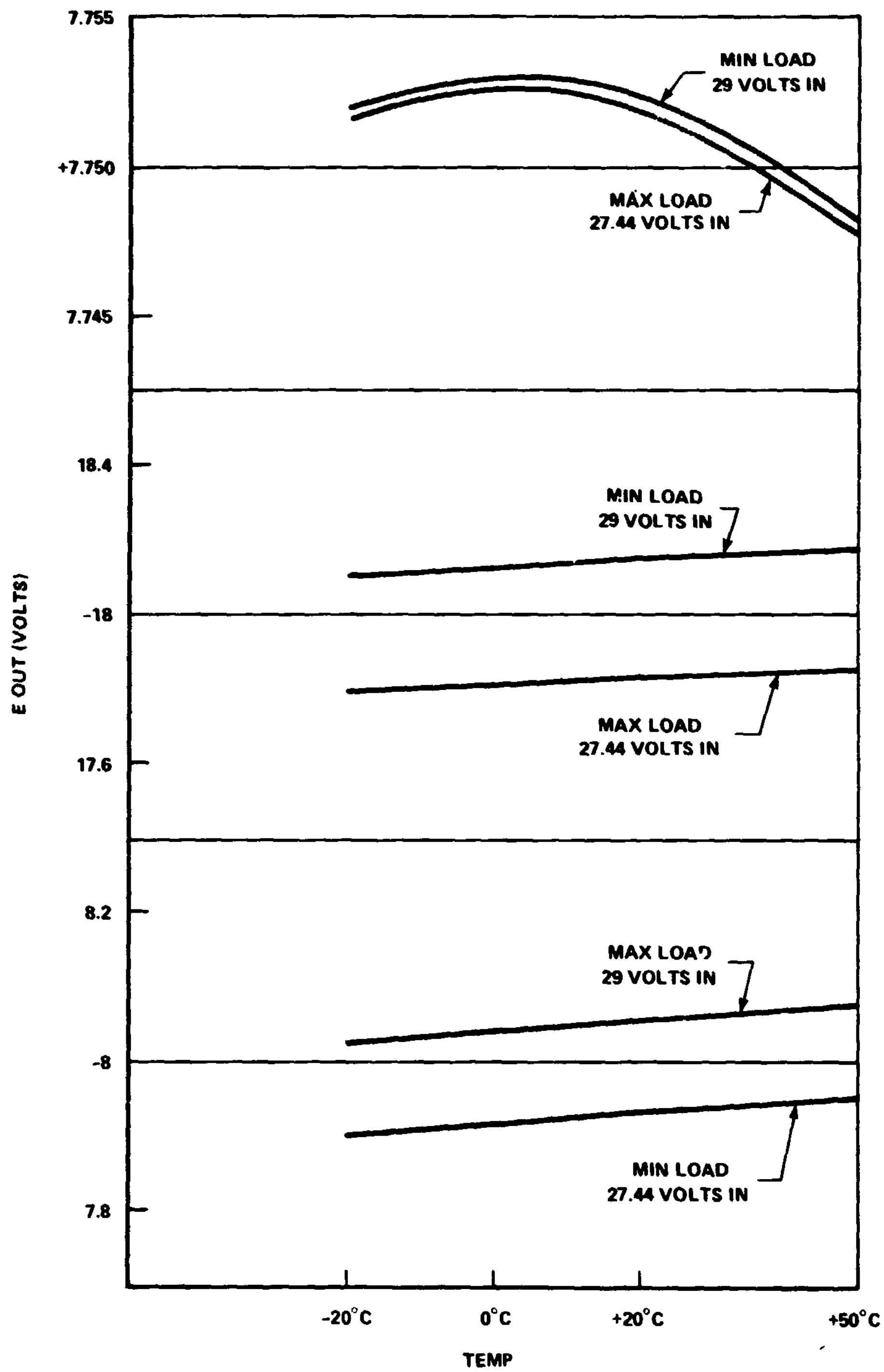


Figure 5. Output Voltages for Varying Temperature for the Two Extreme Cases at Load and Line Voltage

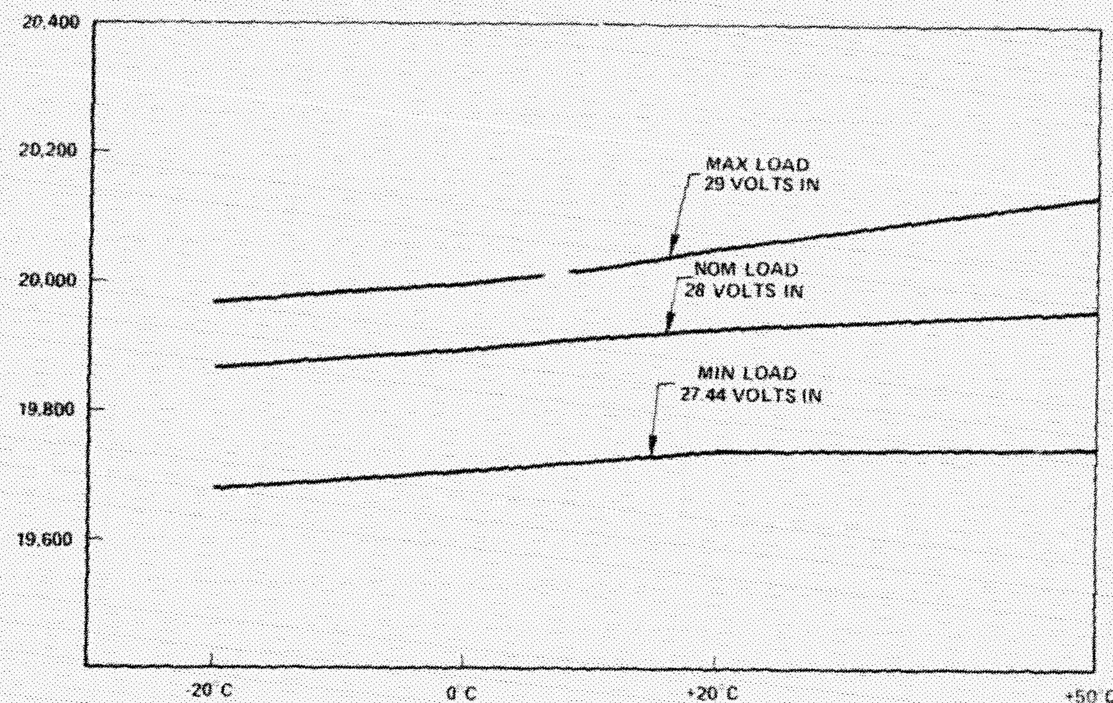


Figure 6. Frequency as a Function of Temperature

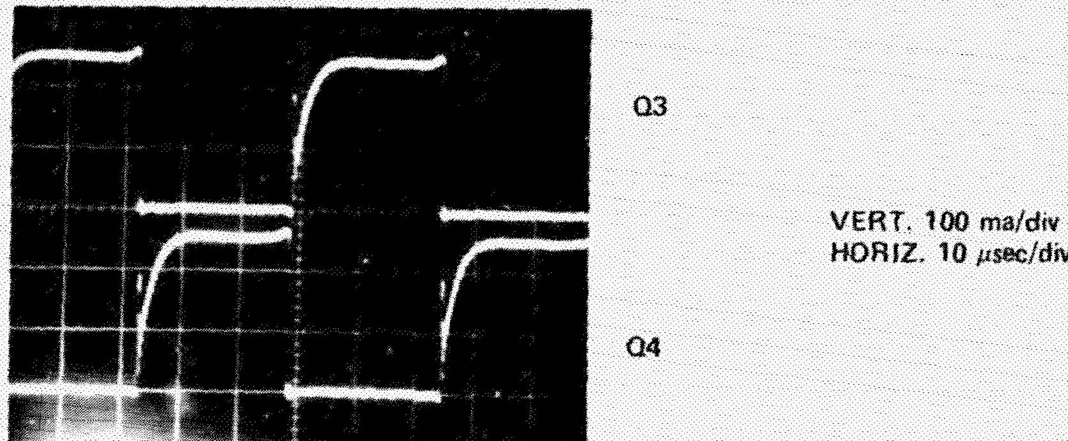
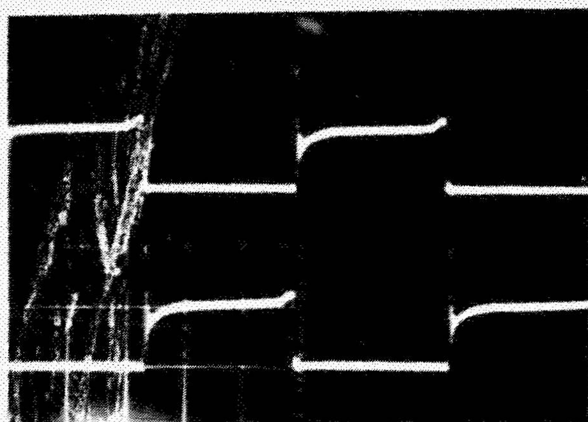


Figure 7. Q3 and Q4 Collector Current at Maximum Load

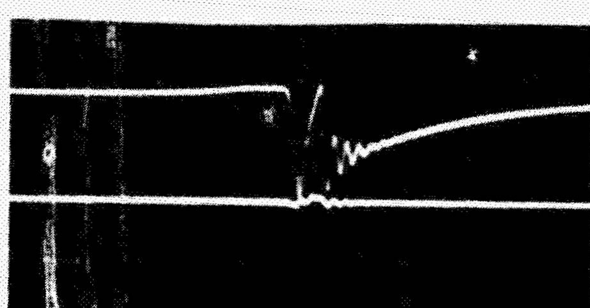


Q3

Q4

VERT. 100 ma/div
HORIZ. 10 μsec/div

Figure 8. Q3 and Q4 Collector Current at Minimum Load



VERT. 100 ma/div
HORIZ. 1 μsec/div

Figure 9. Q3 Turning Off, Q4 Turning On, Nominal Load

long as they are fairly well balanced, and show no spikes other than that due to the winding capacitance of T2 at turn on, the circuit is normally operating in a healthy manner. Figure 9 shows an expanded view of the turn off of one transistor and the turn on of the other. It is essential that one be completely off by the time the other starts to come on. Capacitance C6 and C7 are adjusted to ensure this is the case, and their value has typically been anywhere between .01 μf and .033 μf.

Figure 10 shows the Q3 collector to ground voltage at nominal load. The spike which occurs during turnoff is about 6 or 7 volts and should always be low enough to ensure staying well within the voltage rating of Q3 and Q4 (30 volts).

Figure 11 shows the Q3 base drive current and the oscillator feedback loop current through R13. Base drive to Q3 and Q4 is typically 18 to 20 milliamperes.

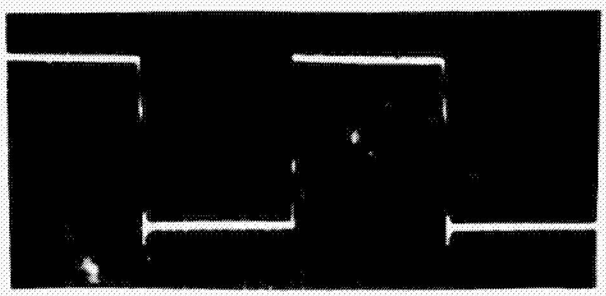


Figure 10. Q3 Collector to Ground Voltage, Nominal Load

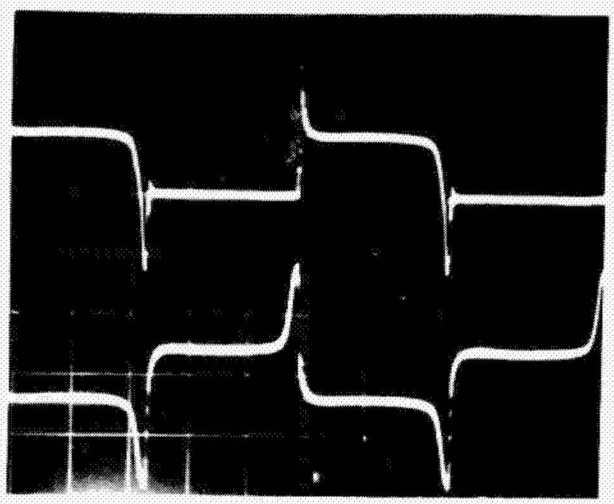
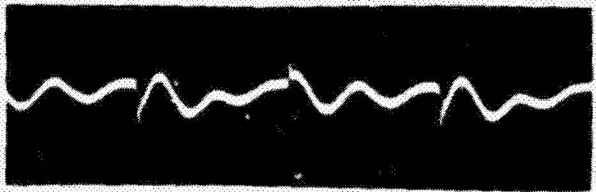


Figure 11. Q3 Base Drive (Top) and Feedback Loop Current, Nominal Load

The feedback loop current spike occurs when L2 saturates, and its width depends on the storage time of Q3 and Q4. Since this current spike through R13 represents circuit losses, it is desirable to keep it as narrow as possible. It is for this reason, as previously mentioned, that CR3, CR19 and CR20 are available for use.

Figure 12 shows the input current ripple and the three output voltage ripples. As can be seen, the packaging technique used has kept the ripples very low.



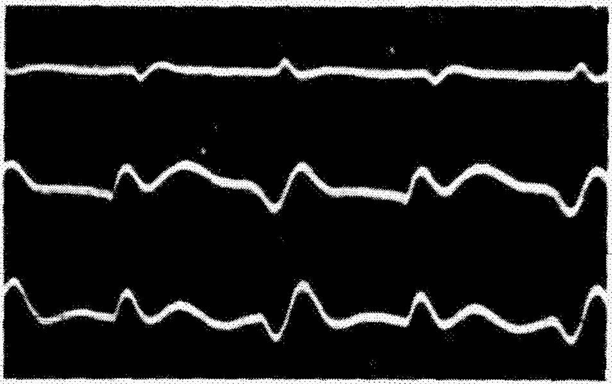


Figure 12. Input Current Ripple (Top) and Output Voltage Ripples at Maximum Load

PARTS SELECTION

Q1: This device is used as a single stage control element in the input regulator. Units selected should preferably have high gains (i.e., 160 to 170 @ 200 milliamperes), and low output admittance down to low values of collector voltage.

Q3 and Q4: These devices act as the switches in the power oscillator. Their arrangement is push-pull so it is desirable to have them matched as closely as possible. The most important parameter to match is the storage time. This can be done quite easily using a Tektronix type R transistor risetime plug in unit or some similar instrument. Also of importance to match is the saturation voltage. It is desirable to have the transistor gains matched, but this is of lesser importance. Some small imbalances in the transistors can be compensated for somewhat by trimming the base drive with R10 or R11.

A1: In selecting the integrated circuit regulators, two factors were considered; reference voltage stability and reference voltage noise. Units were tested for stability by putting them in a test circuit identical to the actual regulator in which they are to be used. As a general rule, those which show the least drift in the first hour or two of operation turn out to be the most stable over long periods of time. Some devices would have an initial output voltage drift of only two to three millivolts, while others would change 25 millivolts or more. The better units were further checked for several weeks under temperature cycling conditions (room temperature overnight, +50° C during the day). After this conditioning, they generally could operate for months with no evidence of any further significant reference voltage drifting.

Reference voltage noise in these devices causes low frequency jitter on the output of a few hundred microvolts. While this in no way should bother the power supply loads, units were compared with one another to select those with the lowest noise. There was some indication that those with the lowest noise would also be the most stable with time.

Rectifier Diodes: CR6-CR7, CR8-CR9, CR10-CR11 and CR12-CR13 should all be matched pairs. This is done quite easily by comparing them on a curve tracer at their respective load levels. Having matched pair rectifier diodes keeps voltage and current ripples symmetrical and at a minimum.

Other Design Considerations

Winding turns correction: Both L2 and T2 may require slight turns adjustments. In the case of L2, correction to its single winding could be required to set the oscillator frequency at the proper value. The following relationship can be used as a guide.

$$\Delta f = -100 \, \Delta \text{ turns (hz)} \qquad 1$$

The frequency may also be boosted slightly by using the small capacitor C8, but this has generally been found to be unnecessary.

T2 may have to have some slight correction to the -18 volt, -8 volt or +8.4 volt windings. Typical values of these voltages at nominal load should be as follows:

-8 volts : -8.05 volts

-18 volts : -17.95 volts

-8.4 volts : +8.48 volts

The +13 volts to Q5 is not too critical and should need no correction as long as it is within a few hundred millivolts.

Both regulators require feedback voltage adjustment to set their output voltages. For the input regulator, R7 and R8 are adjusted to around 12 k ohms to give 27.3 volts out at nominal load.

For the output voltage regulator, R25 is normally set at 2430 ohms and R23 and R24 may be a single sensistor or two in parallel. The R20 through R22 combination is adjusted to give the proper output voltage and typically has a total value of around 8500 ohms.

To adjust the power oscillator, C6 may initially be set at around .022 μf, and adjusted from there to give the proper crossover of Q3 and Q4 collector currents. R10 or R11 may be used if necessary to correct any slight unbalances. There value will typically be greater than 1000 ohms. Q3 and Q4 collector currents should be checked for proper operation on the bench with Q3 and Q4 both hot and cold by using a heat gun and circuit cooler.

The connection to Q3 and Q4 collectors, and CR6, CR7 cathodes are mechanical by means of a solder lug. For reliability these are all made dual connections. Q3 and Q4 have a lug on each bolt holding them to the heat sink. These lugs are wired together and to the board. CR6 and CR7 also use two lugs each, one on each side of the heatsink. These are soldered together through a hole in the heat sink.

The ferrite beads shown on the schematic are physically placed on the wires leading from the collector and emitter to the board. These are fixed in place by slight bends in the wire and the use of solathane.

Figure 13 a-f show photographs of SN01 for IUE. The connector will actually be held to the frame with standoffs to accept the harness connector.

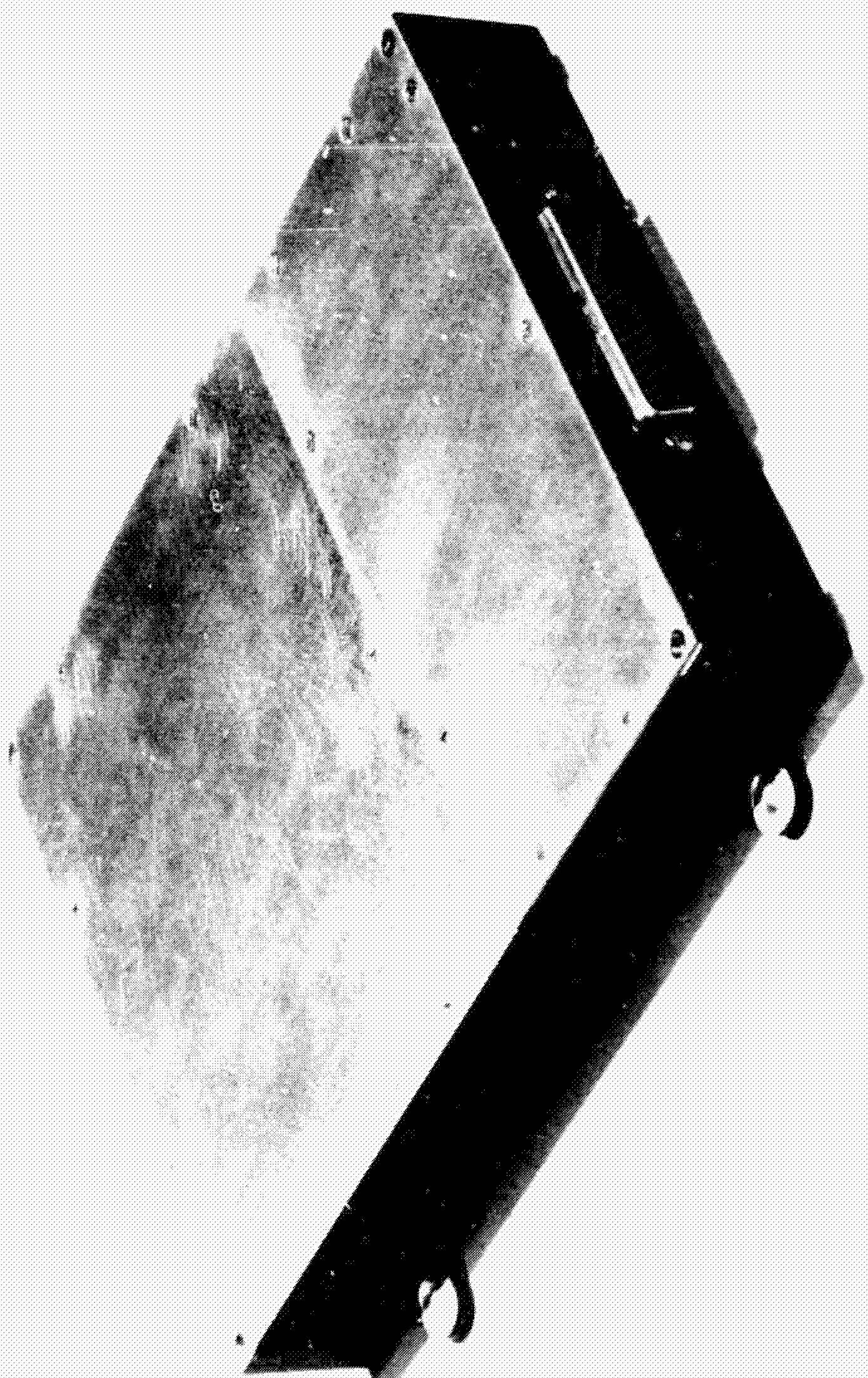


Figure 13a. SN01 with Covers.
Figures 13b-f Show Various Angles without Covers.

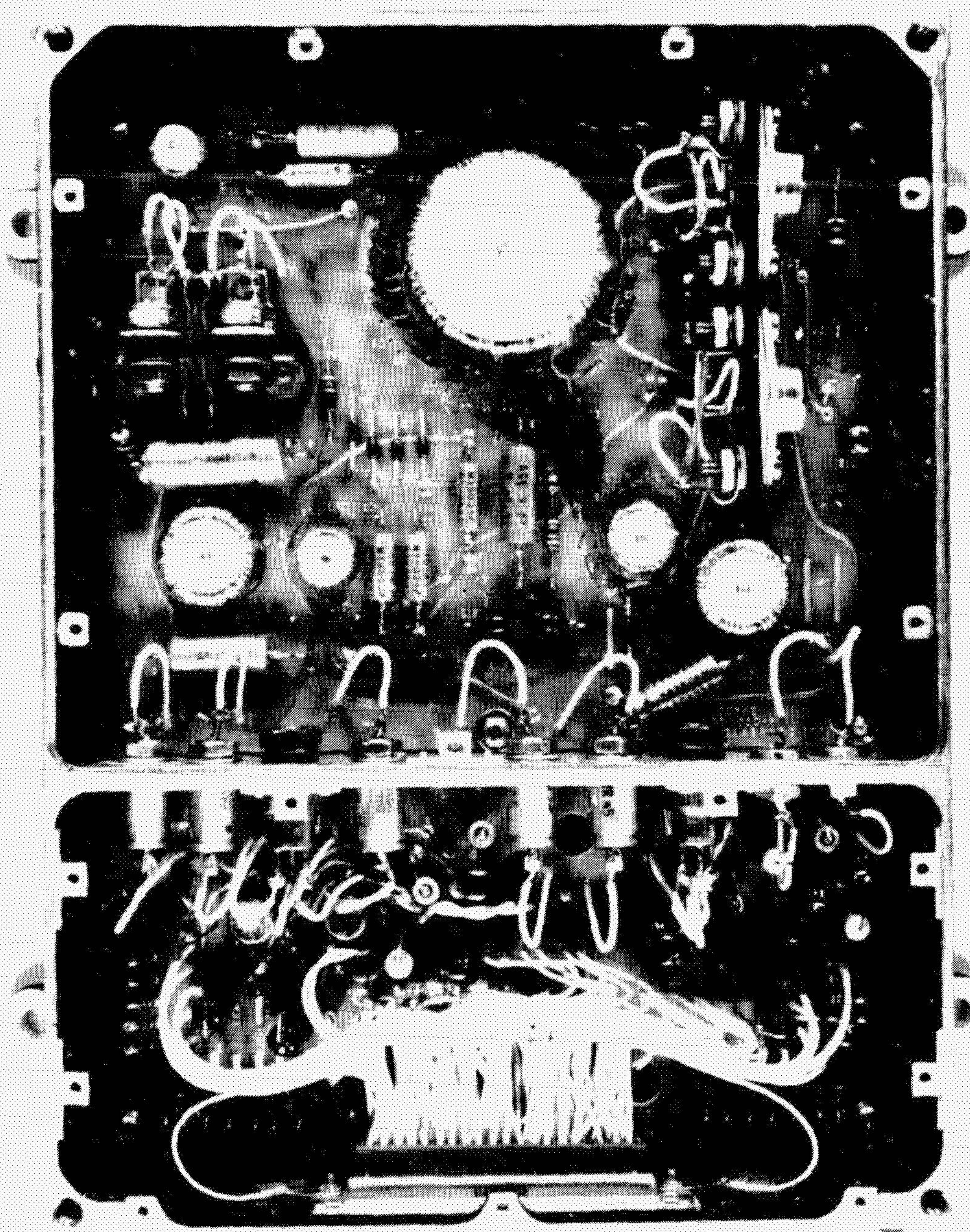


Figure 13b.

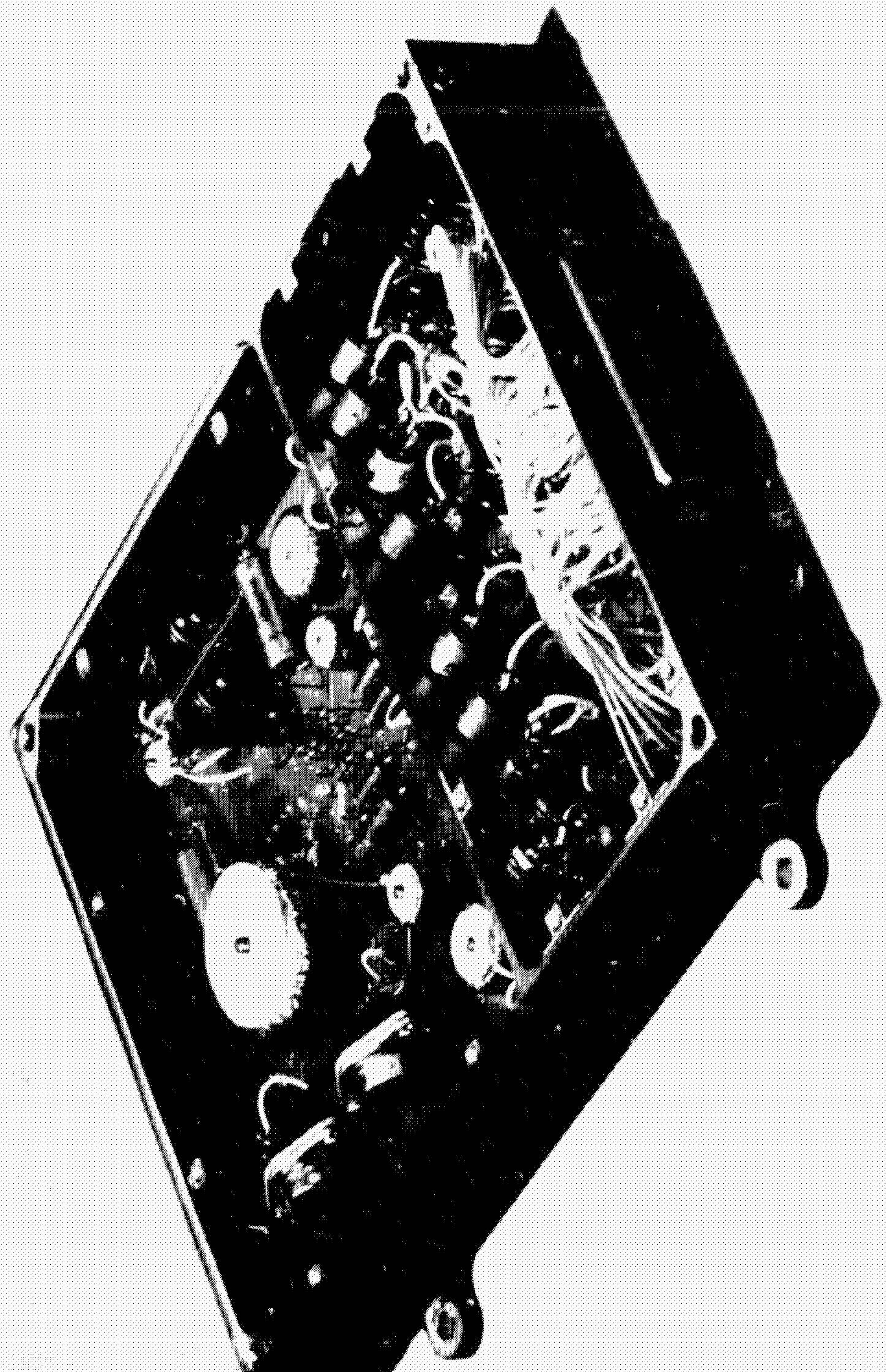


Figure 13c.

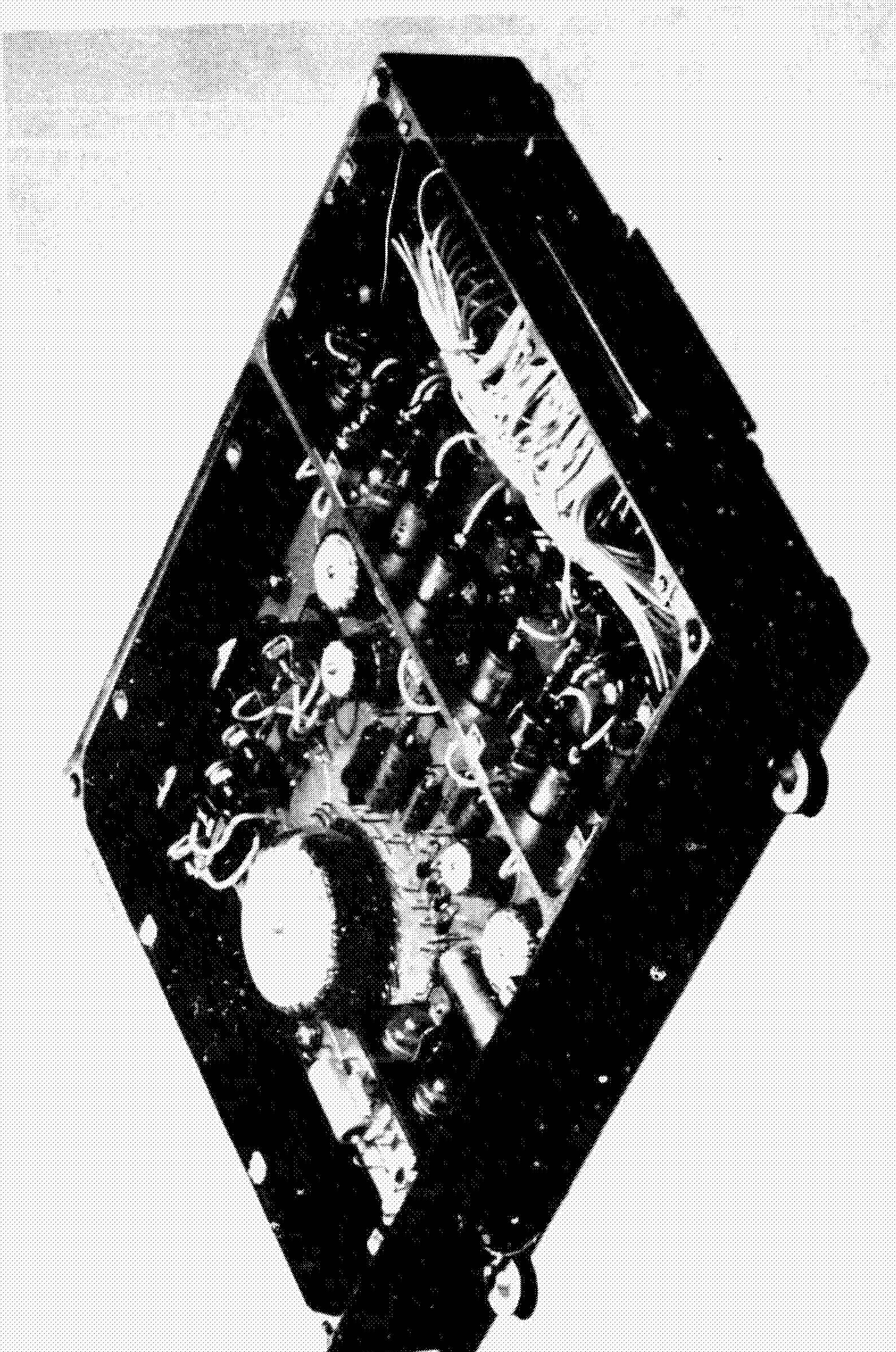


Figure 13d.

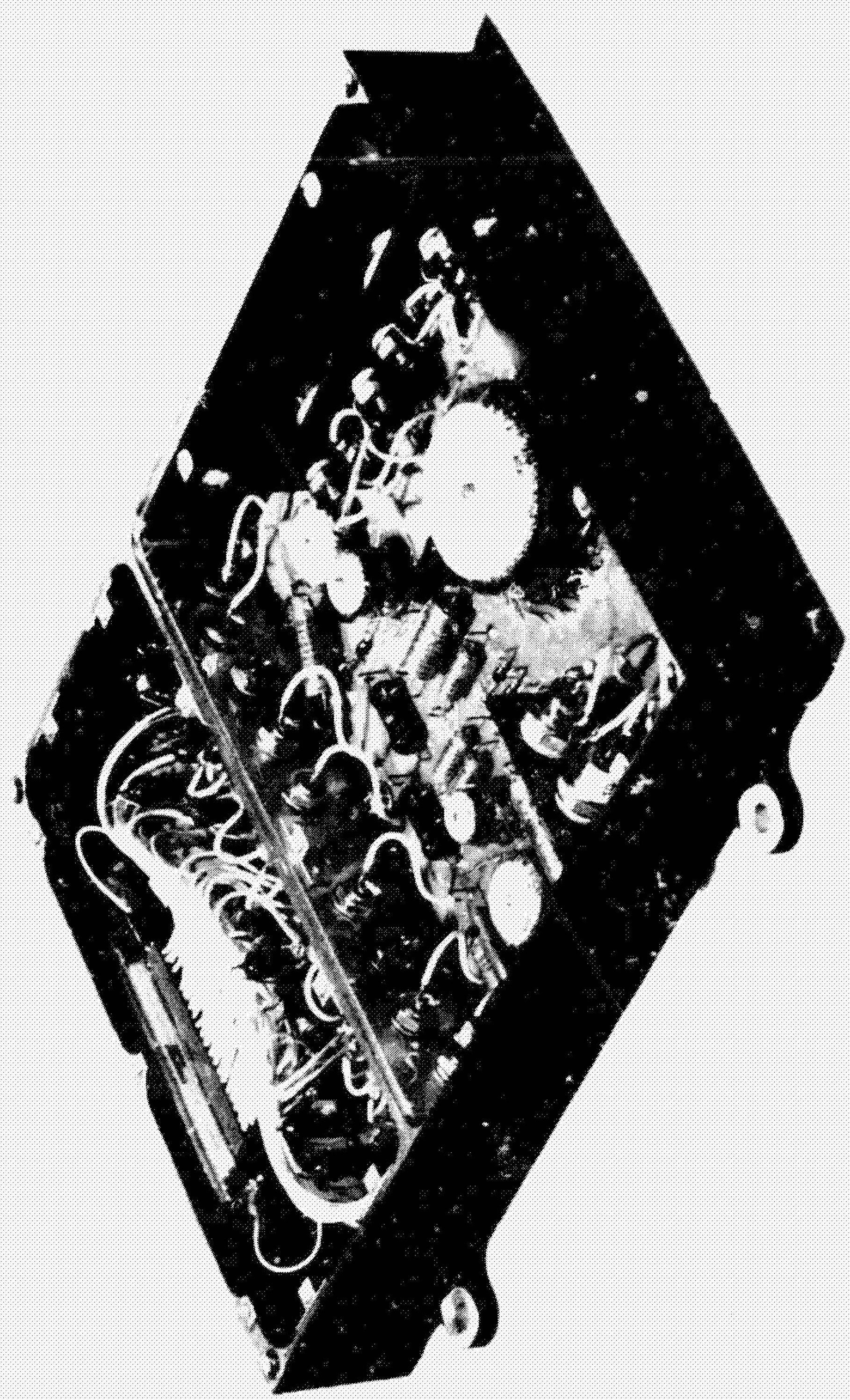


Figure 13c.

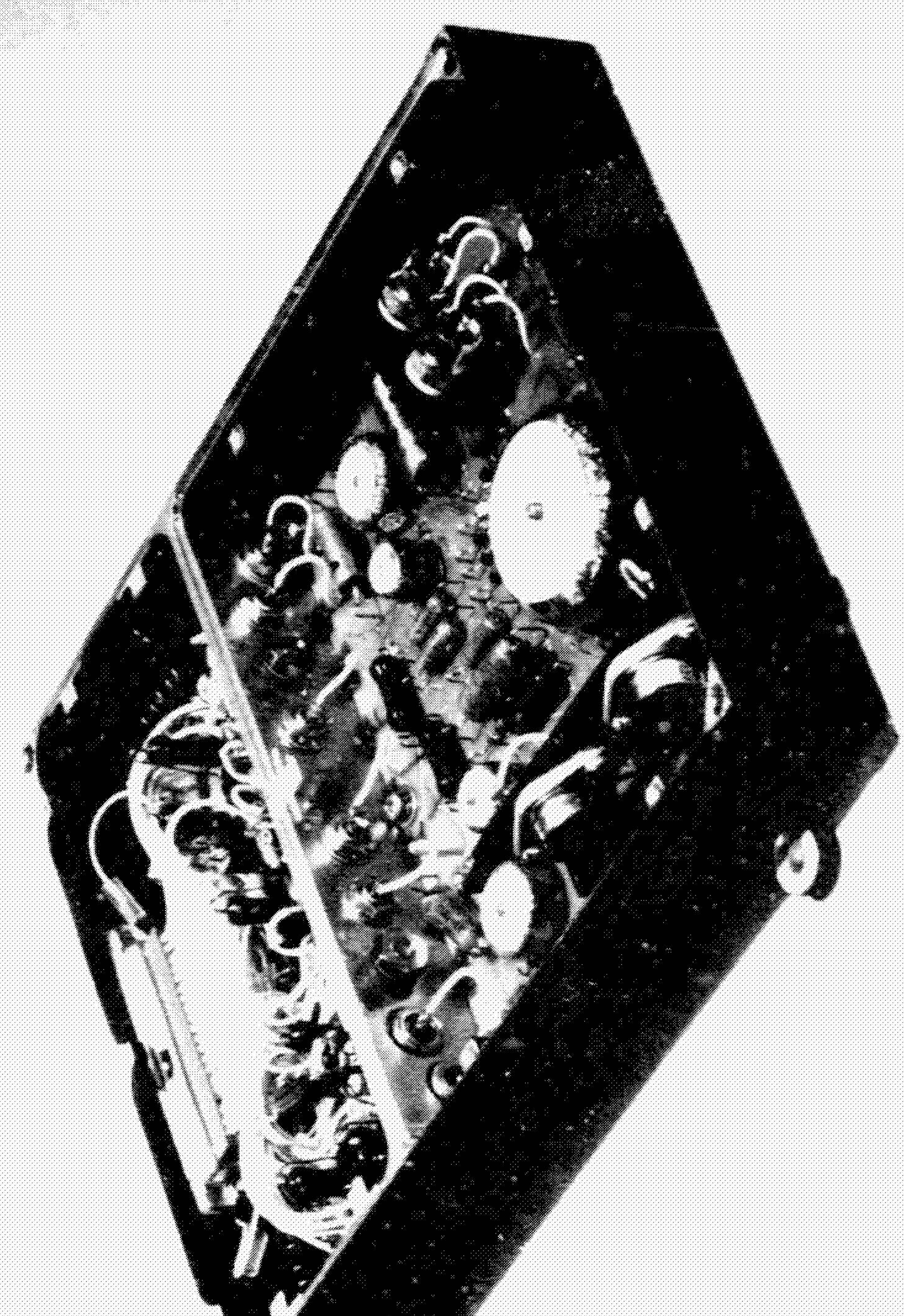


Figure 13f.

APPENDIX A

PARTS LIST

Transistors		Case Style
Q1, Q6	: G2N2854-2	MT26
Q2	: G2N3350	R131C
Q3, Q4	: JTX2N3741	TO66
Q5	: JTX2N2905A	TO5
Q7	: JTX2N2222	TO18 (see schematic, note 4)

IC's

A1	: SM105G	CN1a

Diodes

CR1 : JTX1N939A	DO7
CR2-CR5, CR8-CR17 : JTX1N5615	A248e
CR6, CR7 : 1N5410	DO4 (This device is screened to GSFC Spec. SP08.51)
CR18 : JTX1N968B	DO7 (see schematic, note 4)

Capacitors (Values as shown on schematic)

C1, C4-C7, C15 :	CKR06
C8, C16 :	CKR05
C2, C12-C14, C20-C22 :	CSR13 Case size B

Capacitors (Values as shown on schematic) (Continued)

C17 :	**CSR13 Case size A**
C3, C10, C11, C18, C19 :	**CSR13 Case size C**
C9 :	**CLR25 Case size G2**

Resistors (Values as shown on schematic)

R1, R3-R13, R20-R22 :	**RNR65**
R2, R14-R19, R28-R51 :	**RCR07 (see schematic, note 4)**
R23-R26 :	**A combination of RNR65's and TI TG1/4 or 1/8 sensistors**
R27 :	**Either RCR20 or RCR32**

Feedthru Filters

LC1, LC2	Erie 9051-500 screened to GSFC Spec. S-311-P-5/3
LC3-LC7 :	Erie 1200-700 screened to GSFC Spec. S-311-P-5/3
Ferrite beads:	Ferroxcube 56-061-92 Ferroxcube 56-590-65

APPENDIX B

MAGNETIC COMPONENT DESIGN

T1	Core: Arnold Engineering			12634-P250
	N1-2:	51 Turns	AWG 32	bifilar*
	N3-4:	51 Turns	AWG 32	
	N5-6:	200 Turns	AWG 33	
T2	Core: Ferroxcube			K300500
	N1-2:	150 Turns	AWG 27	*
	N3-4:	150 Turns	AWG 27	
	N5-6:	111 Turns	AWG 32	
	N7-8:	51 Turns	AWG 23	*
	N9-10:	51 Turns	AWG 23	
	N11-12:	25 Turns	AWG 32	*
	N13-14:	25 Turns	AWG 32	
	N15-16:	49 Turns	AWG 32	*
	N17-18:	49 Turns	AWG 32	
	N19-20:	54 Turns	AWG 32	*
	N21-22:	54 Turns	AWG 32	
L1	Core: Magnetics			55120
	N1-2:	53 Turns	AWG 26	
L2	Core: Arnold Engineering			12634-P250
	N1-2:	165 Turns	AWG 30	

L3 Core: Magnetics 55120

N1-2: 41 Turns AWG 22

L4, 5 and 6: Core: Magnetics 55038

N1-2: 48 Turns AWG 30

Ferrite Beads: Q6 Collector: Ferroxcube 6-590-65/3B

Q6 Emitter: Ferroxcube 56-061-92/AA

All windings use Belden Nylclad or Formvar magnet wire with heavy insulation.

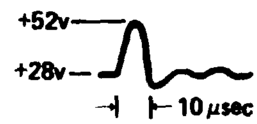
APPENDIX C

RFI — EMI SPECIFICATIONS

The spectrograph and acquisition cameras are potentially susceptible to electromagnetic interference. The spacecraft grounding scheme and converter design philosophy is intended to reduce the total system noise. In order to insure the system noise is maintained at sufficiently low level, the individual electronic boxes shall be subjected to selected tests from the Mil Std. 461, 462, and 463 Electromagnetic Interference Document.

Applicable sections of the Mil Std. are as follows:

CE 01/03	Conducted emission on power lines 20 Hz-150 kHz. Spacecraft level test requires that noise spikes be limited to 20 millivolts peak-peak as measured with an oscilloscope voltage probe.
CE 02/04	Conducted emission on signal, control and command lines. 20 Hz-150 kHz. This test is performed only if RE 02/04 is exceeded.
CS 01/02	Susceptibility to conducted interference on power lines. 20 Hz-150 kHz. An audio signal whose amplitude is ten percent of the dc supply voltage shall be injected into each power lead in accordance with Mil Std. 462.
CS 06	Susceptibility to spikes on power lines. Pulse repetitive to 60 Hz applied for five minutes.



RE 02	Radiated emission, electric fields. 14 kHz-1 gHz Broad Band, 2.0 gHz-2.4 gHz Broad Band. Mil Std. 461 limits.
RE 04	Radiated emission, magnetic fields. 20 Hz-50 kHz, Mil Std. 461 Limits.
RS 03	Susceptibility to electric fields. 150 kHz-500 kHz, Mil Std. 462, dated February 9, 1971.

Magnetic Field Measurements (DC)

The dc magnetic fields shall be controlled to insure that the net dc component does not exceed 100 gamma at one foot. Component measurements will be made at a distance of three feet to determine the magnitude and direction moment. The component shall be exposed to a 15 gauss field, the resultant perm field shall not exceed 40 gamma. Following the exposure, a 50 gauss deperming field shall be applied to the component. The remnant perm shall be less than 10 gamma. Power shall be applied to the electronic assembly and a stray field measurement from 0-5 Hz shall be made. The stray field shall not exceed 10 gamma at three (3) feet.

Magnetic Control for Commonality Hardware

Due to influences of the commonality of hardware that could be used on other GSFC flight programs will be subjected to more stringent magnetic field strength requirements (dc and ac). Other flight programs may carry dc magnetometers and/or ac magnetic fields measuring experiments which would impose certain hardware to be subjected to the more stringent specifications. The Interplanetary Monitoring Platform (IMP-H&J) spacecrafts carry magnetic experiments that are typical and representative of future spacecraft requirements. Therefore, selected assemblies to be flown on IUE shall be subjected to magnetic field measurements in accordance to the magnetic limits as defined for IMP-H&J. Tables C.1 and C.2 give the limits for the dc and ac levels respectively.

Table C-1

Magnetic Limits

Magnetization	Background (Gauss)	Maximum Magnetic Field Disturbance (Gamma)	
		18"	36"
1 Initial Perm	0	8.0	1.0
2 Post 15 gauss Exposure	0	32.0	4.0
3 Post 50 gauss Deperm	0	2.0	0.25
4 Stray Field	0	2.0	0.25

Table C-2

Magnetic Field Strength Limits

Frequency Range	Maximum Allowable Magnetic Field Strength	
	Max Gamma @ .8 ft	Max Gamma @ 1 ft
30 Hz - 100 Hz	4.6×10^{-4}	2.36×10^{-1}
100 Hz - 300 Hz	2.5×10^{-4}	1.28×10^{-1}
300 Hz - 1000 Hz	1.4×10^{-4}	7.20×10^{-2}
1 kHz - 3 kHz	8.0×10^{-5}	4.10×10^{-2}
3 kHz - 10 kHz	4.6×10^{-5}	2.36×10^{-2}
10 kHz - 30 kHz	2.5×10^{-5}	1.28×10^{-2}
30 kHz - 100 kHz	1.4×10^{-5}	7.20×10^{-3}
100 kHz - 200 kHz	8.0×10^{-6}	4.10×10^{-3}