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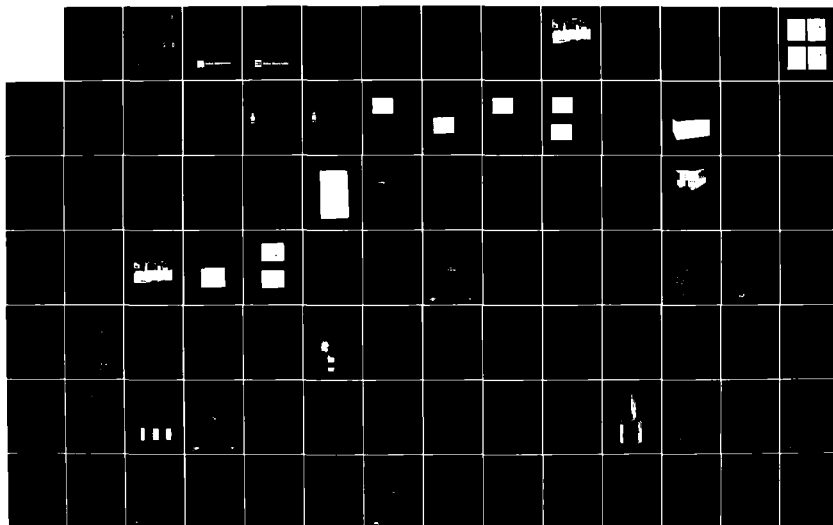
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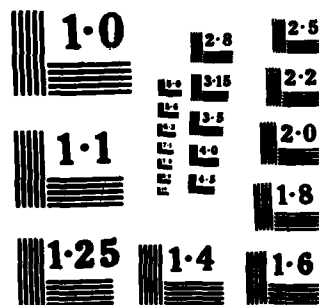
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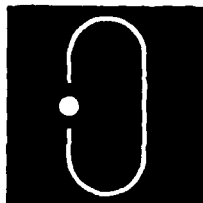
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October 1982

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TECHNICAL REPORT

PROGRESS IN POWER DISTRIBUTION IN FISCAL YEAR 1982



Delco Electronics

*General Motors Corporation
- Santa Barbara Operations
Santa Barbara, California*

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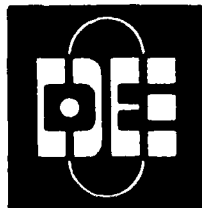
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SECTION I INTRODUCTION

1.1 PURPOSE OF THIS TECHNICAL REPORT

This publication is a report on accomplishments in the area of power distribution made in Fiscal Year 1982. These include:

1. Development and demonstration of a touch screen CRT controller for power distribution control, including paralleling.
2. Development and demonstration of the use of fiber optics for such control.
3. Further reduction in the input current harmonics in the 15 kW Frequency Changer, which uses the Delco Resonant AC-DC Converter.
4. Demonstration of the great tolerance to non-linear loads inherent in the 28-SCR Delco Inverter.

1.2 BACKGROUND

The equipment necessary to meet the FY82 objectives was all designed and, with the exception of the touch screen CRT equipment, fabricated prior to FY82. Some of the equipment was modified and the touch screen equipment was completed within the last year.

This report is organized so that limited background for the various pieces of equipment and some detailed information on modifications are presented in following sections. One section generally deals with one piece of equipment. Also, complete sets of schematic diagrams and some pictures are found in appendices.

In 1980, Delco published a report* which presented general power network control concepts and some specifics on hardware implementation. Many of the details of hardware implementation in this report should be reconsidered in

* Microprocessor Control of Frequency Changers and Power Distribution Systems, Technical Report R80-119. Delco Electronics Division, GM. (3 October 1980)

light of the work performed since then and to date. Another report on this subject of more recent value was included in Delco's IR&D Technical Plan for 1982. A copy of this IR&D project is provided in Appendix A.

1.3 SYSTEM OVERVIEW

By using Government loaned equipment (GLP), the Distribution Unit (formerly called the Paralleling Controller), the 15 kW Frequency Changer, and the 10 kW Firefinder Generator Set (a test bed unit) - combined with a touch screen controller built on IR&D funds, it has been possible, with a relatively low expenditure of money and time, to set up a simple yet comprehensive demonstration. In order to maximize accomplishments and reduce risk to the GLP equipment, the objective of minimizing changes to the GLP equipment was set and rigidly observed. This meant that hardware packaging and many performance features of the various pieces of equipment had to be compromised. Thus, the system and its components are far from what Delco views as highly desirable. Nevertheless, by judicious limitation of the scope of the demonstration to the essentials, comprehensive coverage of major performance features has been achieved.

Paralleling is restricted to two power sources, one functioning as a master and the other as a slave. As such the master cannot be controlled in the demonstration in either output amplitude or frequency. It falls into a broad category of sources - such as the power utility, a motor-generator set, an engine driven generator set, or another frequency changer.

For the demonstration, a 10 kW Firefinder Set was chosen as the master. The slave, then, must be controllable in output amplitude and frequency. In fact, the slave must be capable of phase lock to the load power bus. Further, the slave must be able to track the load power bus in amplitude.

Figure 1-1 shows the laboratory set up of the demonstration. Figure 1-2 is a block diagram of the interconnection of the various pieces of equipment. This set up is dealt with in more detail in Section V.

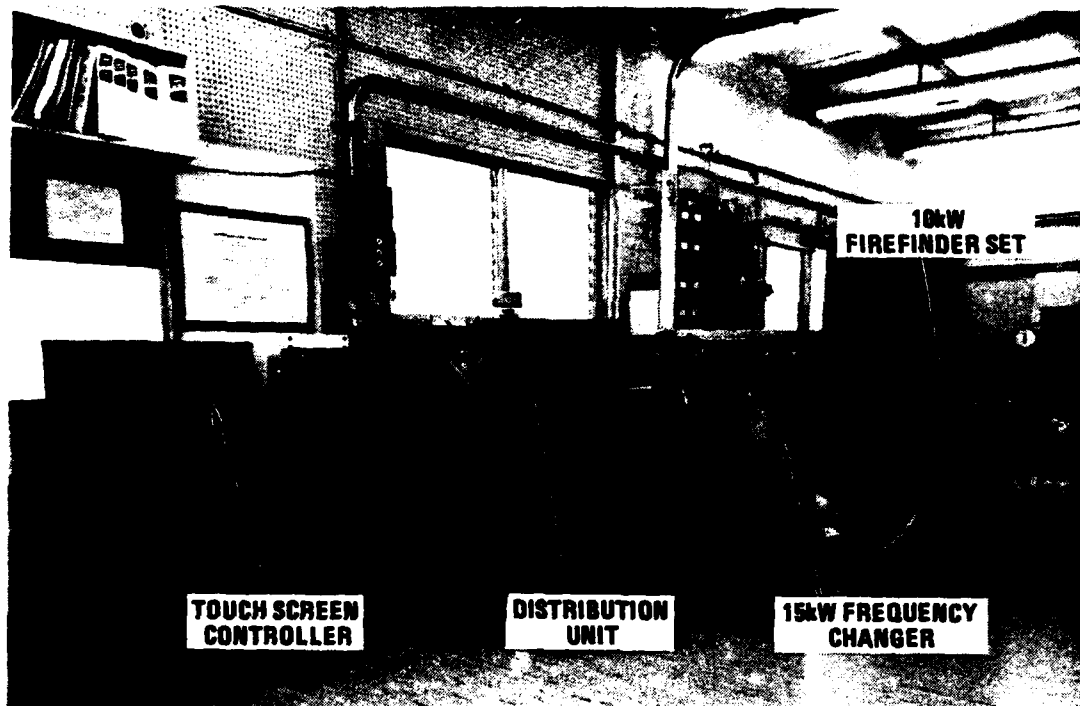


Figure 1-1. Laboratory Setup of Demonstration

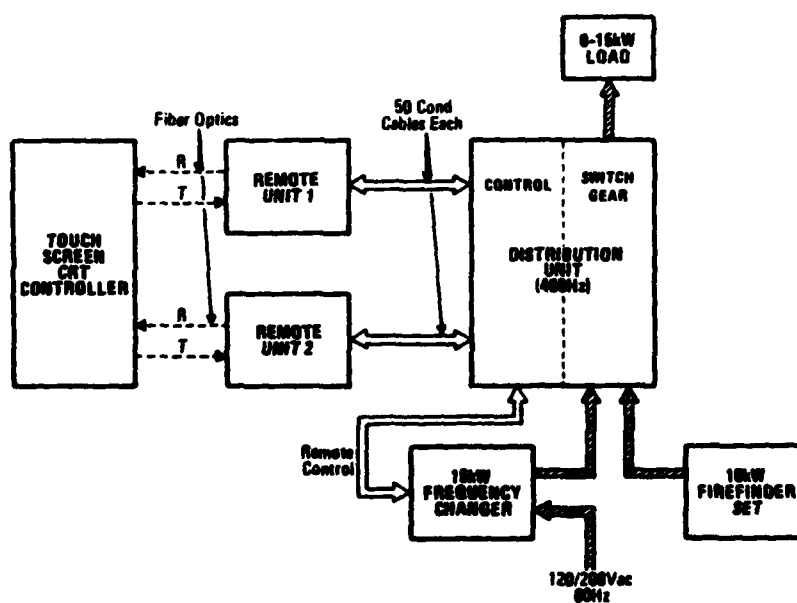


Figure 1-2. Interconnection Diagram of Laboratory Demonstration Setup

Although it is felt by Delco Electronics that phase locking and amplitude tracking features should be an integral part of each frequency changer, the GLP 15 kW unit, being developmental, lacked them. Thus for expediency the control loops necessary for these features were actually mechanized in the Distribution Unit. To further limit the scope to essentials, these loops were made to function at 400 Hz only.

In order to demonstrate touch screen CRT control and monitoring, yet introduce a minimum of changes to the GLP Distribution Unit, analog I/O were added to it. To demonstrate fiber optics using serial digital communications, however, it was necessary to convert analog to serial digital with fiber optic drivers/receivers. This was accomplished with the design and construction of two microprocessor controlled Remote Units completed in FY82. Again, this was done as an expedient and not because Delco Electronics feels this is the best approach. It is felt that Distribution Units should be able to communicate with both the touch screen controller and the power sources through serial digital fiber optic communication ports.

For expediency, the touch screen CRT Controller, constructed in FY82, was designed to be able to handle only one Distribution Unit. This controller is entirely digital and uses one microprocessor for touch screen CRT control and a second for communications and processing. Data and commands in serial digital format are sent between the Remote Units and the touch screen CRT controller over fiber optic "wires". The system adequately demonstrates the use of fiber optics. It is felt that a touch screen CRT controller should be configured in the future to drive not only one but several distribution units and/or power sources.

Although the touch screen CRT Controller is rather simple, both in hardware and software, it demonstrates many of the features Delco feels a power network system controller should have. These features are:

1. Friendly, prompted control of power sources and loads
2. Simple, inexpensive and reliable fiber optic communications
3. Source and load performance monitoring
4. Malfunction displays.

Additional features which would be highly desirable are as follows:

1. Logging of performance history with non-volatile storage
2. Programmed automatic network reconfiguration and load control (for optimum energy usage, highest reliability, system fault tolerance, etc.)
3. System diagnostic display
4. Automatic power network test
5. Operator self-instruction
6. Time standard frequency reference (for accurate time keeping).

The following material in the section describes in summary form the major accomplishments of the demonstration of FY82 and some of the performance features of the equipment used. Later sections and appendices provide more detail.

1.4 HIGHLIGHTS OF FISCAL YEAR 1982 ACCOMPLISHMENTS

This section is provided to very briefly point out some of the most noteworthy accomplishments of the FY82. Some of the most impressive resulting data are provided. The largest portion of the work reported here deals specifically with the Touch Screen CRT Controller and fiber optics used to demonstrate power distribution network control. For this demonstration Delco utilized the following:

1. **Microcomputers** - Eight-bit microprocessors based on the Motorola 6800 family, and 16-bit microprocessors based on the Intel 8086 family with attendant memory, A/D, and I/O chips; system configurations employing distributed processing and co-processing serial communications techniques.
2. **Fiber Optics** - Communication links to route multiplexed serial data between microcomputers and systems; high data rate, EMI-proof, rugged, low cost.
3. **"Touch Screen CRT"** - Simple, compact means to eliminate all mechanical switches and controls and dedicated individual displays; all displays and control functions combined in a ruggedized small screen CRT with a touch sensitive face; totally flexible display format of

alphanumerics and graphics; self-prompting, easy to understand presentation formats.

4. "Hardened Design Techniques" - Specific circuit and system designs address EMI/RFI, fail-safe, fail-soft with backup, hardware and software self-test, and constantly running system diagnostics.

This work was relatively hardware rather than software intensive. It was felt that with the limited funds available for the effort only enough software to demonstrate the real potential of the touch screen would be written. Accordingly, the software for four simple screen displays was written. The four different screen displays are shown in Figure 1-3.

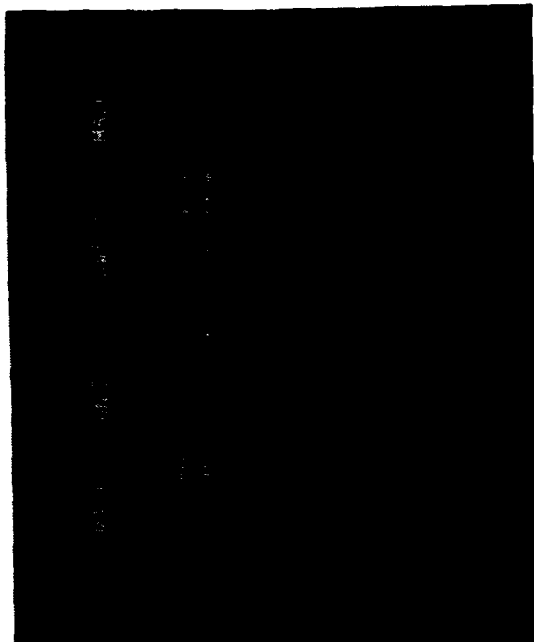
The initial display is the summary screen shown in the upper left corner. This display may be selected at any time by simply touching the word SUMMARY as shown. The Summary screen is used for information display only. It demonstrates the use of a single screen to display complete status. Should there be a system malfunction, a message to that effect would appear in the lower right hand corner of the Summary screen. This is also true in the case of Unit 1 or Unit 2 screens. To determine the nature of the malfunction the operator touches the letters MALF. The Malfunction screen then displays the nature of the malfunction. At present, a communications error to Unit 1 and/or Unit 2 is/are the only malfunction(s) reported.

The Unit 1 screen, selected by touching the letters UNIT 1, demonstrates the use of the touch screen to provide software selectable switches. If the master source's contactor is to be opened or closed, this is accomplished by touching the appropriate word OPEN or CLOSE. The use of reverse video, as shown by the word CLOSE, and a single audible beep indicates the action was taken. Thus reverse video is used much like a pilot light.

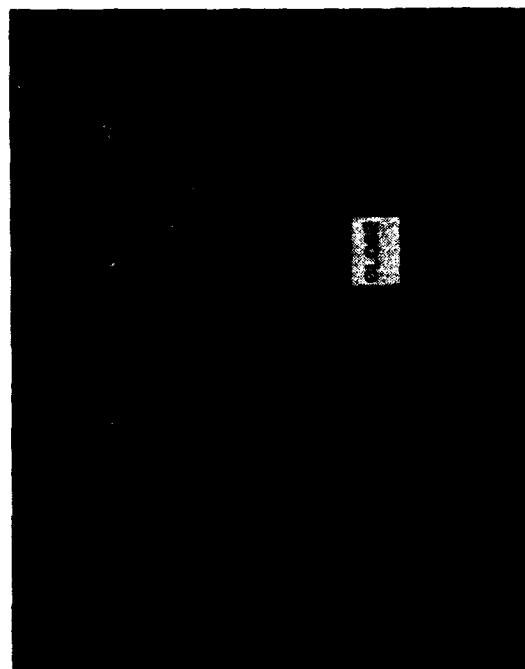
The Unit 2 screen demonstrates the use of the touch screen to provide software selectable potentiometers. For example, if it is desired to increase the amount of power the slave source (Unit 2) contributes to the power bus, the letters INCR are touched. There is a beep and the block including INCR is displayed in reverse video for approximately one second. This causes a single



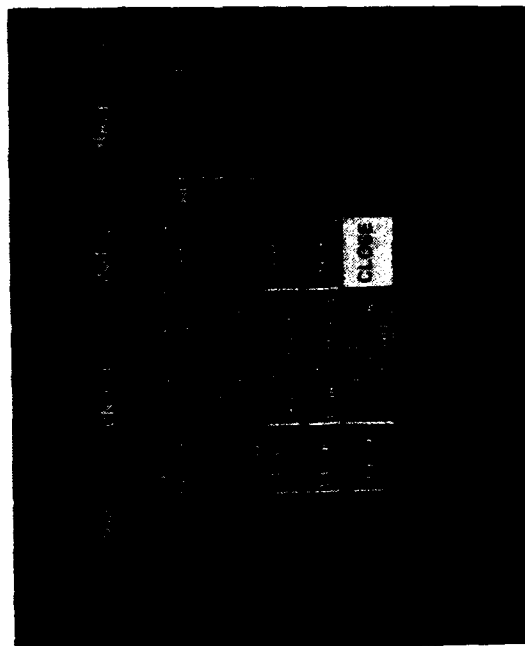
a. Typical Summary Screen



b. Typical Malfunction Screen



c. Typical Unit 1 Screen



d. Typical Unit 2 Screen

Figure 1-3. Touch Screen Display

step change in increased power output. If this is insufficient, additional steps may be entered at the rate of about one per second.

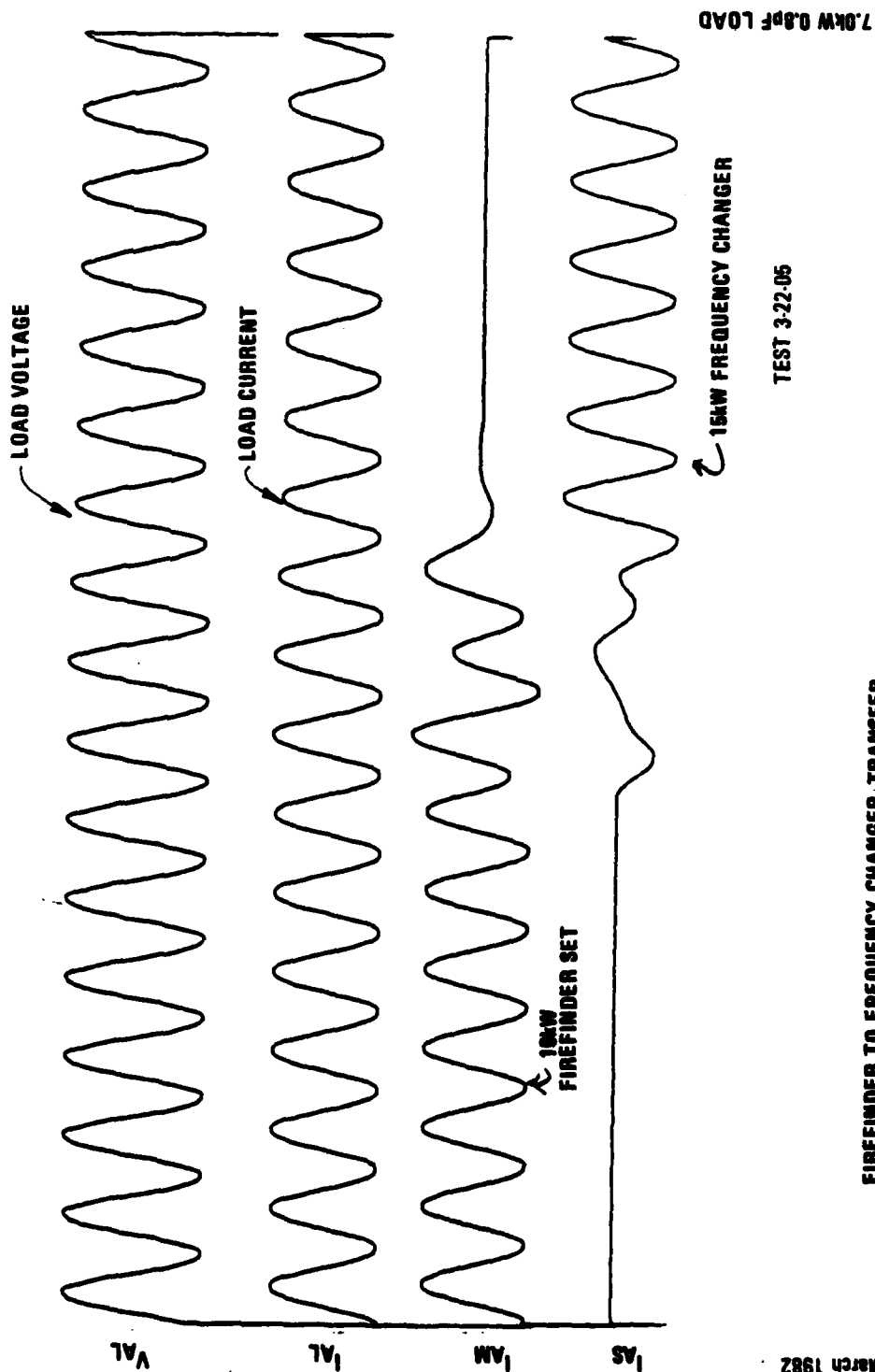
The touch screen CRT hardware was built and the software debugged. The equipment very effectively demonstrates the use and potential value of the touch screen concept.

Another noteworthy aspect of this development is the use of fiber optics as the sole communications link to the touch screen controller. The mechanization involves four fiber optic "wires". Unit 1 communications and control are handled by one "wire" for transmit and a second for receive. Unit 2 has a corresponding pair. This approach works very well and may be readily adapted to commercial standard RS 232C serial communications or Military Standard 1553 serial communications rates and protocol.

An important use for the touch screen controller is control of paralleling of a power system consisting of two sources. This might be more correctly called remote control of paralleling since the actual controlling is done in hardware other than that of the touch screen controller. Paralleling control is accomplished in the Distribution Unit. In FY82, work was done on this unit to improve its performance relative to paralleling.

Figure 1-4 shows the results of a rapid transfer of power sources from the master (10 kW Firefinder GTE generator set) to the slave (15 kW Frequency Changer). In mechanical switching terminology, this is called make-before-break switching. It is particularly significant here that the slave source at all times before, during, and after the transfer is tracking the master source in output frequency, phase, and amplitude. Thus the transfer is transient free with respect to the nature of the power to the load.

This no break rapid transfer was demonstrated in transfers from master-to-source and source-to-master. Furthermore, slow transfers involving a variable length period of paralleling were also demonstrated. Results were always clean with no break in the power to the load. This performance in transfer operations is mandatory for multi-source power distribution systems and networks of the future.



FIREFINDER TO FREQUENCY CHANGER TRANSFER

Figure 1-3. Rapid Power Transfer Performance

Figure 1-5 shows the phase response of the slave unit to a quasi-step change in master frequency. Note the response is rapid and has no overshoot. This response characteristic is very adequate for any distribution system where the master is an engine or motor driven alternator and where frequency transients could occur. A considerable amount of testing was performed with both amplitude and frequency transients. The performance in all cases was completely adequate for general distribution systems.

Work was done with both the converter and inverter portions of the 15 kW Frequency Changer to improve and characterize its performance in stand alone, as well as distribution, use. The input filter of the 15 kW Frequency Changer was improved with the addition of three capacitors and three inductors so that its input power factor was improved and its input current harmonic generation was reduced. Also, its output voltage waveform (more exactly that of a 10 kW Firefinder GTE generator set with a similar 28-SCR inverter) was recorded with several typical nonlinear load configurations.

Figure 1-6 is a plot of the typical total harmonic distortion (THD), contribution of the 3rd through 13th harmonics and the 5th harmonic of the input currents to the 15 kW Frequency Changer over a wide operating range. These data are taken with the unimproved input filter developed prior to FY82. While this performance is impressive, it does not meet Navy requirements which limit the amplitude of individual harmonics to 3%.

Figure 1-7 is a plot of the same thing except that the input filter improvements of FY82 have been made. Observe that these data meet Navy requirements. It is felt that minor changes in the input filter could reduce the peak of nearly 5% in the THD curve. (This peak is not actually due to distortion which is a harmonic of the 60 Hz input lines, but rather conducted harmonics related to the converter operating frequency.)

Figure 1-8 shows typical input voltage waveform and current at approximately rated input. These results, which indicate the feasibility of producing power supplies which meet Army as well as Navy specifications for input harmonics, are extremely gratifying. As far as known, the Delco approach to harmonic

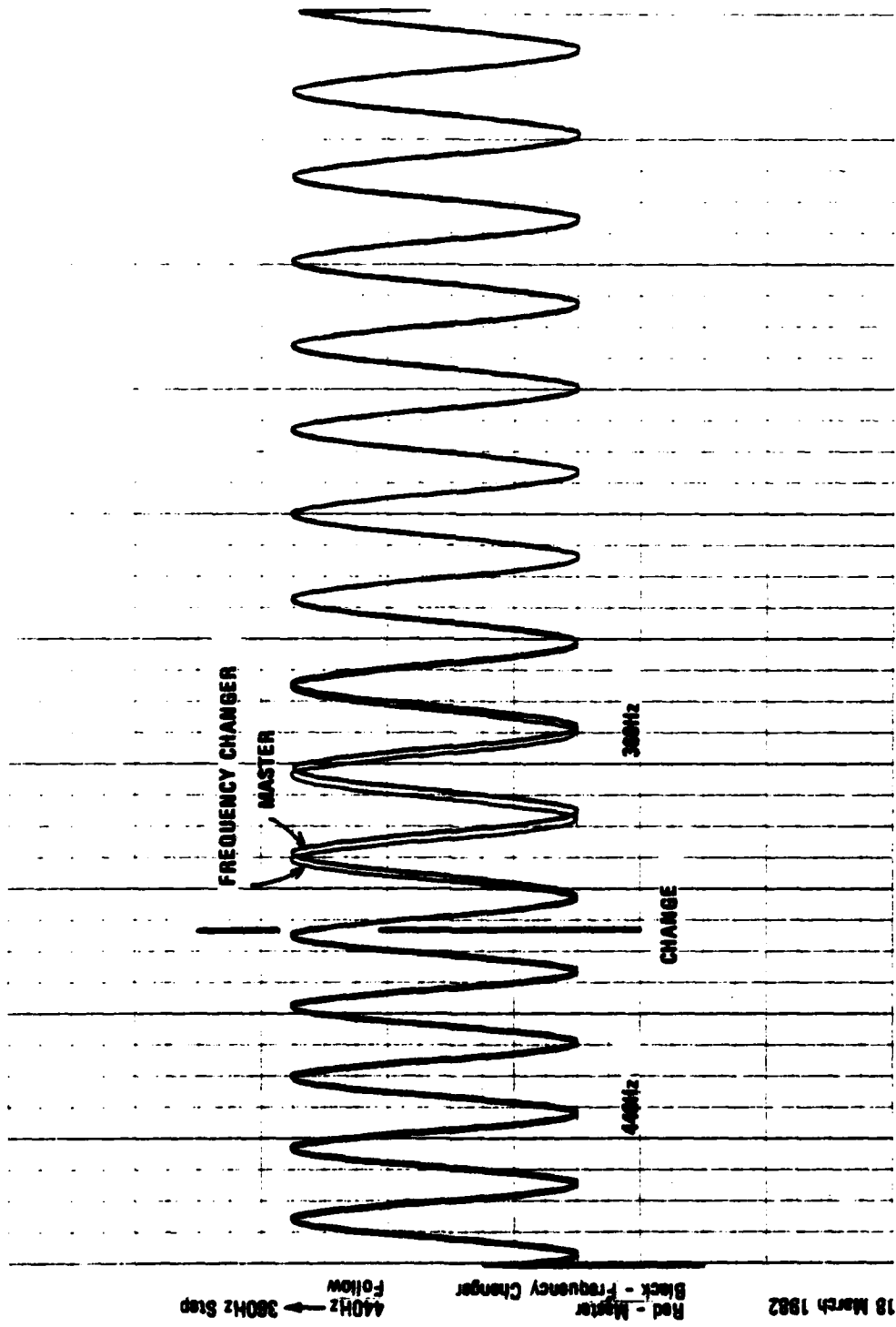


Figure 1-5. Effect of Step Change in Reference Frequency on Phase Lock

EQUIP 15KW FREQ CHGR

MFR DELCO

MODEL NO. _____

SERIAL NO. _____

REF: _____



SANTA BARBARA, CALIFORNIA

TEST NO. SEE TEST REC

DATE MARCH 01, 1982

BY _____

TEST REC 01-03-01

THROUGH 01-03-08

ORIGINAL

INPUT FILTER

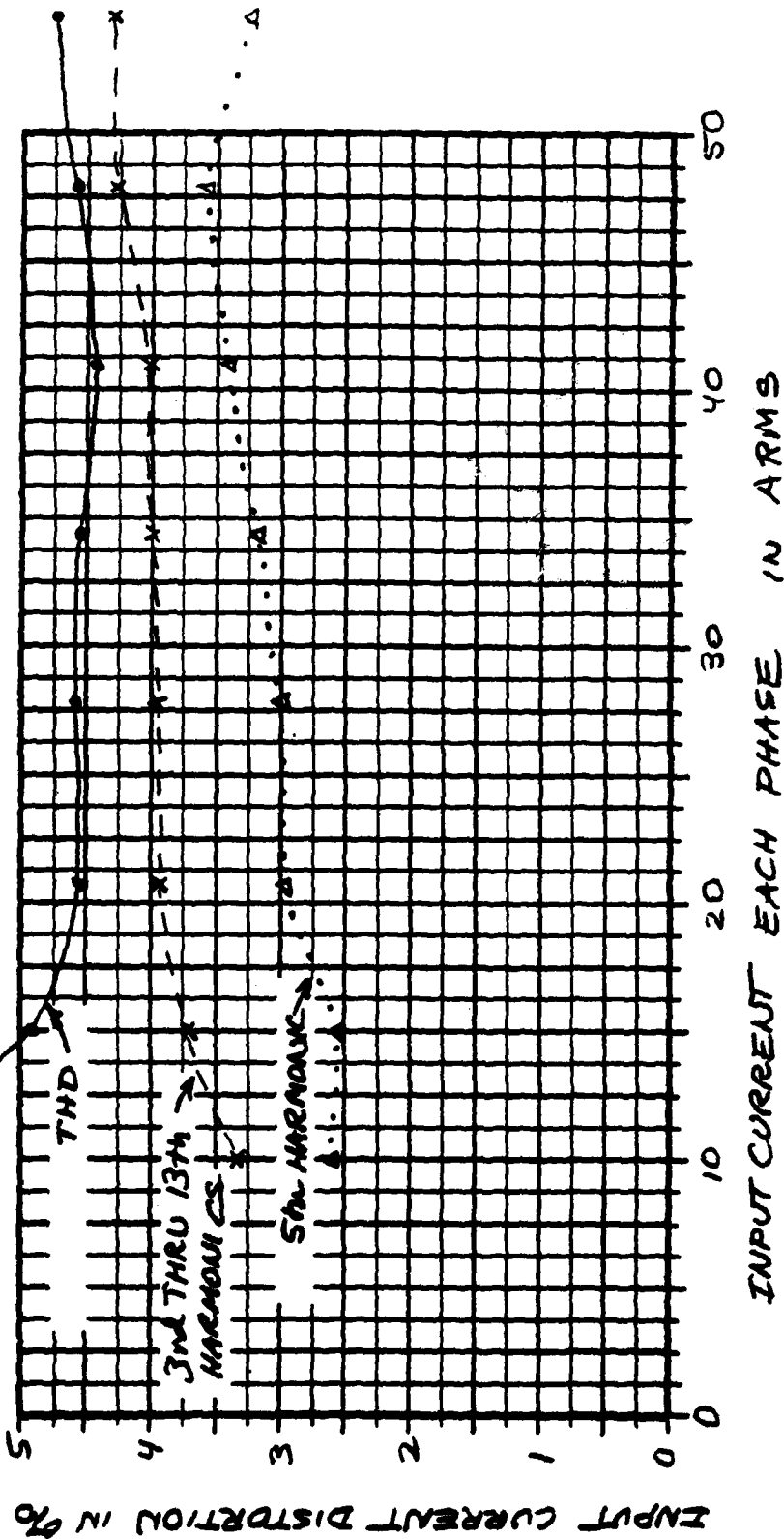


Figure 1-6. Typical Harmonic Distortion Contribution

EQUIP 15KW FREER CHGR

MFR DELCO

MODEL NO. _____

SERIAL NO. _____

REF: _____



SANTA BARBARA, CALIFORNIA

TEST NO. SEE TEST REC

DATE MAY 24 25 1982

BY _____

TEST REC 24-5-01

Q. 25-5-01

AUGMENTED

INPUT FILTER

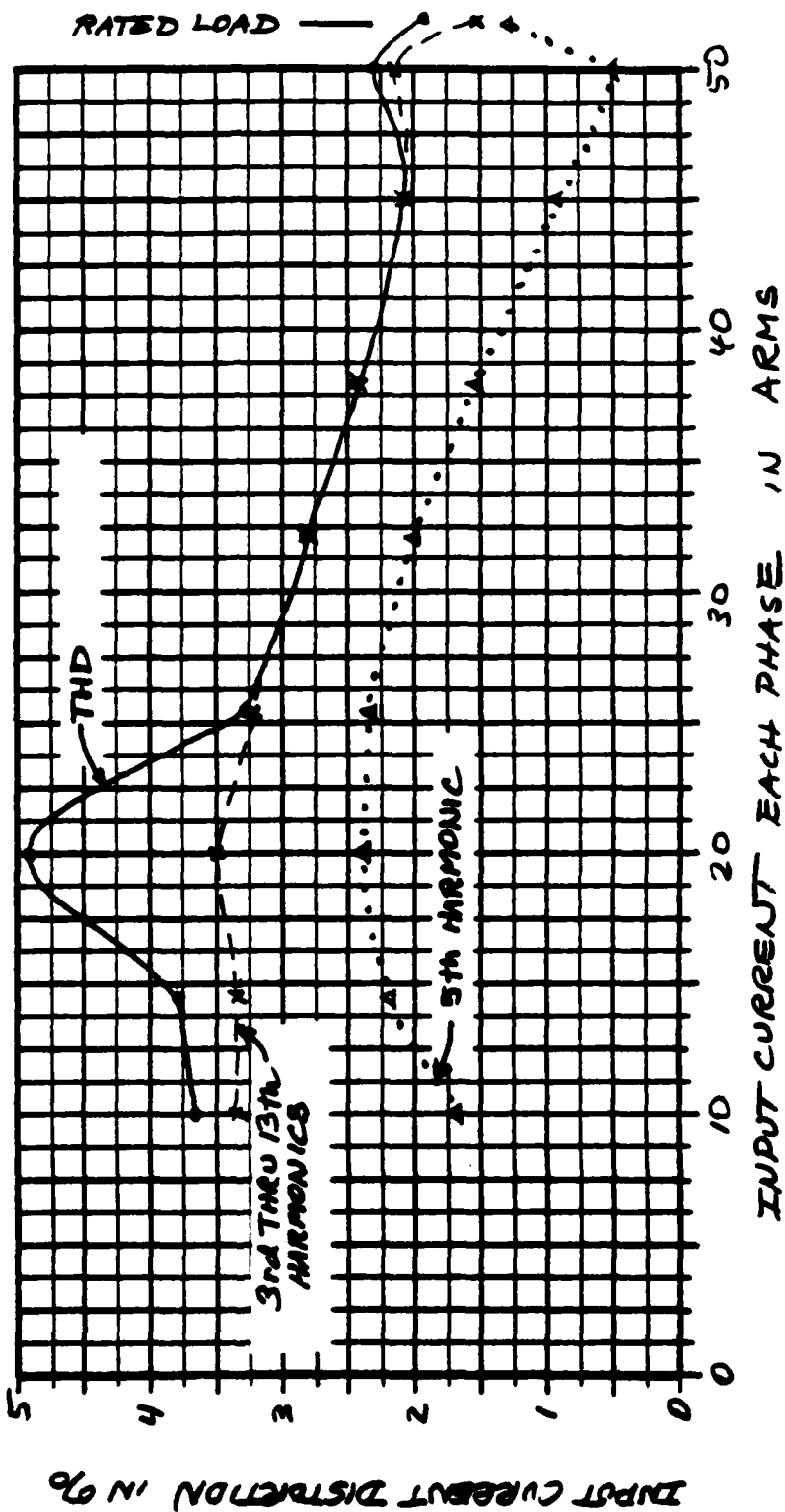
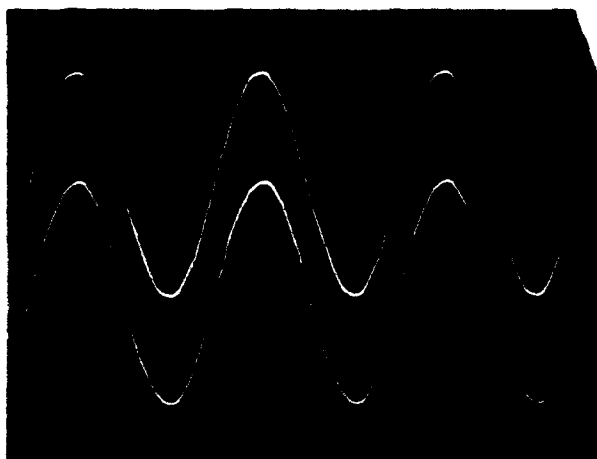


Figure 1-7. Harmonic Distortion Contribution After Input Filter Improvement



TEST DESCRIPTION L-N VOLTAGE
& CURRENT WAVEFORMS

V1 V ϕ A L-N THD=1.23%

V2 I ϕ A THD=2.32%

V3 CONVERTER INPUT

V4 POWER = 19 KW

H1 _____

H2 _____

TEST NO. _____

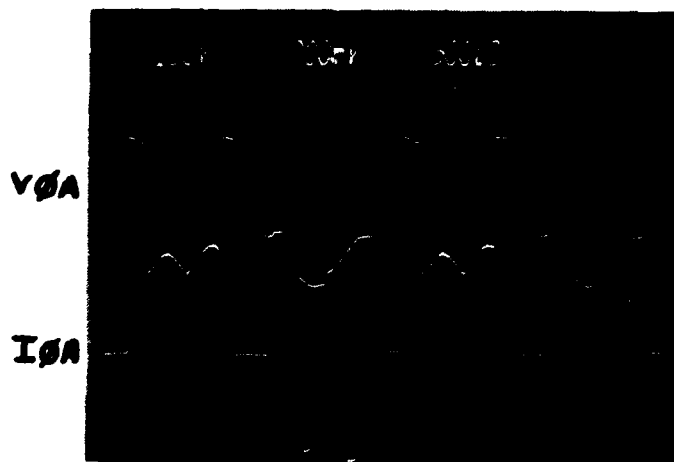
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Figure 1-8. Typical Voltage and Current Waveforms
at Approximately Rated Input

reduction is the only one which is passive, does not use multiphase rectification or large passive filters and yet meets these specifications. While it has been shown by Delco and others that another approach using active (feedback) control can achieve similarly low levels of harmonic generation, this approach lacks the simplicity, reliability and inherent stability of the Delco passive approach.

Implementation of the Delco passive harmonic reduction technique in the power supplies of load equipment should be a highly effective way of cleaning up the power to this load equipment and other equipment on the same distribution system.

Another highly effective approach to having clean power distribution is to use a power source which is less susceptible to degradation by conventional equipment power supplies than the alternators which are often used. Figure 1-9 and Figure 1-10 illustrate this approach with a 10 kW non-linear load simulating typical power supplies. They show the efficacy of the Delco 28-SCR inverter in this approach. Note that voltage waveform distortion - which causes problems with sensitive loads - is approximately 12 percent with the alternator and only about 3.5 percent with the Delco 28-SCR inverter. Furthermore, high order harmonics, which are especially troublesome, do not appear as high in amplitude with the Delco inverter.



TEST DESCRIPTION _____

V1 VΦA 100V/DIV

V2 IΦA 20A/DIV

V3 _____

V4 _____

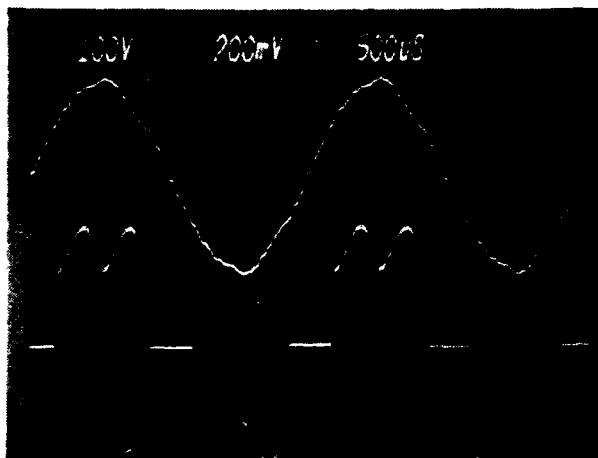
H1 500μs/DIV

H2 _____

TEST NO. 17-06-05

PIX NO. 1

Figure 1-9. Waveforms Which Result When A Typical Power Supply Load Is Applied to a 12.5 kVA Alternator Driven Bus



TEST DESCRIPTION _____

V1 V ϕ A 100V/DIV

V2 I ϕ A 20A/DIV

V3 _____

V4 _____

H1 1 KHz/DIV

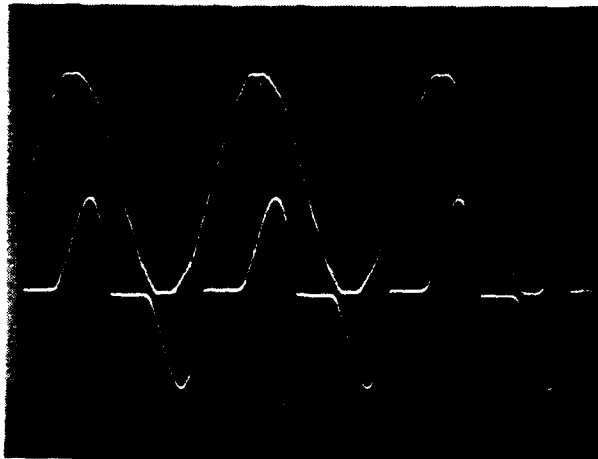
H2 _____

TEST NO. 17-06-03

PIX NO. 1

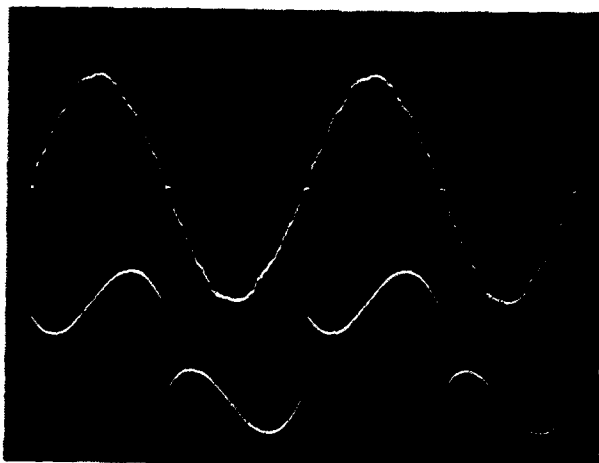
Figure 1-10. Waveforms Which Result When The Load of Figure 1-9 Is Applied To The Delco 28-SCR Inverter

Figure 1-11 and Figure 1-12 show the results of applying, respectively, a 9 kW load simulating a different type of power supply configuration and a 6 kW load simulating still a different configuration to the Delco inverter. These results show remarkably high waveform purity with conventional power supply loads and meet precise classes of military requirements. Most other types of inverters use feedback in the generation of their output waveforms and are prone to having severely degraded or unstable output into typical power supply loads. The Delco 28-SCR inverter, which has no such feedback, experiences no difficulty in driving power supply loads. It even drives pulsed power supply loads.



TEST DESCRIPTION V ϕ L-N &
I ϕ WAVEFORMS
V1 V ϕ L-N THD=2.46%
V2 I ϕ THD=45.5%
V3 _____
V4 _____
H1 5MS/DIV
H2 _____
TEST NO. 24-5-04
PIX NO. 1

Figure 1-11. Delco Inverter Driving A Second Type
Of Power Supply Load at 9 kW Output



TEST DESCRIPTION V ϕ L-N &
I ϕ WAVEFORMS
V1 V ϕ L-N THD=2.98%
V2 I ϕ THD=36.9%
V3 _____
V4 _____
H1 500 μ s/DIV
H2 _____
TEST NO. 24-5-05
PIX NO. _____

Figure 1-12. Delco Inverter Driving A Third Type
Of Power Supply Load At 6 kW Output

SECTION II

TOUCH SCREEN CRT CONTROLLER AND REMOTE UNITS

2.1 BACKGROUND

This effort represents the first application by Delco of either microprocessor or touch screen technology to the area of control of power distribution systems. In the automotive area, however, applications have been extensive.

In 1975, Delco began development of the General Motors Custom Microcomputer (GMCM). In 1979, the GMCM was used in General Motors first production micro-computer engine control. By 1981, all GM passenger cars used one or more GMCM chip sets. Additional applications have been found in multifunction engine controls, transmission controls and other vehicles.

The microcomputer, GMCM and others, are now found in GM electronically tuned radios, electronic climate controllers, fuel, range, and trip computers, digital speedometers and gauges, and computer controlled memory seats. Much of the original application work in this automotive area was done by Delco Electronics - Santa Barbara Operations. Thus, the application of microcomputers to power distribution was easily and successfully made.

Touch screen CRT's have been under development by Delco since 1979. These units have instrument panel applications in GM cars of the future. To date, a number of engineering feasibility units have been built and tested.

Automotive applications for both technologies require high reliability and ruggedness because the automobile is a very harsh environment. Success in this regard indicates high potential for use of these technologies in the area of military power distribution control.

2.2 FUNCTIONAL DESIGN OF THE TOUCH SCREEN CRT CONTROLLER

The Touch Screen CRT Controller is designed to control and receive data from the Distribution Unit by fiber optic "wires". Rather than provide fiber optic communications directly from the Distribution Unit - which would have required very extensive modification of the same - fiber optic communications are handled by external interface units called Remote Units. The Remote Units then may be viewed as adapters which give the Distribution Unit the necessary fiber optic communications ports. Figure 2-1 shows the Touch Screen CRT Controller. Figure 2-2 shows the mechanization of both the Touch Screen Controller and the Remote Units. Figure 2-3 is a block diagram of the Touch Screen CRT Controller.

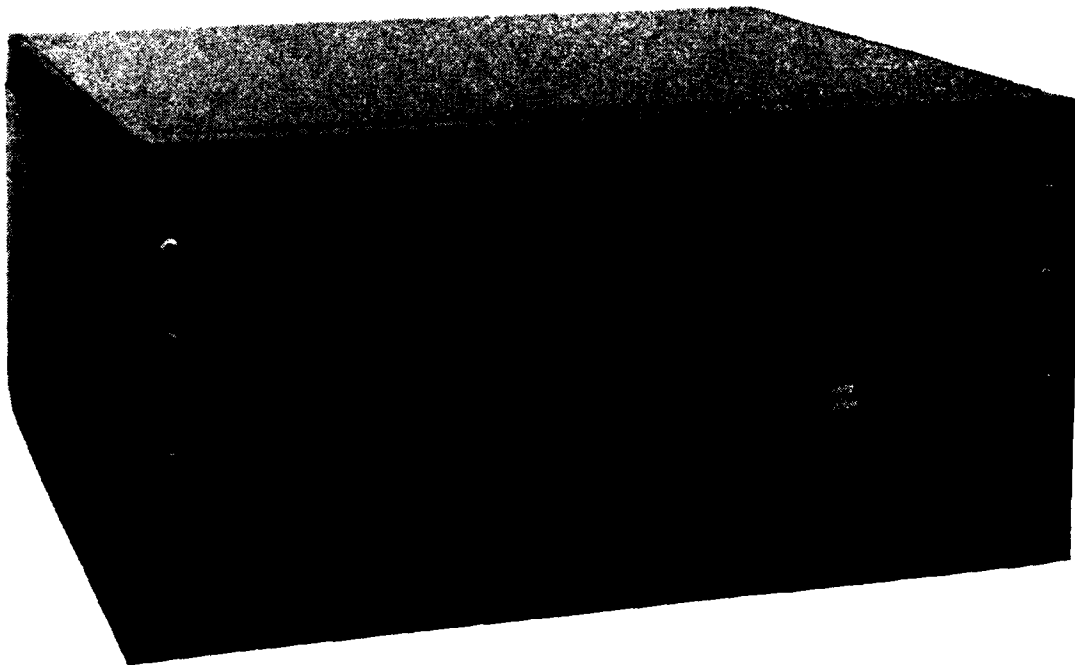


Figure 2-1. Touch Screen CRT Controller

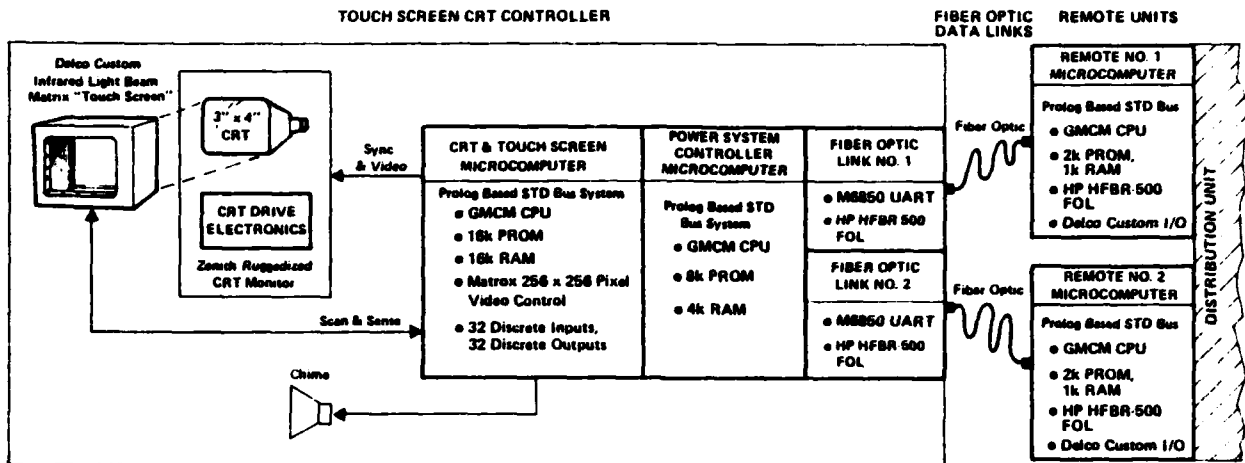


Figure 2-2. Touch Screen CRT Controller and Remote Unit Mechanization

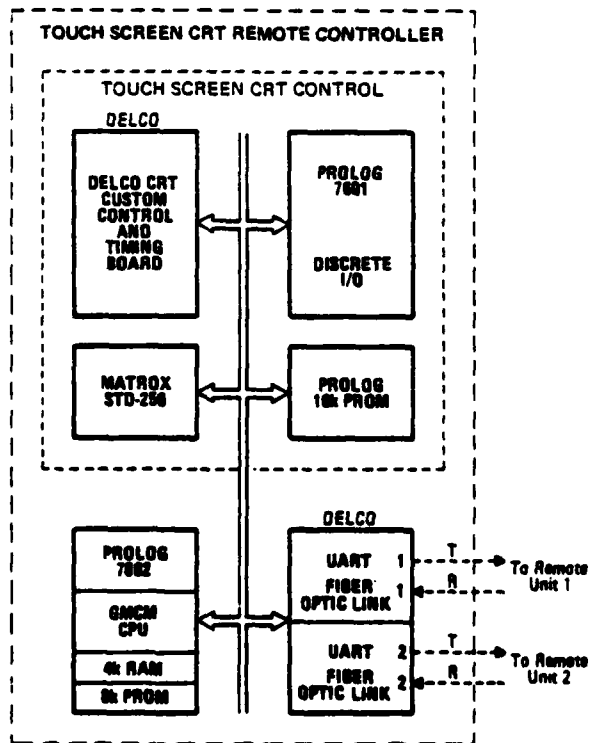


Figure 2-3. Block Diagram of Touch Screen Controller

A matrix of infrared emitters and detectors is placed in front of the CRT. When a finger is brought directly up close to the screen horizontally and vertically, IR light beams are broken. With this approach, it is possible to determine if and where a command is being entered by the operator. Thus, the screen may be considered to be an array of switches which may be identified and reconfigured with software. A chime with a single beep is used to inform the operator that he has "thrown a switch". The CRT is driven by deflection electronics supplied by Zenith. Screen size is 3 inches by 4 inches with bright yellow phosphor against a black background.

Screen presentation is in the form of a bit map. The pixel matrix size is 256 by 256. The video controller for the bit map is supplied by Matrox. The CRT presentation and the touch screen are controlled by a microcomputer as in Figure 2-3. This microcomputer is configured in a Prolog CCA using the Prolog standard bus. The microprocessor used is the General Motors Custom Microprocessor (GCMC) which is a derivative of the Motorola 6800 family. The memory on this bus is 16k bits of programmable read only memory (PROM) and 16k bits of random access memory (RAM).

In an effort to minimize software development heavy usage is made of algorithms and software which had already been written for automotive applications. Actual displays and software controlled touch screen switches are in software unique to the power distribution control application.

The Prolog standard bus is extended to include a second microcomputer which is dedicated to data processing and communications with the Remote Units. This microcomputer is also configured with a GCMC microprocessor and uses 8k of PROM and 4k of RAM. This microprocessor receives the following data at an update rate of approximately one per second:

1. From Unit 1

- $VM\phi A$, $VM\phi B$, $VM\phi C$ (voltage master phase A, etc.)
- $IM\phi A$, $IM\phi B$, $IM\phi C$
- $PM\phi A$, $PM\phi B$, $PM\phi C$
- ϕMA (power factor (PF)) sign bit
- ϕMB sign bit
- ϕMC sign bit

2. From Unit 2

- VS ϕ A, VS ϕ B, VS ϕ C
- IS ϕ A, IS ϕ B, IS ϕ C
- PS ϕ A, PS ϕ B, PS ϕ C
- dSA sign bit
- ϕ SB sign bit
- ϕ SC sign bit

With this data the microcomputer is used to calculate the following:

1. For Unit 1

- VM average
- IM average
- PM total
- IM total
- PFM ϕ A incl sign
- PFM ϕ B incl sign
- PFM ϕ C incl sign
- PFM average

2. For Unit 2

- VS average
- IS average
- PS total
- IS total
- PFS ϕ A incl sign
- PFS ϕ B incl sign
- PFS ϕ C incl sign
- PFS average

Power factor is determined by dividing the power by the volt-ampere product (e.g. $\text{PFM}\phi\text{A} = \text{PM}\phi\text{A} / [\text{VM}\phi\text{A} \times \text{IM}\phi\text{A}]$).

This second microcomputer communicates with the Remote Units through fiber optic "wires" - a total of two for transmit and two for receive. To accomplish this two universal asynchronous receiver transmitters (UART) are used to convert serial to 8 bit parallel. These UART's are operated at a 9600 baud data rate.

2.3 FUNCTIONAL DESIGN OF THE REMOTE UNITS

Each Remote Unit, shown in block form in Figure 2-4, uses a microcomputer for communications control. A UART, again operating at a 9600 baud data rate, is used at the fiber optic interface. The microcomputer uses a GMCM microprocessor with 2k of PROM and 1k of RAM.

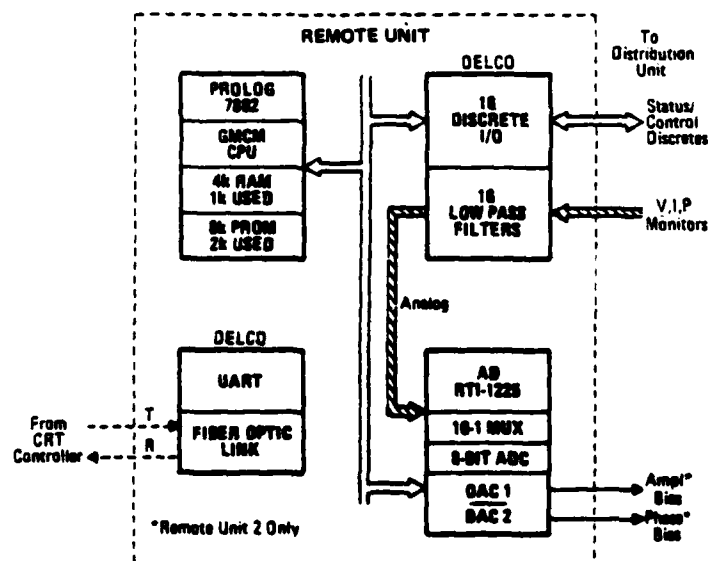


Figure 2-4. Block Diagram of Typical Remote Unit - One of Two

The microcomputer in each Remote Unit operates with a 16 to 1 analog multiplexer (MUX) and an analog-to-digital converter for communicating voltage, current, and power signals. These signals, which are scaled average values, are filtered with low pass filters ahead of the MUX.

In addition to these monitored signals, which the microcomputer communicates to the touch screen CRT controller, the microcomputer also issues command discretes to the Distribution Unit and issues status discretes to the touch screen CRT controller. Remote Unit 1 is configured in terms of hardware and software the same as Remote Unit 2. The distribution Unit uses the two digital-to-analog converters (DAC) of Remote Unit 2 for amplitude and bias control. The outputs of the DAC's in Remote Unit 1 are unused. (The Remote Units may be interchanged.)

2.4 CHARACTERISTICS OF FIBER OPTIC LINKS

In order to keep cost down an inexpensive commercial grade fiber optic link (FOL) was chosen. The components used belong to the Hewlett-Packard HFBR-0500 series. This series uses plastic snapin connectors and operation is limited to five meters. The data rate capability is dc to 5M baud. Delco is using five meter cables and maximum data rate of 9.6k baud.

Delco has not done a survey to find the most suitable fiber optic components for military applications. However, such components are presently available. For commercial applications Hewlett Packard makes components which will operate over a temperature range of -20°C to $+70^{\circ}\text{C}$. They are useful up to 1,000 meters at a 10M baud data rate.

Fiber optic data communications offer many advantages for military applications. Very high data rates are possible at low cost. As the cables are non-conductive they may safely be located close to power lines (even in the same conduits). They offer high security because they are EMI proof and radiate no electromagnetic energy. The cables are lightweight and easy to install.

2.5 HARDWARE DESIGN AND IMPLEMENTATION

The Touch Screen CRT Controller and the Remote Units are housed in low cost commercially available cabinets, since early in the development cycle it was felt unwise to design military type cabinets - especially with immature electronics designs. Commercial power supplies and Prolog card cages were used to reduce development costs.

Photographs and schematic diagrams of the Touch Screen CRT Controller are found in Appendix K. Photographs and schematic diagrams of the Remote Units are found in Appendix L.

SECTION III DISTRIBUTION CENTER

3.1 BACKGROUND

Development of the Distribution Center (formerly referred to as the Paralleling Controller) began in 1980 as part of the 15 kW General Purpose Frequency Changer Performance Improvement Program. In March 1981, Delco published a report* describing this Distribution Center and its use. The Distribution Center was built in 1980 to function with the 15 kW Frequency Changer and permit its paralleling with other power sources. This Distribution Center constituted the entire operator interface for paralleling, which was controlled on the front panel with switches and potentiometers.

3.2 EFFORT FOR FY82

The FY82 IR&D objective was to incorporate a Delco touch screen CRT controller in the paralleling demonstration. This was accomplished by modifying the Distribution Unit furnished as GLP. Although the modification was rather extensive, it was the most expedient way to accomplish the stated objective.

Figure 3-1 is an external view of the Distribution Center. Since all the modifications made in 1982 were internal, none are apparent in the picture. The following features of the design were changed by the 1982 modifications.

1. The phase locking circuitry has component values for 400 Hz operation. (As such, it may not function properly at 50 or 60 Hz.)
2. The power limit and power sharing features and their control potentiometers are disabled.
3. The Single Port mode should not be used.
4. The Distribution Unit must always be used with the Remote Units and the CRT Controller.

* 15 kW General Purpose Frequency Changer Performance Improvement. Technical Report R81-31. Delco Electronics Division, General Motors. (March 12, 1981)

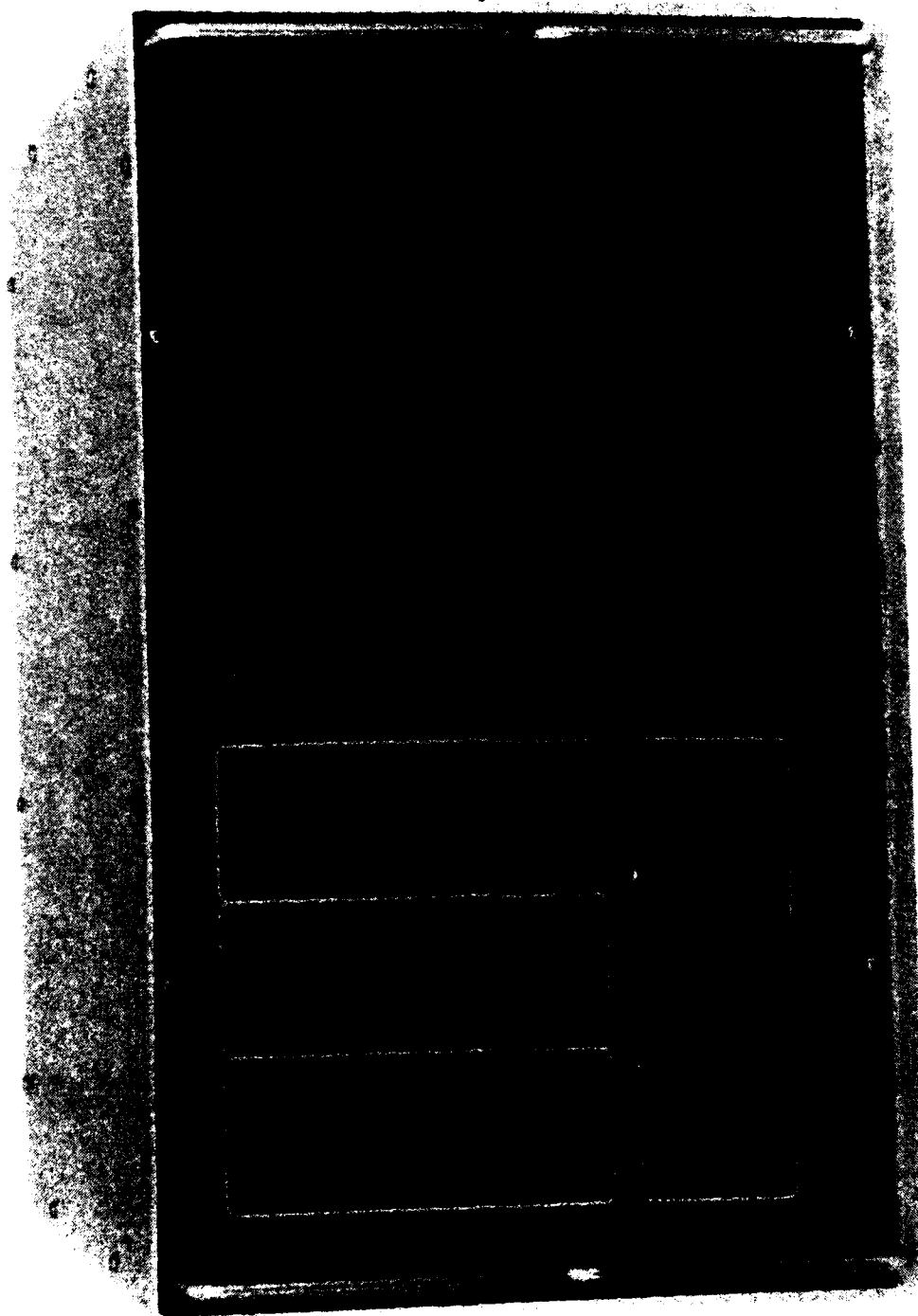


Figure 3-1. Distribution Center

Figure 3-2 shows the indicators and controls on the Distribution Unit front panel, and the restrictions on their use. Figure 3-3 shows the external connections to the Distribution Unit for Two-Port mode operation. These connections are mandatory.

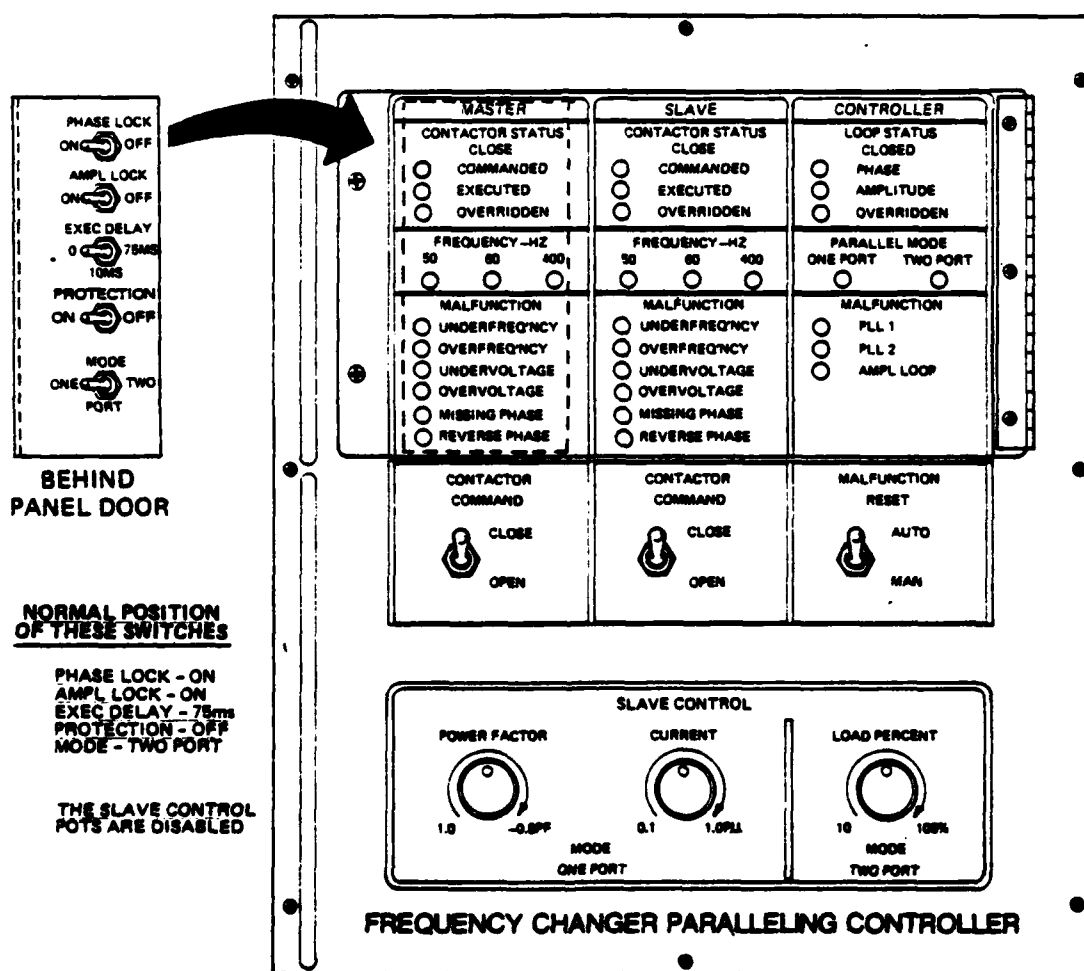


Figure 3-2. Closeup of Distribution Center Front Panel Indicators and Controls

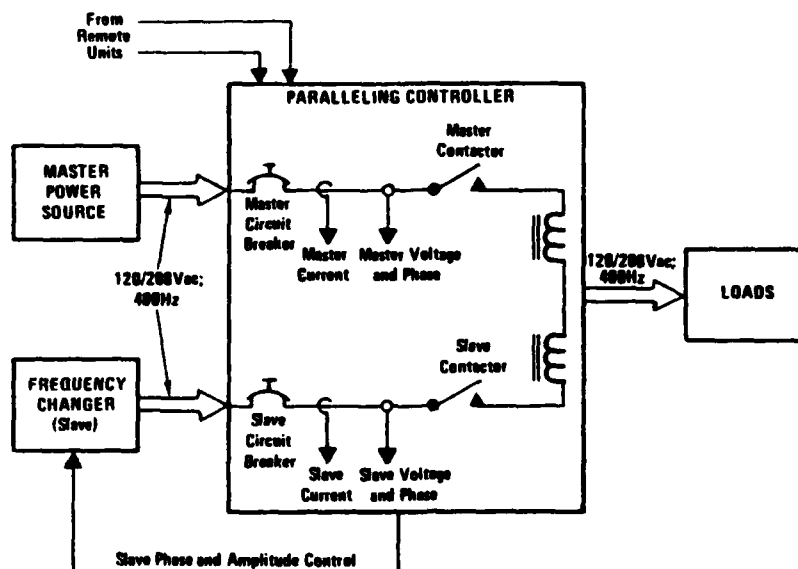


Figure 3-3. Two-Port Mode Connection

3.3 DETAILS OF IMPLEMENTATION

Two control outputs are developed in the Distribution Unit and sent over the remote control cable to the 15 kW Frequency Changer (Slave). Both control outputs are encoded into pulse trains and transformer isolated for low susceptibility to noise. Figures 3-4 through 3-7 show the circuitry which provides amplitude control and phase control.

The amplitude and phase bias signals, shown in Figure 3-4 and 3-6, are supplied by Remote Unit 2 from digital-to-analog converters. By this implementation, the Touch Screen Controller can change the amplitude (power) and phase (power factor) of the Slave Unit in a paralleling operation. Appendix M provides the electrical schematic diagrams of the Distribution Unit.

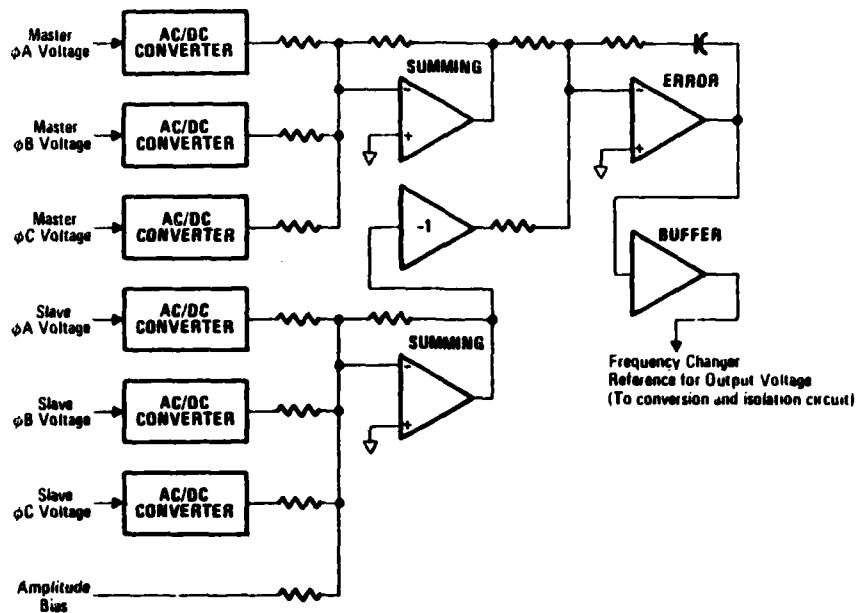


Figure 3-4. Amplitude Control Loop

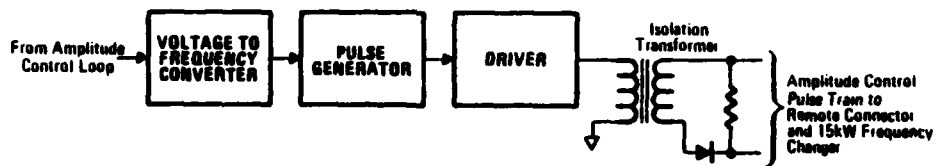


Figure 3-5. Amplitude Conversion and Isolation Circuits

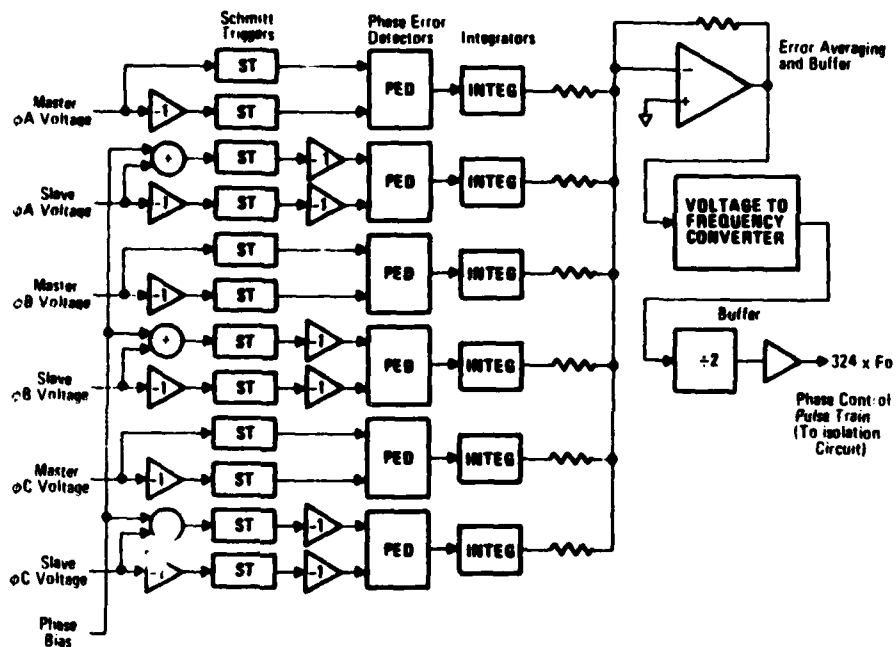


Figure 3-6. Six-Pulse Phase Lock Loop

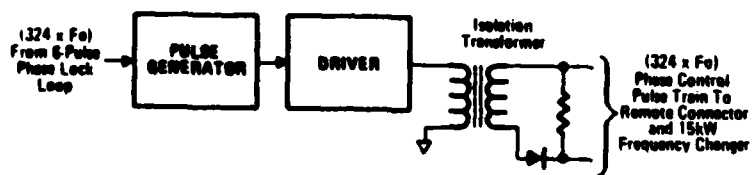


Figure 3-7. Phase Isolation Circuit

SECTION IV

15 kW GENERAL PURPOSE FREQUENCY CHANGER

4.1 BACKGROUND

Development of the 15 kW General Purpose Frequency Changer commenced in 1976. In the course of development Delco generated numerous reports* describing the 15 kW Frequency Changer and its integral parts. This unit uses input power of 120/208 Vac, three phase, either 3 or 4 wire. The input frequency may be 50, 60, or 400 Hz; although at present, the fans and low level power supplies must be operated at 60 Hz only. In general, the quality of the power source should be MIL-STD-1332, utility Class 2B or better.

The 15 kW Frequency Changer (Figure 4-1) supplies at its output 120/208 Vac, three phase, either 3 or 4 wire. The output frequency may be the same or different than the input frequency, and may be 50, 60, or 400 Hz. The general quality of the output power is MIL-STD-1332, precise Class 1.

4.2 EFFORT FOR FY82

When it was originally built, and until 1980, the 15 kW Frequency Changer had none of the remote control features necessary for paralleling its output with other power sources. In 1980, as a part of the contractual effort called the 15 kW General Purpose Frequency Changer Performance Improvement Program, these features were added.

* Inverter Section For 15 kW General Purpose Power Conditioner. Technical Proposal P77-2. Delco Electronics Division, General Motors. (Feb 1977)

15 kW General Purpose Power Conditioner - AC/DC Section. Final Report R78-38. Delco Electronics Division, General Motors. (April 1978)

15 kW General Purpose Power Conditions. Test Report R80-122. Delco Electronics Division, General Motors (September 26, 1980)

15 kW General Purpose Power Conditioner, Inverter/Converter Integration. Technical Report R80-142. Delco Electronics Division, General Motors. (October 1980)

15 kW General Purpose Frequency Changer Performance Improvement. Technical Report R81-31. Delco Electronics Division, General Motors. (March 12, 1981)

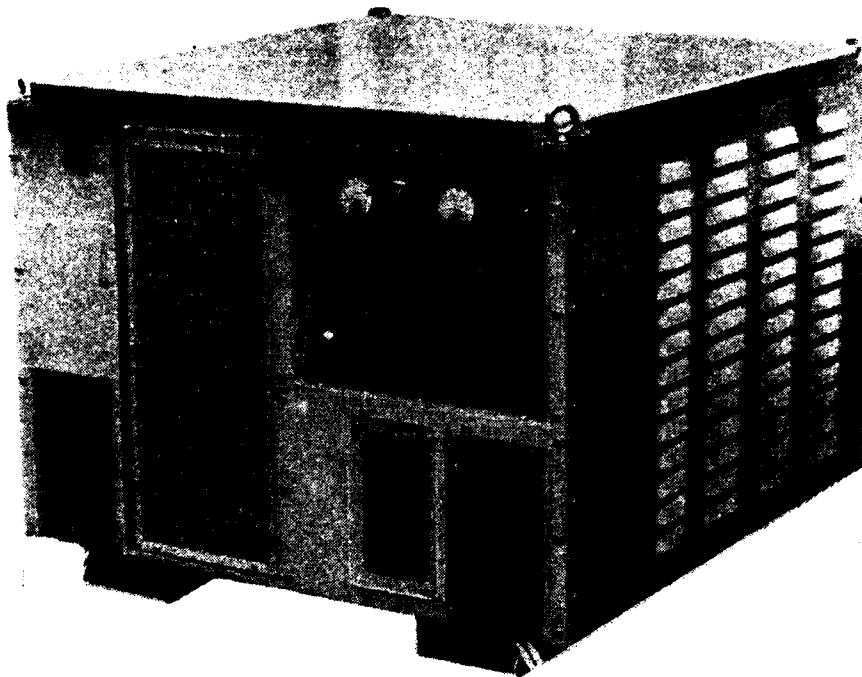


Figure 4-1. 15 kW Frequency Changer

For purposes of the MY82 IR&D Paralleling Control Project, these remote control features of the 15 kW Frequency Changer were deemed satisfactory and remained essentially unchanged.

Figure 4-2 is a block diagram of the 15 kW Frequency Changer. The remote control features necessary for paralleling and described by the block called Amplitude and Frequency Isolation and Conditioning were added in 1980.

4.3 DETAILS OF IMPLEMENTATION

For purposes of paralleling, two characteristics of the 15 kW Frequency Changer's output must be controlled: output amplitude and instantaneous output frequency. The primary function of the circuit card A30 added in 1980 is to permit remote (external) control of these characteristics or parameters. Figure 4-3 is a simplified block diagram of the circuitry for implementing output amplitude control in the external (paralleling) mode. The input is a continuous pulse train with a nominal frequency of 50 kHz. This is isolated from the chassis by a small transformer.

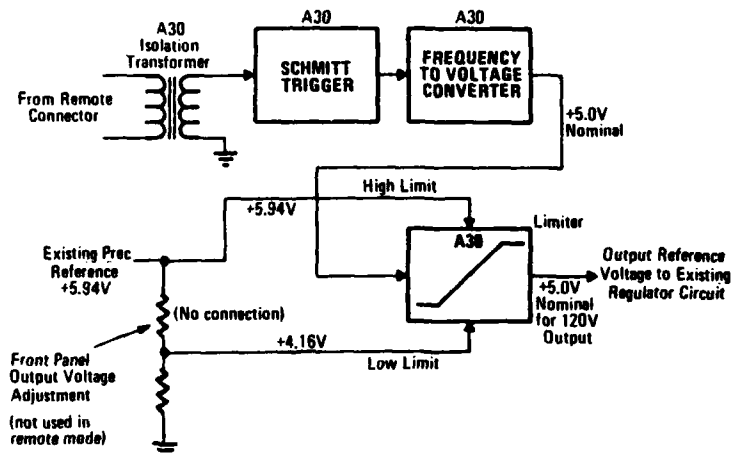


Figure 4-3. External Amplitude Control

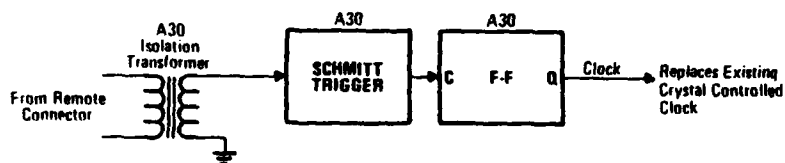
The pulse quality in Figure 4-3 is improved with a Schmitt trigger, which produces a clean frequency. For control purposes, this frequency is converted to voltage. This voltage is applied to a limiter which constrains it to a range corresponding to the nominal output voltage adjustment range of the set.

Three important features of the set's externally controlled output voltage implementation are:

1. Pulse frequency modulation PFM with full transformer isolation is used for extremely high noise immunity.
2. A limiting function is applied to the external control so that even invalid external control cannot cause set output to be out of range.
3. The time response of the external amplitude control circuit (including the frequency to voltage converter) is much faster than that of the internal amplitude control loop, and therefore has a negligible effect on control performance.

Figure 4-4 is a block diagram of the implementation of the output frequency (and phase) control in the external (paralleling) mode. The input is a continuous pulse train with a nominal frequency as follows:

- 50 Hz operation - 16,200 Hz
- 60 Hz operation - 19,440 Hz
- 400 Hz operation - 139,600 Hz



NOMINAL FREQUENCIES

50Hz Operation - 8100Hz
 60Hz Operation - 9720Hz
 400Hz Operation - 64,800Hz

Figure 4-4. External Phase Control

This input pulse train is isolated from the chassis by a small transformer. Pulse quality is improved with a Schmitt trigger. The Schmitt trigger is followed with a toggled flip-flop to give a clock with one half the frequency listed above and a 50 percent duty cycle. For the purpose of frequency (and phase) control, the externally supplied clock is used to replace the internal crystal derived clock.

Appendix N contains a complete set of schematic diagrams of the electrical and electronic circuits of the 15 kW Frequency Changer. This set has minor revisions over previously published sets.

SECTION V
SYSTEM INTEGRATION AND TEST

5.1 THE LABORATORY SETUP

For demonstration purposes a small, yet typical, power distribution system was set up (Figure 5-1) in Delco's Solid State Power Laboratory. The Touch Screen CRT Controller serves as the operator interface. By a total of 4 fiber optic "wires" it enables control of the Distribution Unit and permits monitoring of the system status through the Distribution Unit. The two Remote Units are an expedient for quick and easy hardware development. Since these two units serve as communications interfaces for the Distribution Unit, they would otherwise be incorporated in the Distribution Unit.

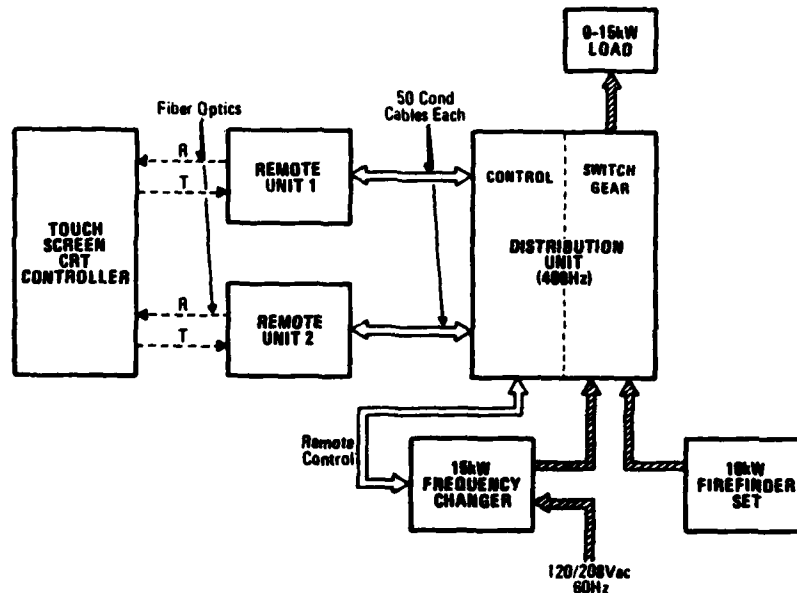


Figure 5-1. Integrated Power Distribution System Block Diagram

The 15 kW Frequency Changer is remotely controlled through the Distribution Unit. For purposes of this demonstration the frequency changer is the only source capable of remote control and must, therefore, be used as the Slave Unit. The 10 kW Firefinder generator set was chosen as the Master Unit. The demonstration was conducted at 400 Hz only.

Figure 5-2 shows the laboratory setup of the power distribution system. From left to right are the Touch Screen Controller, the Distribution Unit, the 15 kW Frequency Changer, and the 10 kW Firefinder PCU. The 10 kW Firefinder PCU is mounted on top of a cooling fixture. The turbine is located in a test cell in another building.

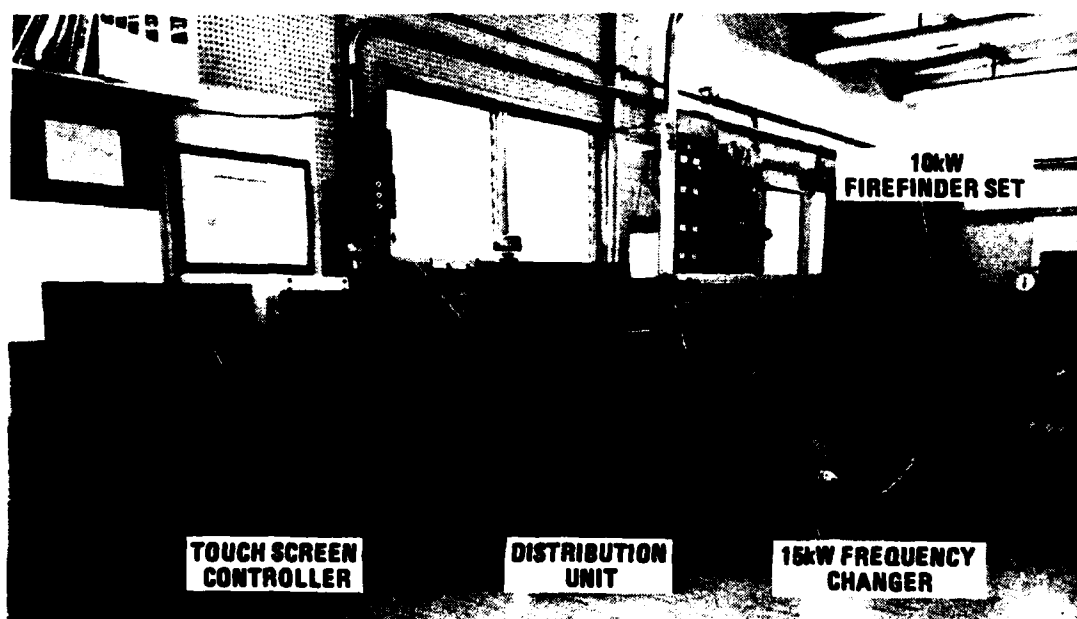


Figure 5-2. Laboratory Setup of Power Distribution System

The Remote Units are located beneath the Distribution Unit and are concealed by the cloth. The reason for this concealment is, as explained in more detail elsewhere, the Remote Units would be included as an integral part of the Distribution Unit.

5.2 DEMONSTRATION AND TESTING

5.2.1 NETWORK DEMONSTRATION

The equipment used for this demonstration (Figures 5-1 and 5-2) was extensively tested. Remote switching, monitoring, and control of paralleling was successfully tested. Especially significant was the performance of "transient free" transfer. Recorded transients were in all cases within the transient response signatures of the 15 kW Frequency Changer and the 10 kW Firefinder Set.

Figure 5-3, 5-4, and 5-5 show three typical touch screen displays recorded during a paralleling demonstration. Note that Unit 1, the 10 kW Firefinder Set, is supplying 2.8 kW to the load bus.

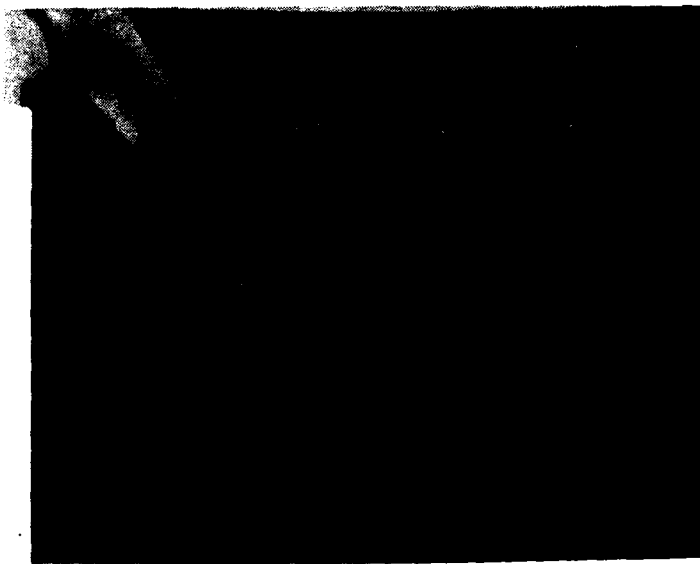


Figure 5-3. Summary Display - Touch Screen CRT

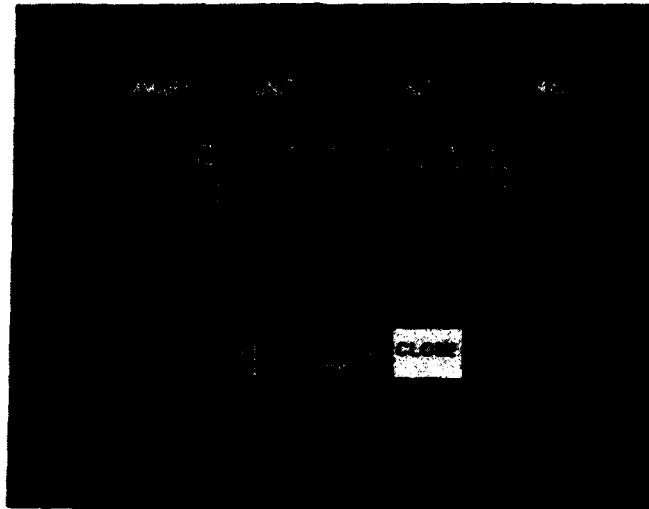


Figure 5-4. Unit 1 Display - Touch Screen CRT

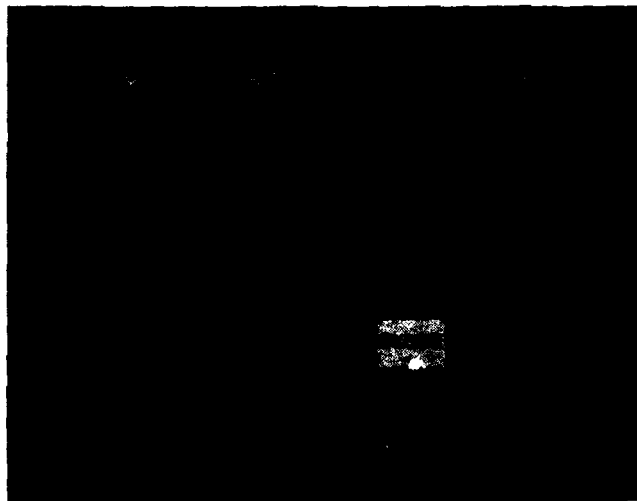


Figure 5-5. Unit 2 Display - Touch Screen CRT

Concurrently, Unit 2, the 15 kW Frequency Changer is supplying 4.1 kW to the load bus. More data are presented in the following appendixes.

- Appendix B - Source Power Transfer Testing
- Appendix C - 15 kW Frequency Changer Load Change Induced Transient Signature
- Appendix D - Effect of Bus Frequency Changes During Parallel Operation
- Appendix E - Phase Lock Capture Behavior
- Appendix F - Effect of Frequency Changes on Phase Lock

5.2.2 INPUT CURRENT HARMONIC REDUCTION

This section deals with the first of two major unscheduled efforts involving a major part of the Network Demonstration of the 15 kW Frequency Changer. Input voltages and currents from the 60 Hz, 120/208 Vac, plant distribution bus were recorded and analyzed for distortion components. This was done both before and after a dramatic improvement was made to the input filter. Data from these tests are provided in the following appendixes:

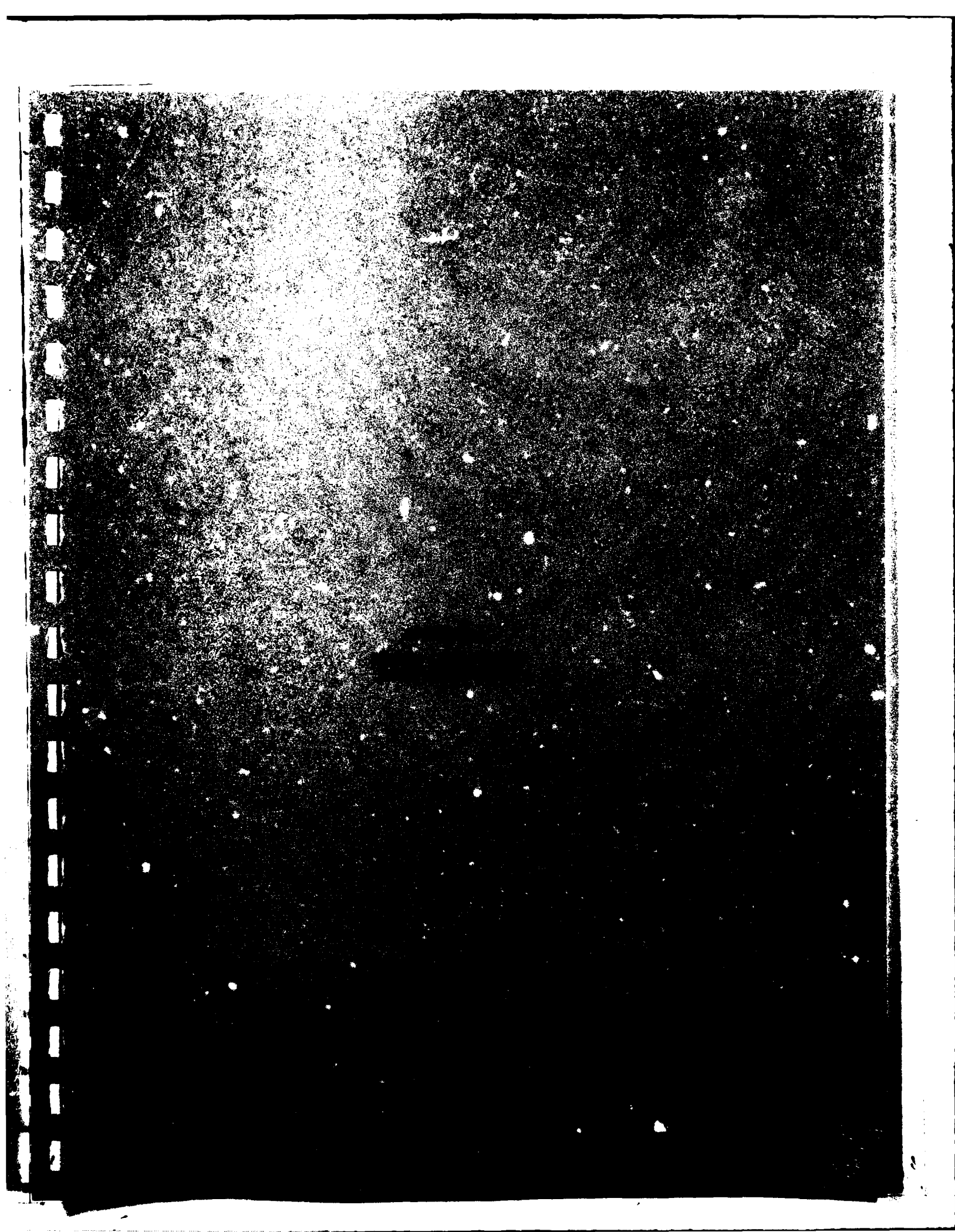
- Appendix G - 15 kW Frequency Changer Input Current Waveform Testing With Original Input Filter
- Appendix H - 15 kW Frequency Changer Input Current Waveform Testing With Augmented Input Filter

5.2.3 EFFECTS OF NONLINEAR LOADS ON THE 28-SCR DELCO INVERTER

This section deals with the second of two major unscheduled efforts involving the Delco inverter. Because of Navy's interest in how well the 28-SCR Delco inverter would perform when supplying typical power supply type (highly nonlinear) loads, the 10 kW Firefinder Set was operated with several such loads. Because suitable power supplies were not on hand, their input characteristics were approximated with nonlinear test load configurations.

With some load configurations, a comparison was made between the 10 kW Firefinder Set and a typical 12.5 kVA motor-generator set. Results show that the 28-SCR Delco inverter (10 kW Firefinder PCU) gives far better bus waveform when operating into a nonlinear load than does a similarly sized motor-generator set. Data from these tests are provided in the following appendixes:

- Appendix I - Inverter Output Waveform Degradation With Nonlinear Loading
- Appendix J - Testing With Single Phase Nonlinear Loading



E80-03 SOLID STATE POWER

INTRODUCTION

The ultimate goal of this project is the definition and demonstration of modern tactical power distribution methods using modular solid state building blocks. The emphasis is on an integrated systems approach that includes power conditioners, distribution centers and controllers for network status reporting and power control.

Status

The status of Delco's overall solid state power program through MY81 is as follows.

- Power Distribution and Control: Evaluated several concepts, solicited tri-service feedback, demonstrated power source sensing and paralleling (under contract DAAK70-77-C-0157), and initiated microprocessor based network controller design which incorporates "touch screen" CRT display plus fiber optic data communication links.
- Power Conditioning
 - Inverters: Completed initial production of the MEP-D423A generator set inverter (Contract DAAK 70-79-C-001) which resulted from previous IR&D activity.
 - Frequency Changers: Completed and demonstrated 15 kW, 60/400 Hz prototype Army unit (Contract DAAK 70-77-C-0157).
 - Converters: Delco in-house efforts reduced earlier 4-SCR converter approach (Contract DAAK 70-77-C0035) to use of 2-SCR power modules; developed universal fixture and controls for high frequency, high power converter studies.

BACKGROUND

Delco is currently developing and producing high power inverters and frequency changers for Army tactical use. These development activities have been aimed at reducing military dependence on the use of engine generation sets in lieu of local utility power. In recent years, changes have occurred in the perception of combat environment needs which make it apparent that power conditioner

development cannot focus solely upon the specific performance requirements of individual power conditioning units, but must also consider the larger system aspects of diagnostics, interface, control, and performance within the total tactical power distribution network. These concerns are addressed in our long term IR&D Plan which takes a top-down systems approach to defining total tactical needs and developing a family of modular system building blocks to satisfy those needs. To achieve the overall objective, Delco is taking advantage of recent Government/Industry efforts by selectively adapting emerging technology to those earlier achievements which show promise of satisfying the stated critical need.

In the area of power distribution, the Marine Corps has developed and tested (1976-1979) prototype power panels and associated cables which provide a very good baseline for meeting the needs of the standard distribution system. These rugged prototypes are definitively specified by MIL-P-29183 (Navy) for the panel boards and MIL-C-29184 (Navy) for the cable assemblies. The system (referred to as MEPDIS) provides local circuit breaker fault protection, but has no provision for centralized control/management and does not address paralleling or control of diverse power sources. Recent technology advances allow expansion of the MEPDIS capability to include these essential control features.

In the area of power conditioners, Government agencies and industry have been applying solid state power device technology advances to achieve replacements for engine generators. 1.5 kW to 15 kW prototype systems have been developed which meet Army mobile electric power requirements. Navy shipboard prototype 60 to 400 Hz frequency changers have been demonstrated to 250 kW levels. Delco/Army have successfully provided full scale engineering development and production of a 10 kW conditioner for the Army's Firefinder TPQ-36 radar.

PROBLEM

The present tactical power distribution methodology requires that a tactical generator set, specific to the load system, be co-located with each load and be compatible in voltage, frequency and quality of power. As a consequence,

logistic support of fuel supply and maintenance for the power source must be provided to the user site. This situation results from a lack of power conditioning equipment which can convert available power to user requirements, and from a lack of general purpose distribution systems which can supply power to a number of users from a single central source. In addition to its impact on logistics, correction of the present deficiency will reduce noise and extend the life of small tactical generators by reducing reliance on them to those occasions when no other source is available, or as back-up in the event of a power conditioner failing. It should also eliminate the existing problem of not being able to operate U.S. forces equipment with equipment of other nations due to differences in voltage and frequency.

Figure 1 contrasts a current tactical distribution scenario with a future distribution scenario representing Delco's approach to solving the problem. This concept evolved from close interchange between our power systems engineers and tri-service users. This integrated system approach draws upon current and evolving technology in the areas of solid state power, micro-processor/computers, optical link data exchange and CRT display. The resultant distribution network provides fuel or energy management through centralized power source and load control, plus rapid deployment/high mobility via local center disconnect and control features.

The upper table in Figure 1 indicates, for various applications, the potential for reducing both the equipment complement and the operating costs accruing from the use of standardized power distribution networks and power conditioners. The existing mode tactical field data (applications 1 through 6) were taken from a BDM Corporation study "Evaluation of Tactical Electric Power Distribution Systems" submitted to the Army Mobility Equipment Research and Development Command (MERADCOM). Fixed site data (applications 7 and 8) were taken from USAF Missile Weapon System data available at Delco and information provided through the DOD Project Manager for Mobile Electric Power (PMMEP).

The lower table in Figure 1 illustrates the potential for extending operating life of small tactical generators since a very high percentage of these units are not required during standard network operation. This greatly enhances the availability of these engine generators for stand-alone operation when they

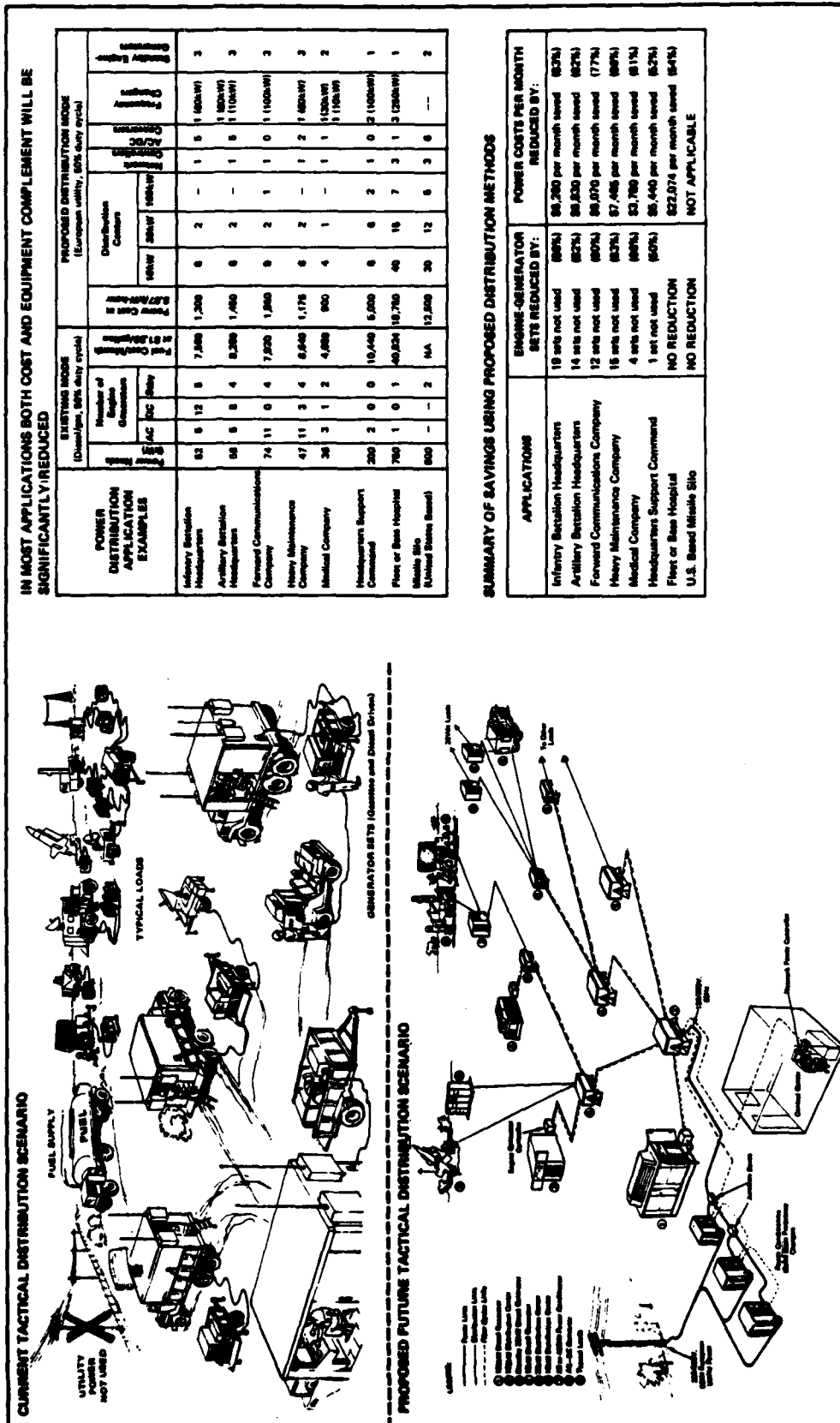


Figure 1. Distribution Scenarios — Solid State Conversion and Distribution Reduces Cost and Dependence on Engine Generator Sets

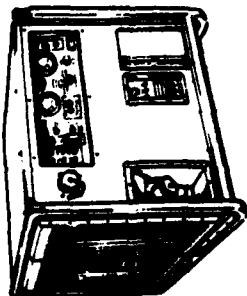
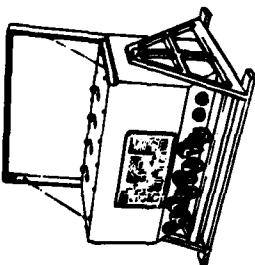
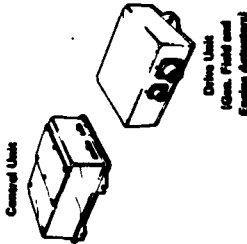
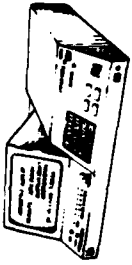
POWER CONDITIONERS  KEY FEATURES • Utility U.S. and European or dc voltage inputs • Input Line Current, THD < 3% • Microprocessor/optical link interface • Diagnostics and fault monitor • Lightweight, rugged units. DEVELOPMENT STATUS • Delta 10kW Inverter in field use • Army "Freelander" (DAAK79-79-C-0001) • Delta/Army 25kW Converter (DAAK79-77-C-0034) • Delta/Army 18kW Frequency Converter (DAAK79-77-C-0107) ADDITIONAL DEVELOPMENT REQUIRED • Microprocessor/optical link interface • Diagnostics/fault monitor • Adapt for field use.	DISTRIBUTION CENTERS  KEY FEATURES • Microprocessor/optical link interface • Remote or local control of centers • Rapid couple/decouple to network • Standard cables and connectors • Dual power frequency operation (60 or 400 hertz). DEVELOPMENT STATUS • USMC built prototypes (1975-1979) • 16/30/100kW centers manual control • Rugged, field-tested cables and centers. ADDITIONAL DEVELOPMENT REQUIRED • Microprocessor/optical link interface • Remote and local control • Dual power frequency operation (60 or 400 hertz) • Adapt for field use.	ENGINE GENERATOR CONTROLLERS  Control Unit Drive Unit (Gen. Field and Engine Automates) KEY FEATURES • Microprocessor-based control • Remote or local control • Automatic paralleling • Diagnostics and fault monitor • Optical link data exchange • Rugged control unit. DEVELOPMENT STATUS • Navy basic development of 30kW Engine Generator Controller (1975-1981) • Delco development of Fuel Injection and Engine Controller (1980-1981). ADDITIONAL DEVELOPMENT REQUIRED • Incorporate paralleling controls • Adapt microprocessor-based controls • Network interfaces • Adapt for field use.	NETWORK CONTROLLERS  KEY FEATURES • Microprocessor based control • "Touch screen" interface with sources and load centers • Diagnostics and fault monitor • Optical link data exchange • Compact, rugged unit. DEVELOPMENT STATUS • Conceptual design and layout (Delco IR&D, 1980 and 1981) • Delco demonstration of "touch screen" control in autos (1980 and 1981). ADDITIONAL DEVELOPMENT REQUIRED • Controller software • Integrate with optical link • Integration and demonstration with net-work elements. • Adapt for field use.	FIBER OPTIC LINKS  KEY FEATURES • Low loss, wide bandwidth • Secure data transmission • No reflection/low susceptibility • Rugged and lightweight. DEVELOPMENT STATUS • Standard fiber cables available • Optical drivers/sensors available. ADDITIONAL DEVELOPMENT REQUIRED • Develop control interfaces • Network interface/test • Adapt to field use.

Figure 2. Power Network Building Blocks -- Required for a Systems Approach to Satisfying Total Tactical Power Needs

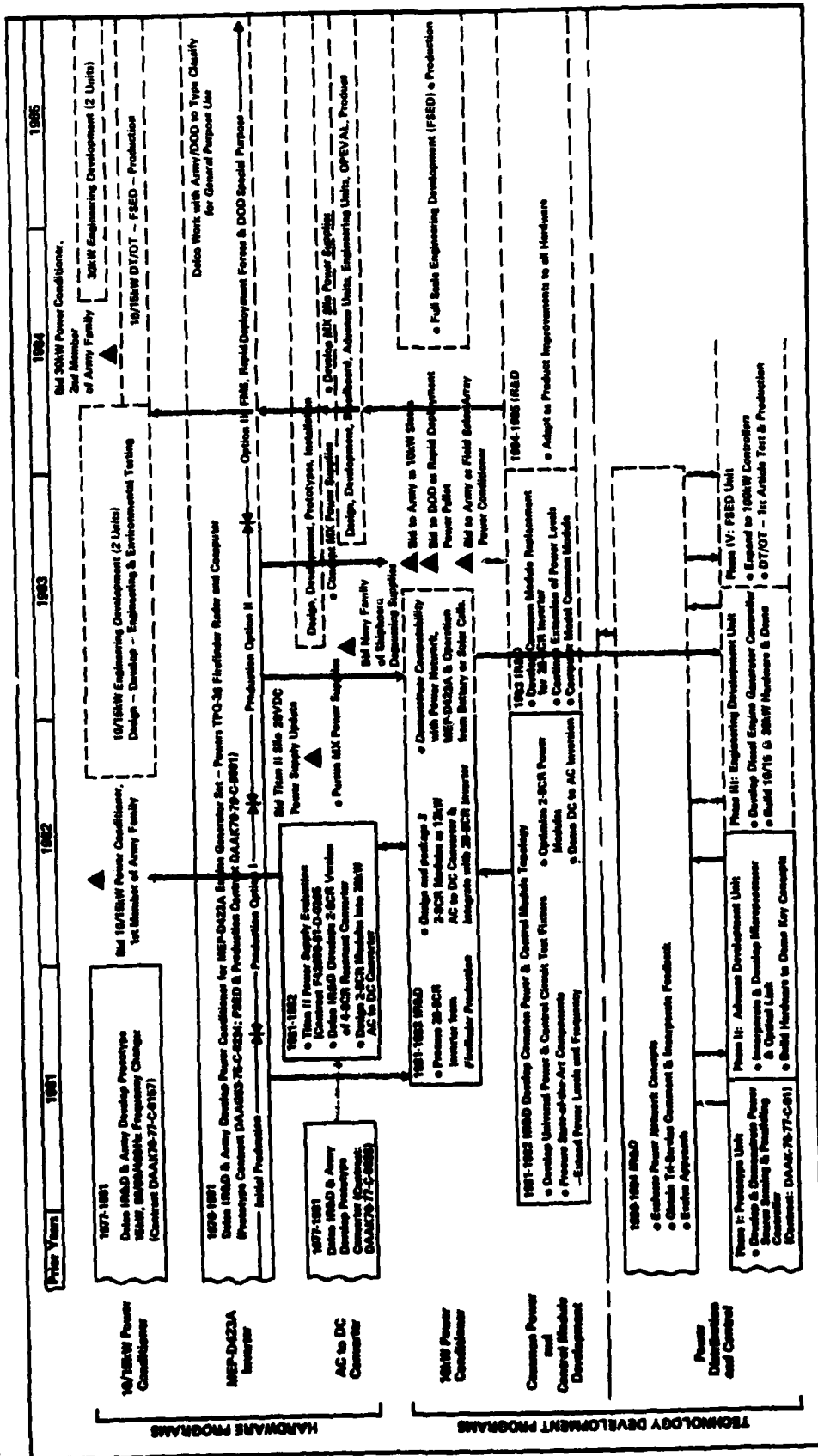


Figure 3. Overall Program Plan

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are needed for combat or training exercises (less than 20% of time). The power cost reduction data was based upon 1981 costs of fuel and electricity in Southern Germany. Assuming continuation of present trends, these figures will reflect even more favorably upon use of local utilities to power standard distribution networks in the future.

OBJECTIVE

Overall Objective

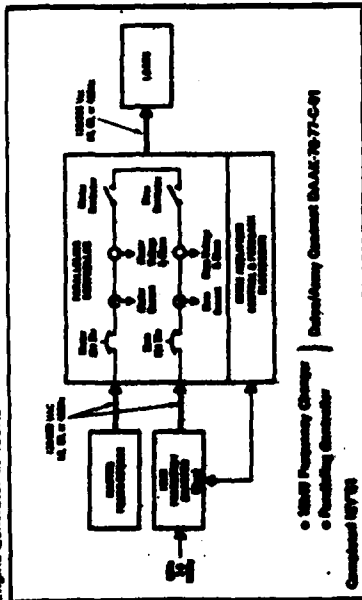
The overall objective is to achieve circuit commonality among various types of power conditioners and to develop a standard power distribution system that can interconnect, monitor and control tactical power generators and loads. The required power distribution network design must provide efficient direction of power from a primary source to various loads, and provide capability for quickly adding or deleting alternate power sources or loads to the network. Delco's modern distribution network scheme is capable of meeting these needs through development and integration of the necessary distribution network building blocks. Figure 2 shows key features and development status of each network element. Additional development required is primarily concerned with adapting the demonstrated technology to a specific application and carrying it forward to tactical field use. Integration of microprocessor and optical link technology into any system requires detailed knowledge of overall requirements before proceeding with the extensive software development to effectively adapt the proven hardware items. Therefore, an important objective is to obtain tri-service user agreement and system specification for a DOD standard network.

MY82 Objectives

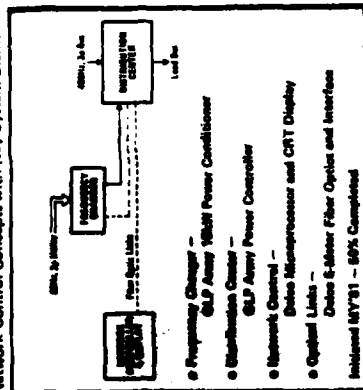
Objectives for MY82 are to:

1. Demonstrate the feasibility of the Delco distribution network concept as the basis for obtaining Government funding for a follow-on Engineering Development Phase. The feasibility demonstration effort was initiated in MY81; the associated hardware/ software development will be completed in MY82. In August 1981 through a Government Loan Agreement, the Army provided Delco with 15 kW power conditioner and power controller hardware for use in the MY82 demonstration.

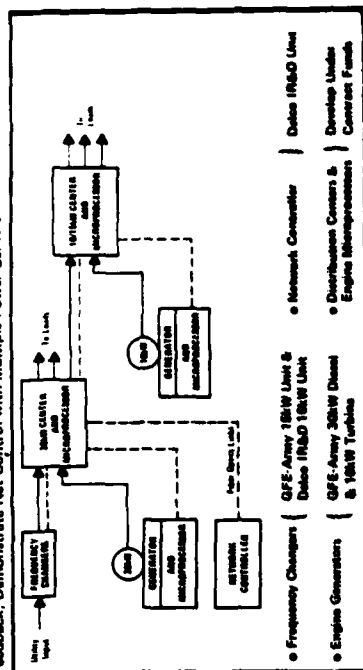
Phase I Prototype—Demonstrate Paralleling with Utility at 60Hz and with Engine Generator at 400Hz



Phase II Advanced Development Unit—Demonstrate Network Control Concepts with Key System Elements



Phase III Engineering Development Unit -- Based on Analytical Evaluation and Tri Service Feedback. Demonstrates Net Control with Multiple Power Centers



Between IV: Full Scale Evaluation Dashboard Model—Demonstrate Net Control and Orientation in a Scenario Embodying all the Salient Features Anticipated in a Typical Tactical Situation

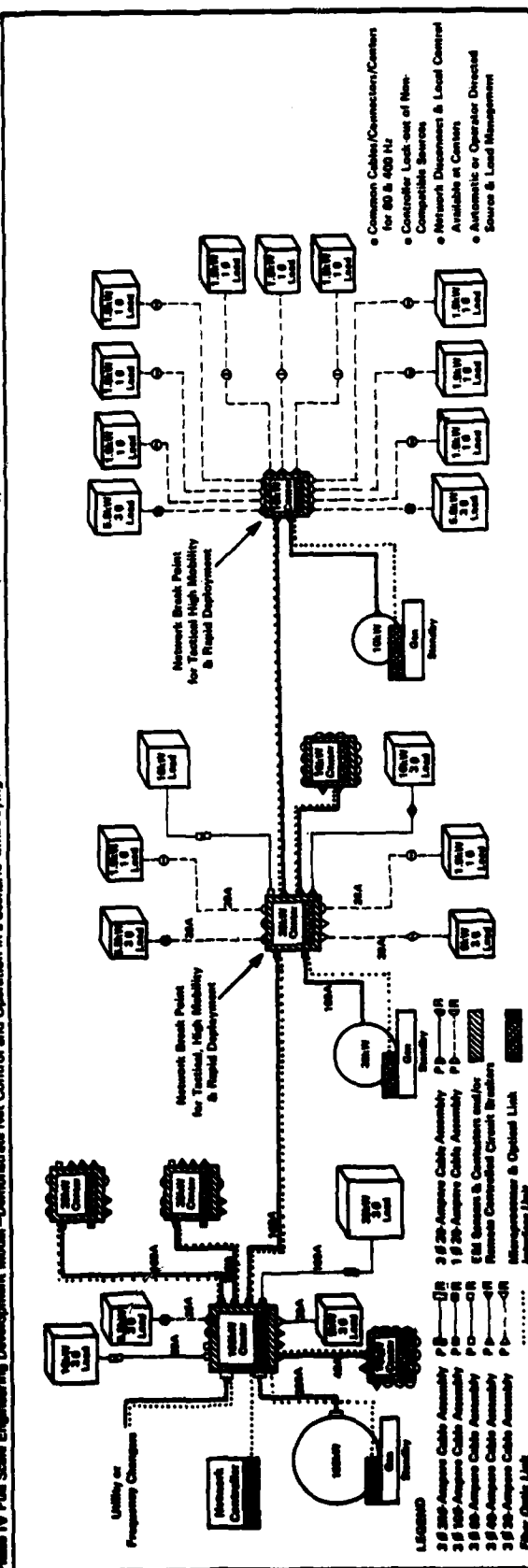


Figure 4. Power Distribution Network Demonstration Evolution Plan

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2. As part of the continuing effort, started in 1981, develop common power and control modules and demonstrate a six kilowatt, 2-SCR common module which operates at frequencies up to 16 kHz. The common control circuit under development will allow the new module to function as part of an ac-to-dc converter or dc-to-ac precision sinewave inverter and be applicable to various types of power conditioners or power levels.
3. Demonstrate commonality features by adapting the new common module to a 10 kW frequency changer. The new unit will integrate an Army 28-SCR Firefinder production inverter with three 2-SCR common module converters.

Our detailed approach for achieving these objectives is described in the following section.

APPROACH

Delco's overall five year development plan for solid state power is shown in Figure 3. The upper section shows an overview of Government hardware programs in process or planned, and how Delco IR&D effort has focused on these production efforts. The lower sections shows how current Delco technology development is directed toward the Objectives stated. The overall thrust is toward yearly technology advances, coupled into hardware programs, both to support competitive bidding activity and to provide product improvement in power systems production programs.

Power Distribution

To demonstrate power distribution network control, Delco will utilize the advanced, proven technology developed for GM automotive use, plus procedures and design techniques developed to provide environmental protection, high reliability, ruggedness, and ease of use. Every GM domestic passenger car since 1981 has at least one sophisticated microcomputer for engine control and as many as four more for controlling operator displays and comfort, convenience, and entertainment functions. Current microcomputer production rates of over 20,000 units per day make Delco the world's largest manufacturer of small computers.

The automobile environment is comparable to the tactical field environment. EMI and power bus transient requirements exceed MIL-STD-461, and exposure to temperature cycles and extremes, vibration and shock, fuels, coolants, solvents, and water are normal occurrences. Control and display operator interfaces have to be rugged, tolerant of abuse, and (most importantly) easy to use and understand by untrained operators. Extensive built-in-test and continuously running diagnostics are essential for the service of these sophisticated microcomputers by relatively untrained service technicians. Major emerging automotive technologies to be used to demonstrate the concept of power network control include:

- Microcomputers - Eight-bit microprocessors based on the Motorola 6800 family, and 16-bit microprocessors based on the Intel 8086 family with attendant memory, A/D, and I/O chips; system configurations employing distributed processing and co-processing serial communications techniques.
- Fiber Optics - Communication links to route multiplexed serial data between microcomputers and systems; high data rate, EMI-proof, rugged, low cost.
- "Touch Screen CRT" - Simple, compact means to eliminate all mechanical switches and controls and dedicated individual displays; all displays and control functions combined in a ruggedized small screen CRT with a touch sensitive face; totally flexible display format of alphanumerics and graphics; self-prompting, easy to understand presentation formats.
- "Hardened Design Techniques" - Specific circuit and system designs address EMI/RFI, fail-safe, fail-soft with backup, hardware and software self-test, and constantly running system diagnostics.

Figure 4 illustrates the phased approach being taken to achieve the stated Objective, to provide a standard network required by DOD, as described in the problem statement.

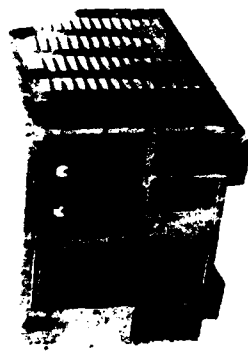
Phase I (1980-1981). The MY80 IR&D results led to an added scope item to a Delco/Army 15 kW Frequency Changer Development Contract to demonstrate the capability of paralleling the unit with 60 Hz, 3-phase utility or 400 Hz, 3-phase engine generators (60 kW, EMU-30). This effort proved the sensing and control circuit concepts and resulted in a Government loan of developmental items for Delco's IR&D distribution network Phase II effort.

Phase II (1981-1982). Advanced Development Unit hardware design and fabrication began late in MY81 after securing tri-service user feedback and the Government loaned property (GLP) agreement. Based on government user review comments, the network functions were expanded to include remote control of load circuit breakers (or contactors) and control of engine generators. The updated concept incorporates microcomputers in the main controller, the distribution centers, and onboard each controlled power source. These elements are controlled via interconnecting fiber optic data links. This year's approach is to continue fabrication of Phase II hardware: the network controller (CRT display and microcomputer), the microcomputers to control the GLP, and the optical link interfaces. Software development will continue and culminate in a feasibility demonstration of the network control concepts.

Phase III (1982-1983). Engineering Development Unit hardware planning anticipates that Government contract funds will be obtained to fabricate and demonstrate deliverable distribution network items. The main technology approach during Phase III requires adaptation of microprocessor/computer control to the expanded power network. This effort would be an outgrowth of work at NAEC (Lakehurst, NJ) which demonstrated the application of microprocessor based control to a DoD standard engine generator to provide MIL-STD-704C level power. The achievements of the Lakehurst NJ group will be extended to include precise speed control of engine generators so that automatic paralleling and power transfer may be demonstrated with these sources. The Phase III effort will demonstrate network control of multiple power sources and distribution centers.

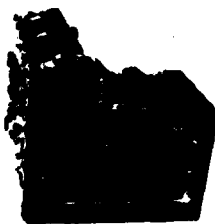
Phase IV (1983-1984). Full Scale Engineering Development (FSED) could closely follow a successful Phase III effort. The approach Delco proposes makes use of

THE NEW FREQUENCY CHANGER PROTOTYPE COMBINED BOTH CONVERTER AND INVERTER FUNCTIONS AND PROVIDES THE TECHNOLOGY BASE FOR OUR NEXT MAJOR IR & D THRUST...



Delco IR&D and Army developed prototype 18kW, 60/60/400Hz Frequency Changer (Contract DAAK-70-77-C-01) that embodied both inverter and converter technology.

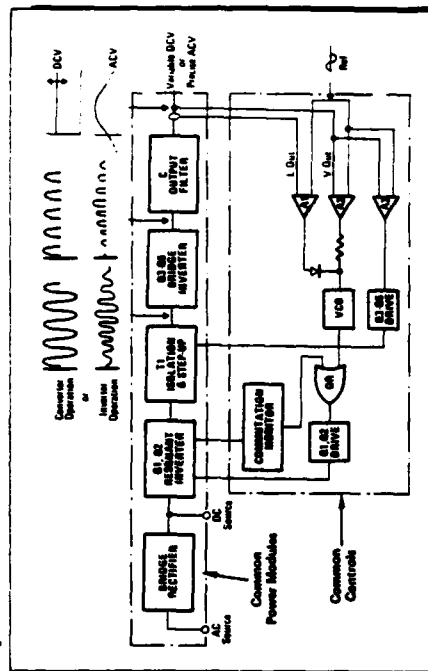
TECHNOLOGY TRANSFER



Delco IR&D and Army developed prototype 12-SCR Converter (Contract DAAK-70-77-C-0000).
Input - 120/208V, 60/60Hz
Output - 0 to 280Vdc, 280W at 280Vdc
Line Current Harmonics (THD) - < 3 percent
Volume - 3 cubic feet
Weight - 175 pounds

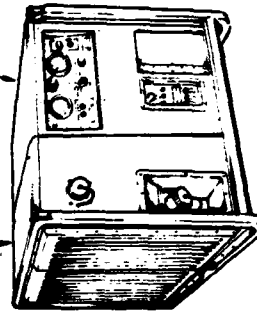
Delco IR&D and Army developed MSP-Q422A 28-SCR Inverter prototype (Contract DAAK-70-77-C-0234) and production (Contract DAAK-70-77-C-0001).
Input - 120V, 60, 1,800Hz, variable engine generator
Output - 120/208V, 400Hz
Volume - 3 cubic feet
Weight - 160 pounds

...A COMMON TOPOLOGY FOR ALL CONVERTER/INVERTER POWER CONDITIONER DESIGNS...



...WHICH WILL PROVIDE THE FIRST STEP TOWARDS ACHIEVING MODULAR COMMONALITY VIA A RECONFIGURED CONVERTER IN A 10kW POWER CONDITIONER...

New 8-SCR Converter 28-SCR Production Inverter



10kW Power Conditioner
Input - 220/360V, 50Hz, 240/418V, 60Hz, or 400Vdc
Output - 120/208V, 400Hz, 10kW, 0.8pf
Line Current Harmonics (THD) - < 3 percent
Volume - 10 cubic feet
Weight - 360 pounds

...IN 1983, A COMMON MODULE REPLACEMENT FOR DELCO'S 28-SCR INVERTER.

10/18kW POWER CONDITIONER COMPETITIVE DESIGNS

KEY PARAMETERS	Army Qualification	Delco Prototype	Westinghouse Converter	Westinghouse Inverter	Delco Power Conditioner
Weight	821 lbs	618 lbs	1,200 lbs	472 lbs	11 N ³
Volume	14 ft ³	12 ft ³	28 ft ³	11 ft ³	11 N ³
Output	100kW/400Hz	100kW/400Hz	400Hz only	400Hz only	400Hz only
Frequency	100/60/400Hz	100/60/400Hz	400Hz only	400Hz only	400Hz only
Line Current Harmonics (THD)	< 5%	< 3%	< 3%	< 3%	< 3%
Efficiency	> 80%	> 79%	> 81%	> 82%	> 82%
MTBF	1,500h	3,015h	5,010h	3,500h	5,000h
Number of Power Modules	...	40 SCR's	60 SCR's	56 SCR's	24 SCR's

Figure 5. Power Conditioner Evolution - The Ultimate Goal is a Common Circuit Topology for Power Conditioners of Any Size

existing MEPDIS cable designs and use of common distribution centers, engine generator controls and network controllers for either 60 Hz or 400 Hz distribution systems. Power conditioners (frequency changers) presently being specified for Army development must provide multiple output frequencies and could contain the necessary microcomputers for interface with the DoD standard distribution network.

Power Conditioning

Through IR&D and contract supported effort Delco is providing concepts, prototype units and production hardware aimed at meeting the stated DoD need for power conditioner units. The approach is to build upon previously demonstrated achievements while working closely with user agencies to compose specifications that reflect state-of-the-art developments in the solid state power field. Figure 5 illustrates this evolutionary approach, the basis for our 1981-1982 objective of achieving commonality through a common module.

The power conditioner for MEP-D423A (Figure 5) helped satisfy an urgent need for a very light weight generator to power the Army's TPQ-36 mortar locating radar. Although the inverter uses 28 identical SCR's, the approach does not result in internal power module commonality. The 12-SCR converter shown made tremendous advances in achieving low input line current THD at very light weight, and great strides in providing power module commonality. Three identical 4-SCR converters are used (one per input phase) and the SCR's are common to those in the 28-SCR inverter.

The 28-SCR inverter concept and 12-SCR converter were combined as a prototype 15 kW, 60/400 Hz frequency changer. The importance of this integration is reflected in the Army's New Purchase description for a 10/15 kW Power Conditioner being released for competitive bid as the first member in an Army "Family of Power Conditioners". Key parameters of the new specification are shown in the table of Figure 5 which compares those competing designs known to have addressed the difficult harmonic current THD requirement. The comparison shows a Delco weight advantage and lower power switch device count.

Delco's present high SCR count is due to lack of modular commonality between the inverter and converter functions. Therefore, Delco's IR&D technology thrust is toward common power modules and common control modules for both the inverter and converter functions, and a circuit topology applicable over the entire power range of interest to DoD users. The final column of the table in Figure 5 is an estimate of what can be achieved upon successful completion of the present IR&D effort.

The common module effort centers on expansion of previous Delco resonant converter designs to include the functions shown in the block diagram of Figure 5. The power circuit has a high frequency resonant inverter (SCR's Q_1 and Q_2) operating in a PFM mode to produce the waveforms shown at the output of the high frequency transformer, T_1 . A bridge inverter (SCR's Q_3 through Q_6) operates as a 60 Hz or 400 Hz demodulator of the resulting PFM/PAM wave when the common module operates as a frequency changer. A 4-diode rectifier demodulates the high frequency waveform when operating as a converter.

During MY81 Delco successfully demonstrated the 2-SCR converter operation depicted by the upper waveforms in the block diagram. This year we will concentrate on optimizing the 2-SCR common module by increasing operating frequency from 8 kHz to 16 kHz and output power from 3.5 kW to 6 kW. This will include completion of a breadboard "universal" power circuit test fixture and control and evaluation of state-of-the-art materials, components and devices in the fixture. After optimizing converter performance, the fixture will be used to demonstrate the inverter mode with the 2-SCR controls.

Upon optimizing the 2-SCR converter common module, hardware development of a 10 kW power conditioner will be initiated as a first step to demonstrating commonality and logistic benefits which accrue to the common module concept. The approach is to integrate a 6-SCR converter configuration (three 2-SCR common modules) with a 28-SCR production inverter (procured during 1981) which is presently in the Army's logistics system. The unit will further demonstrate capability to operate from U.S. and European high voltage inputs and applicability to solar cell, battery, or fuel cell dc voltage inputs. The unit will, in 1983, serve as a vehicle to demonstrate the common module replacement for Delco's present 28-SCR inverter.

MY82 Planning and Task Definition

Figure 6 shows our detailed plan for MY82 in the form of a Summary Task Table. This table provides an expansion of the previously stated Objectives, detailed task structure, technical approach, work efforts/methods/special items required, and anticipated results of each task. It also serves as an evaluation tool for assessment of Delco's plans, objectives, approach and allocation of resources (skills and time span) to MY82 Power Distribution and Control, Common Module Development and Power Conditioner Development.

PROGRESS

Power Distribution

The Phase II Advanced Development Unit Demonstration effort was not initiated until late in MY81. Before release of funds for the feasibility demonstration hardware, Delco met a related technology contractual commitment to the Army to develop and demonstrate a paralleling controller for the prototype 15 kW power conditioner unit. This goal was completed via a sell-off demonstration to MERADCOM in January 1981 and submission of the final report in March 1981.

From September 1980 to March 1981, Delco continued its military needs analysis and interface with tri-service users to establish the viability of our power distribution concepts and the potential for Government funded follow-on. Success with the paralleling controller, coupled with favorable user community comment, led to a Delco management decision to proceed with the proposed MY81 effort in June 1981.

In this manner, the original MY81 effort was shifted to encompass the last three months of MY81 and first five months of MY82. The Phase II effort required approximately the same total manpower and resource commitments as originally planned.

The summary progress table in Figure 7 shows the progress made during the last three months of MY81. The controller concept has been detailed and laboratory model has been built which will be used to test "status display" and "control" scenarios. Figure 8 presents an example of a typical network scenario.

AREA	ISS OBJECTIVES	TASKS REQUIRED TO ACHIEVE OBJECTIVES	GENERAL APPROACH	INPUTS REQUIRED	PROCESS OR METHOD	OUTPUTS EXPECTED	SPECIAL EQUIPMENT/CAPABILITIES REQUIRED	REQUIRED SKILLS/TIME	RELATIONSHIP TO OTHER TASKS
POWER DISTRIBUTION HARDWARE AND FEASIBILITY DEMONSTRATION	Complete Demonstration Hardware	Integrate Delco "switch screen" CRT hardware into the controller.	Review interface requirements and adapt as needed.	• CRT hardware • Design drawings, schematics, and specifications.	• Analyze electrical interfaces • Design adaptive connections • Fabrication and checkout.	Highly flexible, easy to use operator display and control unit.	Delco "switch screen" CRT and documentation from other Delco programs.	Engineering, 0.5mm Strip, 0.2mm 1.5 month span time Sep 81 through mid-Oct 81	Integrated CRT and controls used in all tasks below.
	Complete Control and Display Software	• Complete fiber optics communications software • Develop display, operator interface, and distribution control software.	• Analyze data and rate transfer and incorporate • Adapt Delco CRT display software to new requirements and expand existing algorithms.	• Communications detail requirements from 1081 effort • Basic Delco CRT display software • New expanded control and display specifications.	• Adapt previous protocol and signal conventions to increased rates • Iterative modify and checkout approach to expanding existing software to meet needs.	• Solid foundation for expansion of fiber optics links to total system • Power system remote control, data acquisition and diagnosis software adaptable to any expanding network requirements.	• Communications software from 1081 • Purchased optics and interface electronics • Previous Delco-developed software • Detailed system requirements • Microcomputer compatible logic analyzer (HP1611).	Engineering, 1.5mm 2.0 month span time Sep 81 through Oct 81	Checked out software used in all tasks below.
	Integrate Control Hardware with GLP Power Equipment	• Checkout of controller elements in Power Lab • Complete integration of communications distribution network.	• Power Lab bench setup and test of controller • Integrate with GLP power conditioner and distribution center.	• Controller hardware and software • Power equipment interface definition • Checkout and test plan.	• Use Power Lab equipment to simulate GLP for initial checks • Move to actual GLP units at low volts and power • Advance to full voltage and power.	• Integrated and functional power distribution controller system • Checkout and refined control algorithms.	Delco Power Lab facilities and test equipment compatible logic analyzer (HP1611)	Engineering, 2.0mm Technician, 1.5 mm 2.0 month span time Late Oct 81 through Nov 81	Integration and checkout of requirements for task listed below.
	Field System Evaluation and Demonstration	• Estimate system performance • Demonstrate performance.	• Conduct system level tests • Tri-Service user demonstration at Delco.	• Complete and checkout system • System test plan • Demonstration plan.	• Perform system test using both utility, 400 hertz motor generator and GLP 15kV frequency changer. • Provide technical briefing and demonstration.	• Detailed performance data • Achieve Government-funded follow-on.	Special equipment and capabilities as listed in task above.	Engineering, 1.0mm Technician, 0.5 mm 2.0 month span time Dec 81 through Jan 82	Results and feedback needed for task listed below.
	Provide Final Report	• Data collection • Technical evaluation • Establish follow-on system specification.	• Analysis of data and review comments • Assemble, summarize, and record.	• Design data • Test data • Review inputs • Tri-service system specification comments.	• Engineering and system analysis • Delco management review • Tri-Service review.	• Final report • Basis for follow on Government funding.	Special equipment and capabilities as listed in task above.	Engineering, 0.5mm 1.0 month span time January 82	Basis for Government funded follow-on work

Figure 6 (Sheet 1 of 3). Summary Task Table

1982 OBJECTIVES	TASKS REQUIRED TO ACHIEVE OBJECTIVES	GENERAL APPROACH	INPUTS REQUIRED	PROCESS OR METHOD	OUTPUTS EXPECTED	SPECIAL EQUIPMENT/ CAPABILITIES REQUIRED	REQUIRED SKILLS/TIME	RELATIONSHIP TO OTHER TASKS
Select Power Components, Connect, and Materials	Evaluate 1981 processed state of the art devices/materials.	Validate supplier specification	- Data sheets and/or supplier specifications - Supplier's test methods and procedures - Test set-up and plan - Designs for fabricated components.	- Electrical/thermal test and measure - Fabricate and test special components - Correlation to specification.	Selection of components and devices for use at high voltage, high power, and high frequency	- State of the art items from 1981 - Delco's Power Lab. fixtures, test equipment and talent.	Engineering, 0.5mm Technician, 0.3mm 3 month time span from Sep through Nov 81.	Select, tested devices and components used in all tasks listed below
Complete Universal Power and Control Circuit Test Fixtures	- Incorporate power circuit magnetics - Add control circuit error amplifiers.	Integrate laboratory bread-board magnetics and error amplifiers with 1981 fixtures.	- Inductor and transformer specifications - Detailed magnetics designs - Error amplifier input/output specifications - Detailed circuit design.	- Technician—build; engineer—evaluate magnetics - Technician—build; engineer—evaluate CCA's - Technician—integrate with 1981 fixture - Engineering—check-out.	- Low density, well-cooled universal power circuit fixture - Universal control circuit card file with PWM, card edge connector CCA's.	- Techniques to minimize stray L's - Litz wire fabrication techniques.	Engineering, 0.5mm Technician, 2.2mm Shop, 0.2mm 2 month time span from Sep through October 81.	- Incorporate the state of the art tested components (above) - Provides functional power circuit fixture and controls for all tasks listed below.
Optimize 2-SCR Converter Module	- Develop high voltage input circuit - Double the operating frequency of module - Double the DCV output power.	Incorporate state-of-the-art power devices and materials.	- Tested state-of-the-art devices and materials - High voltage power circuit design - Detailed circuit and component design iterations.	- Iterative test and modify process - Empirical design made to reduce stray inductance - Measure and record thermal and electrical data.	- Breadboard of 2 SCR converter and controls: - Input: 380 or 416Vdc single ϕ, or 400Vdc - Output: 300Vdc, 0 to 20 amper, 8kW - Efficiency: > 83% - Power module frequency: to 18kHz - Line 1 THD: < 3%	- Universal test fixture 2-SCR design from 1981 - Knowledge of high power frequency techniques.	Engineering, 1.5mm Technician, 1.0mm 2.5 month time span: from Nov 81 through mid Jan 82 \$18,400, material	- Incorporate the state of the art tested components (above) - Provides basic common module approach for all tasks listed below and 10kW power condenser build.
Demonstrate DC-to-AC Inverter	- Develop required mode to converter power circuit - Develop inverter control circuits - Integrate and test.	Modify 2-SCR converter module and controls to provide inversion.	- Design mode to power and controls from ac-to-dc converter - Amplitude/phase ref circuit design and CCA layout 4-SCR demodulator and filter control/power circuit designs and layouts - Energy return circuit and controls—designs and layouts.	- Technician—build; engineer—test; evaluation of designs - Technician—integration; engineer—evaluate system - Iterative test and modify demodulator and energy return control and power circuits.	- Breadboard of 2 SCR inverter and controls: - Power demodulator and output filter - DC to 120Vdc, 80 or 400Hz - Specifications and designs for energy return circuits.	- Universal test fixture - Delco-developed SCR monitor and protection circuit designs.	Engineering, 3.0mm Technician, 3.0mm Shop, 1.0mm 5 month time span: from Jan 82 through May 82.	- Incorporate the state of the art tested components (above) - Utilizes Universal Power Test Fixture and controls - Mechanical and thermal inputs directly relate to the task listed below
Integrate Converter and Inverter Functions	- Develop common power circuit module - Develop common control circuits - Develop mechanical and thermal design - Fabricate, integrate, and test.	Expand and modify above converter and inverter bread-board designs.	- Design mode to converter and inverter control circuits - Output demodulation and rectifier designs - Common High frequency module design. - Energy return, circuit design.	- Technician—build; engineer—test; evaluation of designs - Technician—integration; engineer—evaluate system - Iterative test and modify.	- Breadboard of 2 SCR common power module/controls: - Input: 380 or 416Vdc single ϕ, or 400Vdc - Output: 120Vdc, 14 or 300Vdc at 8kW - Efficiency: > 80% - Power module frequency: to 18kHz - Line 1 THD: < 3%	- Modified universal power module fixtures - Modified universal card file and control circuit card assemblies.	Engineering, 1.0mm Technician, 2.0mm Shop, 0.2mm 3 month time span: from May 82 through Jul 82.	Lays essential ground work for 1983 R&D

Figure 6 (Sheet 2 of 3). Summary Task Table

10kW POWER CONDITIONER DEMONSTRATION HARDWARE								
1982 OBJECTIVES	TASKS REQUIRED TO ACHIEVE OBJECTIVES	GENERAL APPROACH	INPUTS REQUIRED	PROCESS OR METHOD	OUTPUTS EXPECTED	SPECIAL EQUIPMENT/ CAPABILITIES REQUIRED	REQUIRED SKILLS/TIME	RELATIONSHIP TO OTHER TASKS
Provide Advance Development Unit 10kW Frequency Converter	System packaging design.	Extend modular packaging of prior Firefinder and 15kW Frequency Converter contracts.	- Mechanical layouts for inverter, converter, auxiliaries, and control CCA's - Monitor/display requirements - Device description - Thermal requirements.	- Thermal analysis - Iterative mechanical/electrical/thermal layout - Maintainability review - Human factors review.	- Packaging, layout, and engineering drawings - Control and display engineering drawings - Electrical and mechanical interfaces defined.	- Packaging experience of previous Delco/Army designs 28-SCR Army Firefinder Inverter built in 1981.	Engineering, 1.0mm Technician, 0.5mm Shop, 2 month time span: from mid-Nov 81 through mid-Jan 82	Results essential to all tasks outlined below.
Demonstrate Integration of Converter Common Module with Existing Army 28-SCR Inverter	Develop three 2-SCR converters and controls.	Package three 2-SCR converters and controls using optimized design from common module development task.	- Packaging constraints - Power circuit design updates - Control circuit design updates - Tested components.	- Engineering design - Technician-build; engineering-evaluation of components and modules and CCA's - Technician-integrate; engineering-checkout three converters and controls.	- Three 2-SCR converter modules and controls: - Input: 280 or 418Vdc 3%, or 400Vdc - Output: 300Vdc, 0 to 40 amp, 121kW - Efficiency: > 80% - Line THD: < 2%	2-SCR design from 1981 - Design updates from 2-SCR optimization task.	Engineering, 1.5mm Technician, 1.0mm Shop, 0.5mm Shop, 2.5 month time span: from mid-Dec 81 through Feb 82.	Converter used in final system integration.
Demonstrate Evolution of Advance Power System using Existing Army Logistic Items	Develop system controls and auxiliary supplies.	Update Delco/Army 15kW Frequency Converter controls and auxiliary supply design.	- Control and circuit design modifications - Communication supply design modifications - Low voltage supply modifications - Mechanical design layouts.	- Engineering-design modifications - Technician-build; engineering-evaluate supplies and circuit card assemblies - Technician-integration; engineering-checkout.	- Modular packages of all low level and auxiliary supplies - Control circuit card assemblies and harness - Mechanical and electrical interconnections and schematics - Engineering sketches and schematics	- Drawings and schematics from previous Delco/Army development - Army 10/15kW draft purchase descriptions and specifications.	Engineering, 1.5mm Technician, 2.0mm Shop, 0.5mm Shop, 2 month time span: from Feb 82 through Mar 82.	- Auxiliary supply modules and controls used in final system integration - Establish new control/circuit designs for Army 10/15kW power conditioner.
Incorporate New Army 10/15kW Control Specifications and Features	Fabricate, assemble and test integrated system.	Implement packaging design and layout.	- Inverter modifications to 28-SCR inverter - Finalize electrical and mechanical drawings - System harness and interconnect design - Control/display design and wire layout - Fan/filter design and wire layout - Test plan and procedure.	- Engineering design - Technician-build; engineering-evaluate subsystem - Technician-integration; engineering-checkout - Technician and engineering system.	- Advance Development Unit 10kW Frequency Converter - Input: 280 or 418Vdc 3%, or 400Vdc - Output: 120/208Vdc, 400Hz, 101kW - Efficiency: > 82% - Line THD: < 3% - Parts and module common to present Army Logistics System.	28-SCR Army Firefinder Inverter 2-SCR common module converter - Common module control circuits design - Parts and modules common to present Army Logistics System.	Engineering, 1.0mm Technician, 2.5mm Shop, 0.5mm Shop, 3 month time span: from Apr 82 through Jun 82.	- Provides Delco 1980 Unit for 1983 demonstration of: - Solar cell input - No-break and battery input - Fuel cell input - Paralleling demonstration with Delco/Army 15kW unit - Integration and demonstration with Power Distribution Network Engineering Development Unit.

Figure 6 (Sheet 3 of 3). Summary Task Table

Power Conditioning

In MY81 significant progress was made in common power module and common control module development which benefited greatly from a General Motors Corporation solid state power program initiated at Delco during the year. The GMC program centered around developing a 2-SCR converter to charge the high voltage battery of developmental electric automobiles. Success to date in that program makes it unnecessary to optimize 4-SCR converter modules as originally planned for MY81 IR&D. The GMC effort also resulted in a new passive input line current harmonic reduction technique (Figure 9) which will be applied to future military power conditioners applications. This new technique offers several advantages over traditional approaches, including:

- Improved power factor and power utilization
- Greater converter efficiency
- Improved input and/or output voltage accommodation ranges
- Simple low cost mechanization
- Adaptability to active feedback and control for lower THD performance
- Adaptability to previous three-phase mechanization for performance range improvement

Initial efforts in MY81 to specify and procure state-of-the-art components, devices and materials for use in optimizing resonant converter power modules and controls made it clear that the low quantity costs would exceed the allocated material dollars, and that promised dates of delivery for critical items would preclude completion of all tasks. Therefore, a decision was made to perform necessary concept engineering to allow placement of critical item purchase orders for the planned MY82 IR&D, as well as the current year IR&D. The added design and procurement was associated with 1982 plans to optimize and to develop the integrated inverter/converter common module and to develop a 10 kW power conditioner utilizing 1981 achieved commonality concepts. The MY81 program was projected at 10 manmonths and \$8,800 for materials. For the reasons discussed above, actual expenditures were 9.2 manmonths effort and \$46,000 was committed for materials with \$32,100 being received in MY81.

AREA	1981 OBJECTIVES	TASKS REQUIRED TO ACHIEVE OBJECTIVES	TASKS INITIATED IN 1981	TASKS ACCOMPLISHED IN 1981	PLAN DEVIATION AND RATIONALE	SIGNIFICANCE OF ACCOMPLISHMENTS	SPECIAL EQUIPMENT/CAPABILITIES REQUIRED	SKILLS REQUIRED	POTENTIAL APPLICATION FOR GOVERNMENT
POWER DISTRIBUTION - MICROCOMPUTER CONTROLLER CONCEPT EVALUATION BREADBOARD	Application of microcomputer technology to centralized power distribution control.	Establish power distribution system control requirements.	- Analysis of power distribution system control approach - Review of 1980 control study report feedback and comments.	- Established initial control and performance requirements - Defined power-to-control electronic electrical interfaces - Incorporated pertinent 1980 study report review comments.	Additional time was allocated to fully interpret and appropriately incorporate all review comments of 1980 study.	Visible concept breadboard to demonstrate and to evaluate remote power distribution control techniques and associated technology.	- User feedback comments of 1980 report - Design documentation for Daco periback controller.	Engineering, 0.5 mm	
	Design and development of concept demonstration power distribution controller utilizing:	Develop microcomputer-based system mechanization.	Design of breadboard controller for concept and technology evaluation.	- Breadboard design completed for: - Remote microcomputer interface unit - Fiber optic communications link "Touch screen" CRT micro-computer control and display unit.	Task completed as per plan.	Breadboard hardware designs based on industry standard microcomputer parts and sub-assemblies compatible with standard bus structures. Daco custom "touch screen" hard-ware were directly incorporated.	Prolog standard bus micro-computer components, HP HP-81-500 fiber optic link, Daco custom "touch screen" CRT.	Engineering, 1.0 mm \$8,500, material	
	Interface microcomputer to technology to centralized power distribution control.	Develop controller display and control software.	- Definition of controller software structure, control algorithms, and data display format. - Generation of code for: - Remote unit data acquisition and power system interaction - Fiber optic link communication - Control and display.	- Established modular software structure, voltage/current, phase control algorithms, and CRT data display screens - Coding and checkout of remote unit software - Initial communication for early checkout developed.	Task initiation passed by review of 1980 study feedback comments, completion of preliminary controller contract item and negotiation of agreement for GLP hardware. Task effort began July 1981. Remainder carried over into 1982.	Modular software structure allows independent/parallel development of software modules and facilitates rapid changes with minimum coding impact during system checkout, evaluation, and refinement.	Analytical definition of control algorithms, human factors assessments of data format and display. Definition of communications protocol between controller and the remote.	Engineering, 1.2 mm	- Applicable to all tactical power networks. - Base and fleet hospitals. - Missile site power system.
	Fabricate complete breadboard power distribution controller.	Laboratory build of complete set of controller hardware.	Build (2) remote units, (2) fiber optic links, and (1) controller unit with a CRT interface.	Two remote units and two fiber optic links completed. CRT controller in progress.	- CRT controller not complete - Rationale as listed above.	Remote units and fiber optic links checked out.	Controller breadboard hardware with initial communications and display software.	Engineering, 0.2 mm Technician, 0.4 mm \$450, material	Controller and links apply to shipboard power networks.
POWER DISTRIBUTION - MICROCOMPUTER CONTROLLER CONCEPT EVALUATION BREADBOARD	Interface breadboard with Daco and GLP power equipment.	- Batch integration of controller hardware and software checkout. - Laboratory integration with power equipment and checkout. - In-house and customer demonstrations.	Batch integration of remote and fiber optic links and checkout.	Partial checkout completed.	Rescheduled to 1982 due to decision to complete preliminary contract item, market survey, review of in-service inputs and negotiate agreement for GLP 15kW unit and controller.	Controller hardware and software, GLP 15kW power conditioner and GLP periback controller unit.			
	System performance evaluation	Prepare and distribute final report.				Completion of demonstrations and review of pertinent comments.			

Figure 7 (Sheet 1 of 2). Summary Progress Table

1981 OBJECTIVES	TASKS REQUIRED TO ACHIEVE OBJECTIVES	TASKS INITIATED IN 1981	TASKS ACCOMPLISHED IN 1981	PLAN DEVIATION AND RATIONALE	SIGNIFICANCE OF ACCOMPLISHMENTS	SPECIAL EQUIPMENT/CAPABILITIES REQUIRED	SKILLS REQUIRED	POTENTIAL APPLICATION FOR GOVERNMENT
Expand 4-SCR Converter Module Capability: - Frequency to 10kHz - Power to 12kW	Specify, procure, and evaluate state-of-the-art components, devices, and materials for 1981 IR&D.	Specify and procure state-of-the-art material components and devices for 1981 IR&D. - Conceptual design and parts defined for 1982 IR&D.	Specify and place purchase orders (use 1981 receipts). - 1982 concepts specified and parts have been procured (use 1981 receipts).	• \$8.8K planned, but \$25.5K spent • Lead times and costs much greater than planned • Types and quantities were increased to cover 1982 needs • Defers evolution due to lead times.	• Good success in identifying and procuring state-of-the-art for 1981 IR&D • Conceptual designs and major parts now defined and procured for 1982 IR&D.	• Vendor data and contacts and attend • Power circuit stress analysis knowledge.	Engineering, 1.0mm Technician, 0.4mm \$25.5K, material	• Army family of power conditioners (frequency changers) • Army Standard Power Processing (Converter) Modules
Develop 2-SCR Converter Module: - Frequency to 10kHz - Power to 6kW	Design/fabricate universal resonant circuit feature. Design/fabricate demodulator/filter system.	Design/fabricate 2- and 4-SCR resonant circuit module. Design/fabricate 4-SCR or 4-diode demodulator/filter.	Design/fabrication 80 percent complete. Design/fabrication 80 percent complete.	• Resonant components L's and transformers not developed • SCR's, diodes, and CT not mounted. • Long lead precluded design, fabrication and mounting.	• A well-cooled flexible fixture • Layout for minimum stray L's.	• Experience in power circuit layout • Knowledge of stray L's and high frequency technique.	Engineering, 1.0mm Technician, 1.0mm Shop, 0.9mm	• Navy family of shipboard degaussing power supplies • Tison I/MX Sio Power Conditioners
Demonstrate DC-to-AC Inverter with Modified 2 or 4-SCR Modules	Develop ac/dc converter circuit. Develop dc/ac inverter circuit. Develop 4-SCR demodulator circuit.	Design/fabricate converter circuit. Design/fabricate inverter circuit. Design/fabricate demodulator circuit.	Design/fabrication 70 percent complete. Design/fabrication 75 percent complete. Design/fabrication 70 percent complete.	• Error amplifiers and feedback loops not designed/fabricated • Central circuit talents directed to GMC 2-SCR converter for future electric auto battery charger.	• Major control circuit card assemblies tested, meet design requirements • GMC 2-SCR battery charger controls technology transfer at no IR&D cost.	• Linear and non-linear control system expertise • Control and power circuit interface problem knowledge.	Engineering, 2.2mm Technician, 1.7mm	• Army SLEEPS (Fuel Cell) Power Conditioners • Army/Naval Solar Array Power Conditioners
	Optimize 4-SCR converter. Develop and optimize 2-SCR converter. Demonstrate dc-to-ac inverter with 2-SCR module.			• Efforts deferred to 1982 • Power Systems engineering talents and lab facilities directed to GMC 2-SCR ac/dc converter (battery charger) for the electric auto.	• Similarity of efforts provides important technology transfer at no IR&D cost • 2-SCR battery charger at 3.5kW success obviates need to optimize 4-SCR IR&D converters • Single-phase, Line 1 harmonic reduction breakthrough applies.			• Military Field and Vehicle Battery Chargers • Military welders.
Advanced 1982 Planned Effort into 1981	Develop Advanced Development Unit 10kW Frequency Converter for future IR&D and demonstrations.	Conceptual design of approach. Specify and procure long lead parts and materials.	Approach defined. Parts and materials ordered and received late 1981.	• Redirected effort planned for the above • Long lead problems dictated early release of items planned for 1982.	• Despite diversion of effort to electric auto, overall 1981 plus 1982 results benefit from technology transfer and critical parts availability.	• Procured 28-SCR inverter and controls from Finfinder production line • Resolving parts from same Army Logistics issuing.	Engineering, 0.5mm Technician, 0.5mm \$8.8K, material	• Rapid development force power pallets • Integration and demonstration with power distribution network • Parallel demonstration with Delco/Army 15kW Frequency Converter.

Figure 7 (Sheet 2 of 2). Summary Progress Table



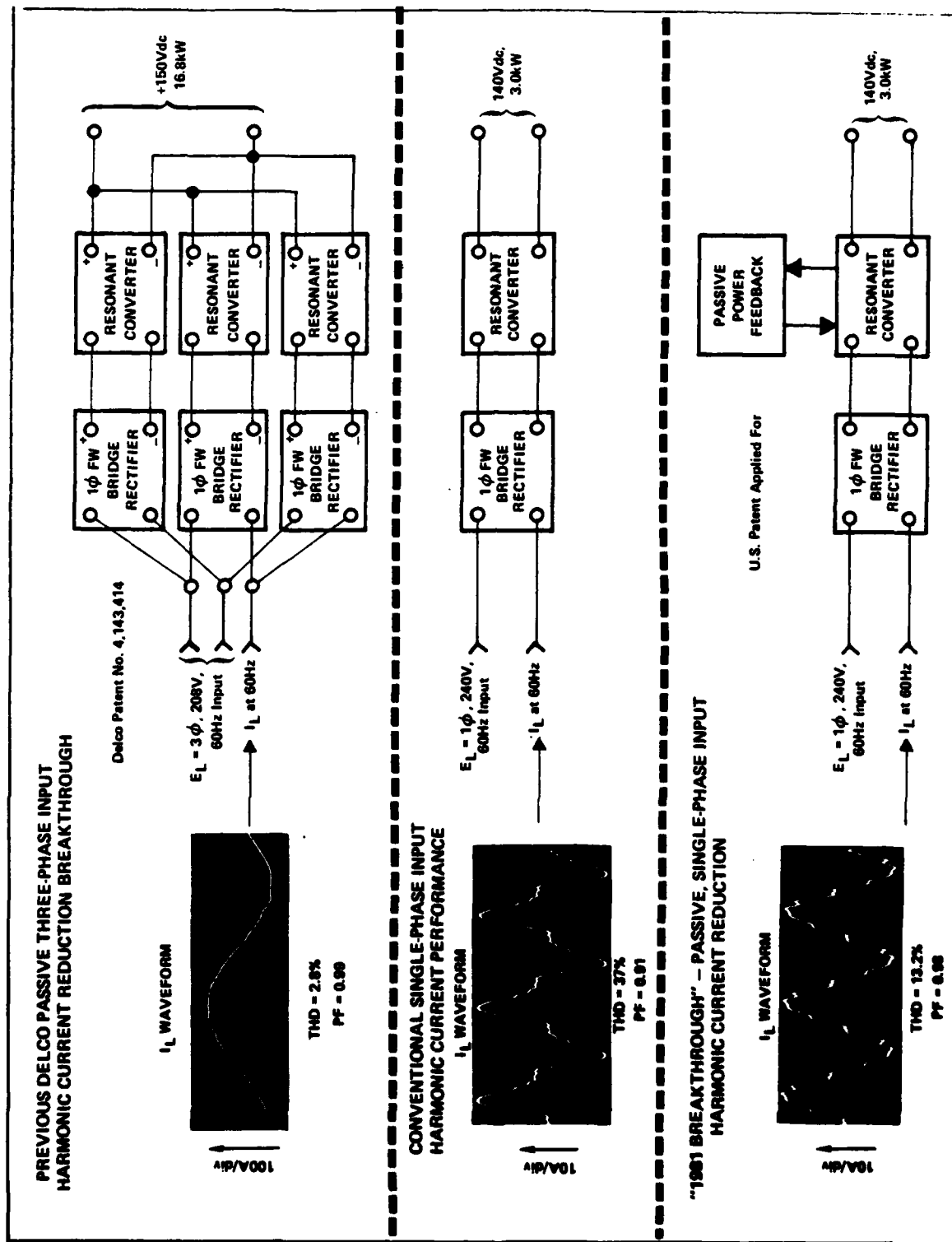
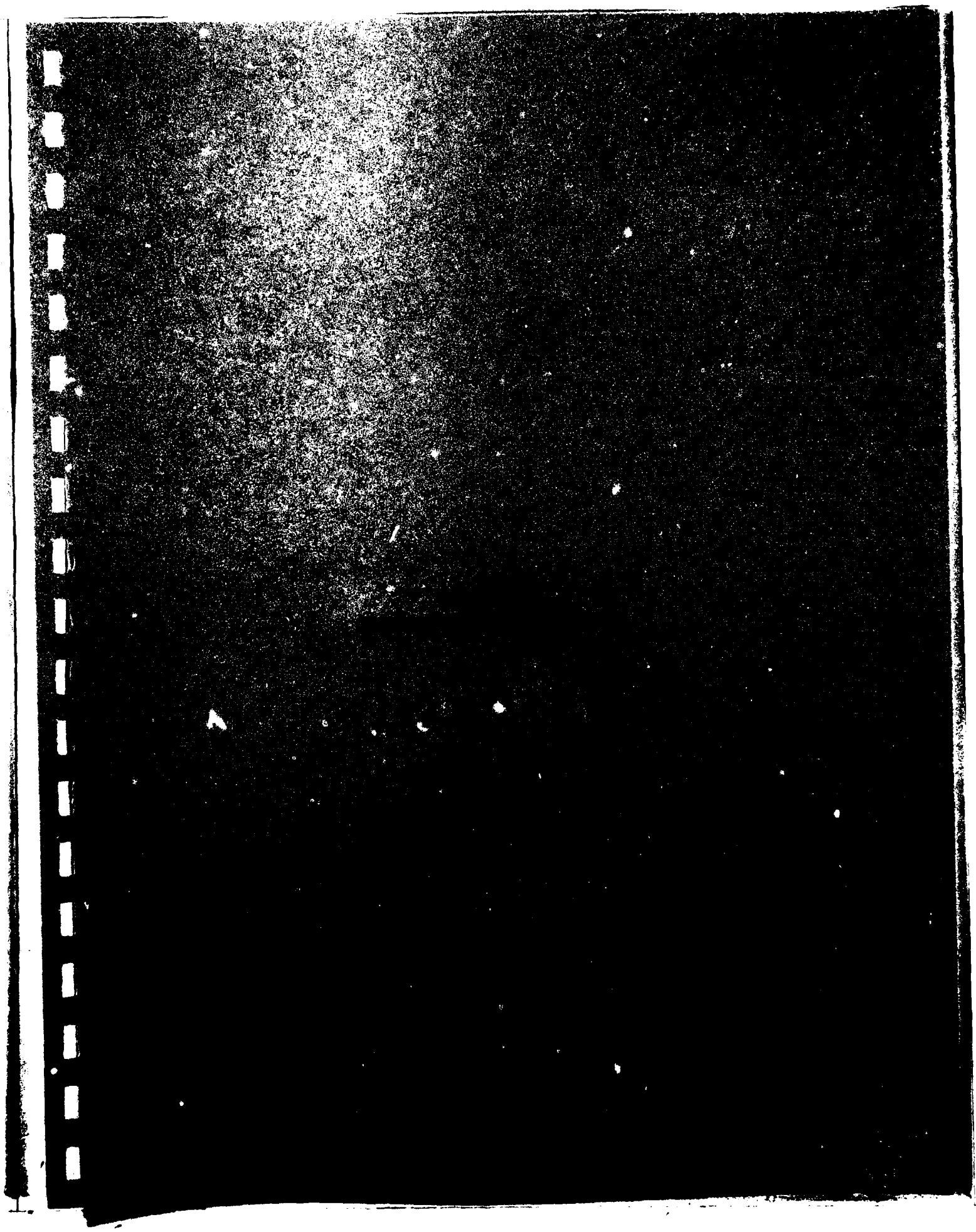


Figure 9. Delco Passive Input Harmonic Current Reduction Breakthrough



SOURCE POWER TRANSFER TESTING

This testing was performed to determine how transient free would be the transfer of power to the bus from Master to Slave and from Slave to Master. For this testing, the Master source was the 10 kW Firefinder Generator Set (MEP D423A). The Slave was the 15 kW Frequency Changer. A rapid transfer was accomplished by simultaneously throwing the Master and Slave contactor switches. There is no provision in the hardware or software to effect a rapid transfer with a single switch operation.

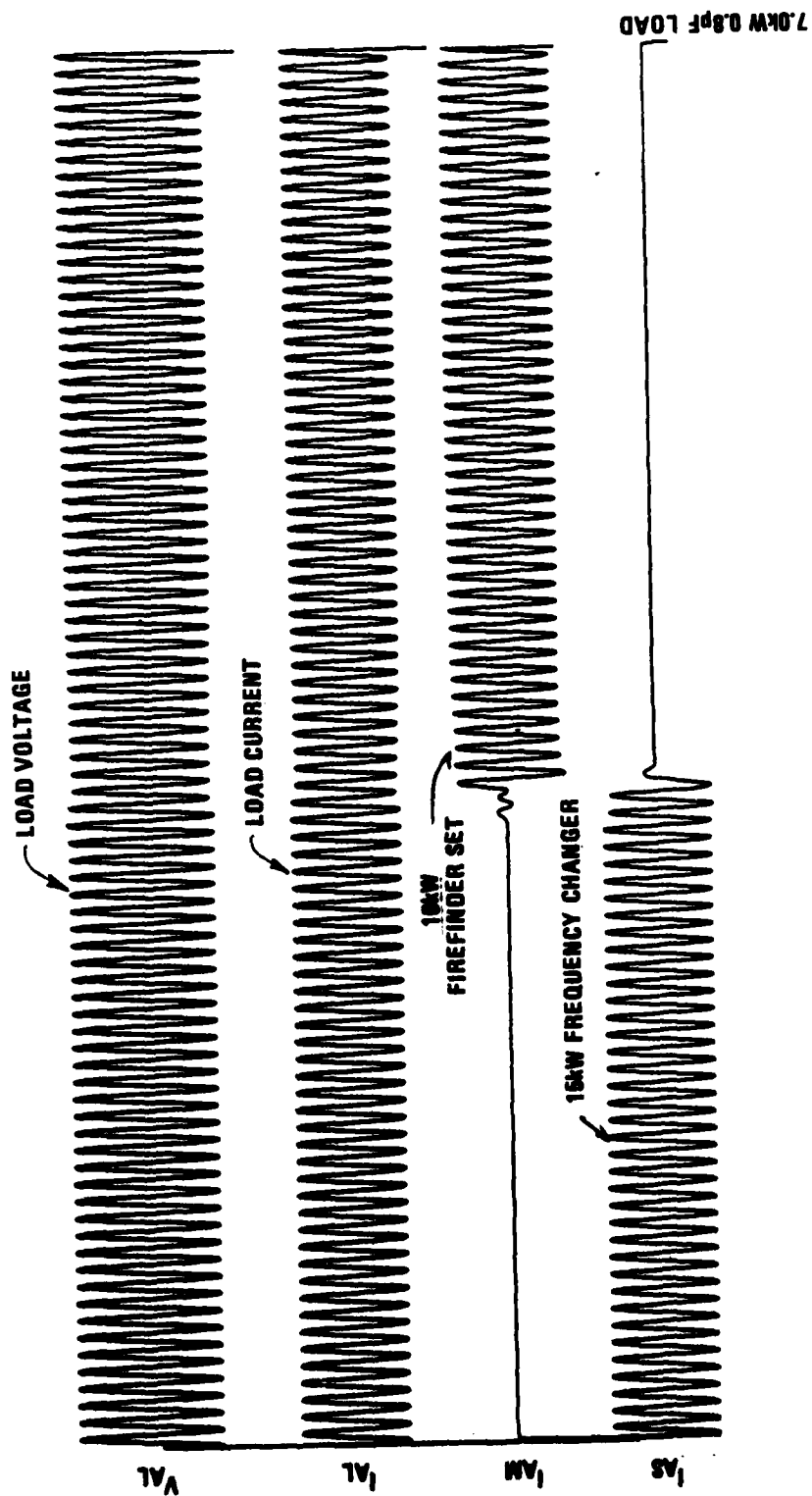
In all the test records the parameters recorded are, from top to bottom, phase A (L1 - L2) bus voltage; phase A (L1) bus current; phase A current from the Master source; and phase A current from the Slave source. Some tests involve the transfer of sources to a 7 kW 0.8 PF load and others to a 11 kW 0.8 PF load.

Test 3-22-01 through test 3-22-04 show the transfer of power source from the 15 kW Frequency Changer to the 10 kW generator set with a 7 kW 0.8 PF load. The only discernable transient is the no load to 7 kW transient load behavior of the 10 kW generator set.

Test 3-22-05 shows the transfer of power source from the 10 kW generator set to the 15 kW Frequency Changer with a 7 kW 0.8 PF load. The only discernable transient is the no load to 7 kW transient load behavior of the 15 kW Frequency Changer.

Test 3-22-06 through test 3-22-08 show the transfer of power source from the 15 kW Frequency Changer to the 10 kW generator set with a 11 kW 0.8 PF load. Again, the only discernable transient is the no load to 11 kW transient load behavior of the 10 kW generator set.

B-2



22 March 1982

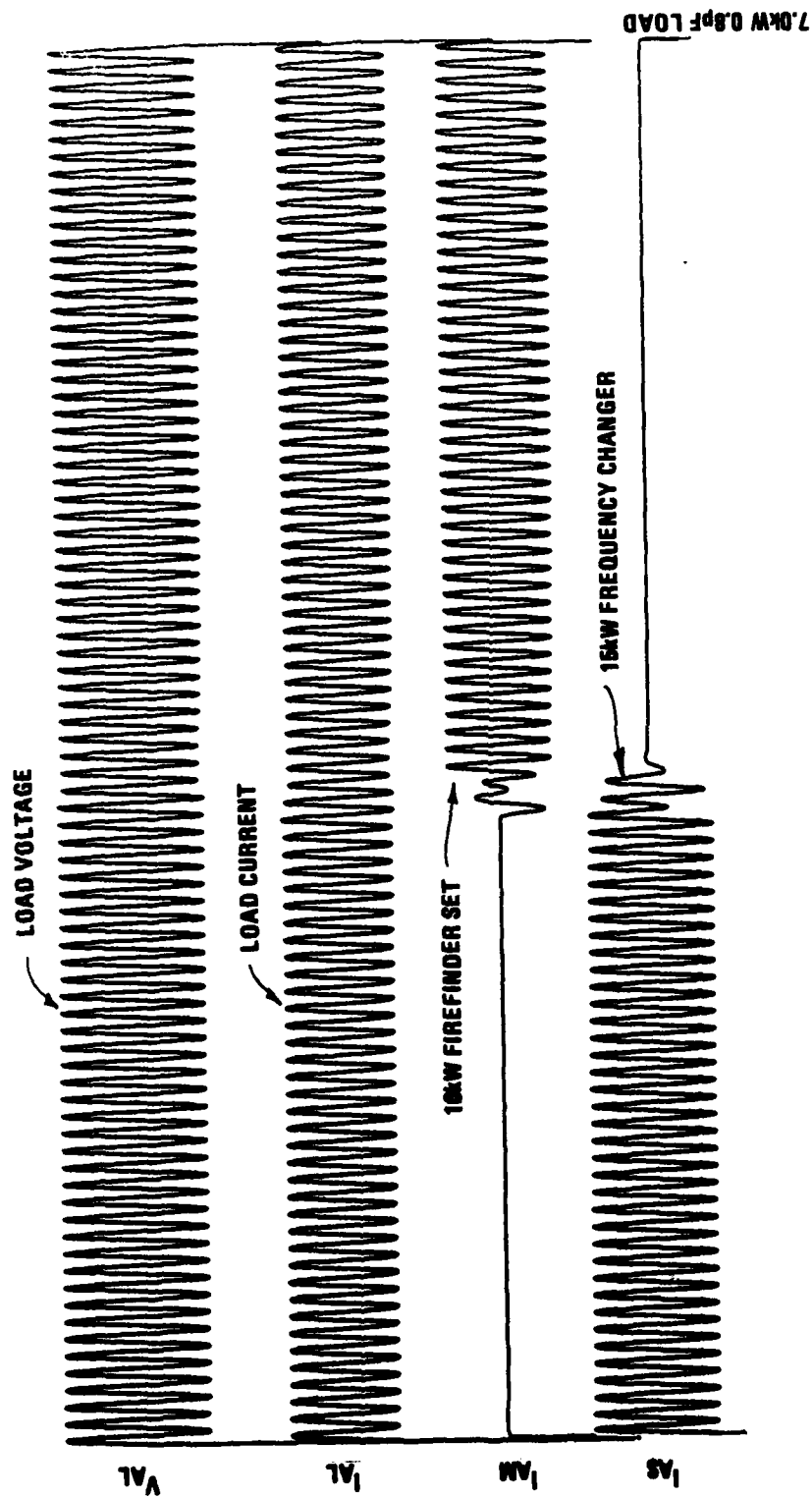
R62-127

15kW FREQUENCY CHANGER TO FIREFINDER TRANSFER TEST

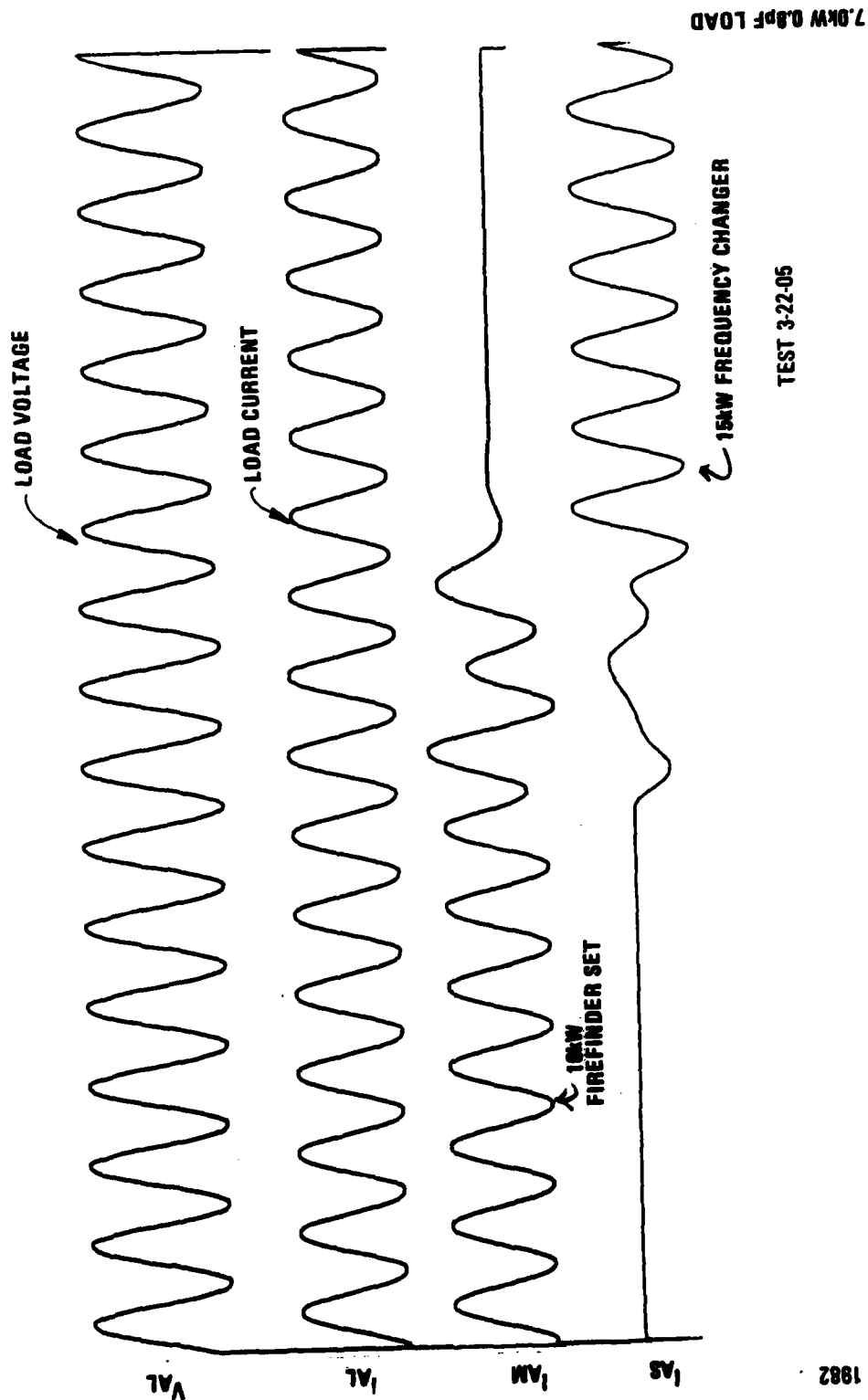
22 March 1982

FREQUENCY CHANGER TO FIREFINDER TRANSFER

TEST 3-22-02



22 March 1982



TEST 3-22-05

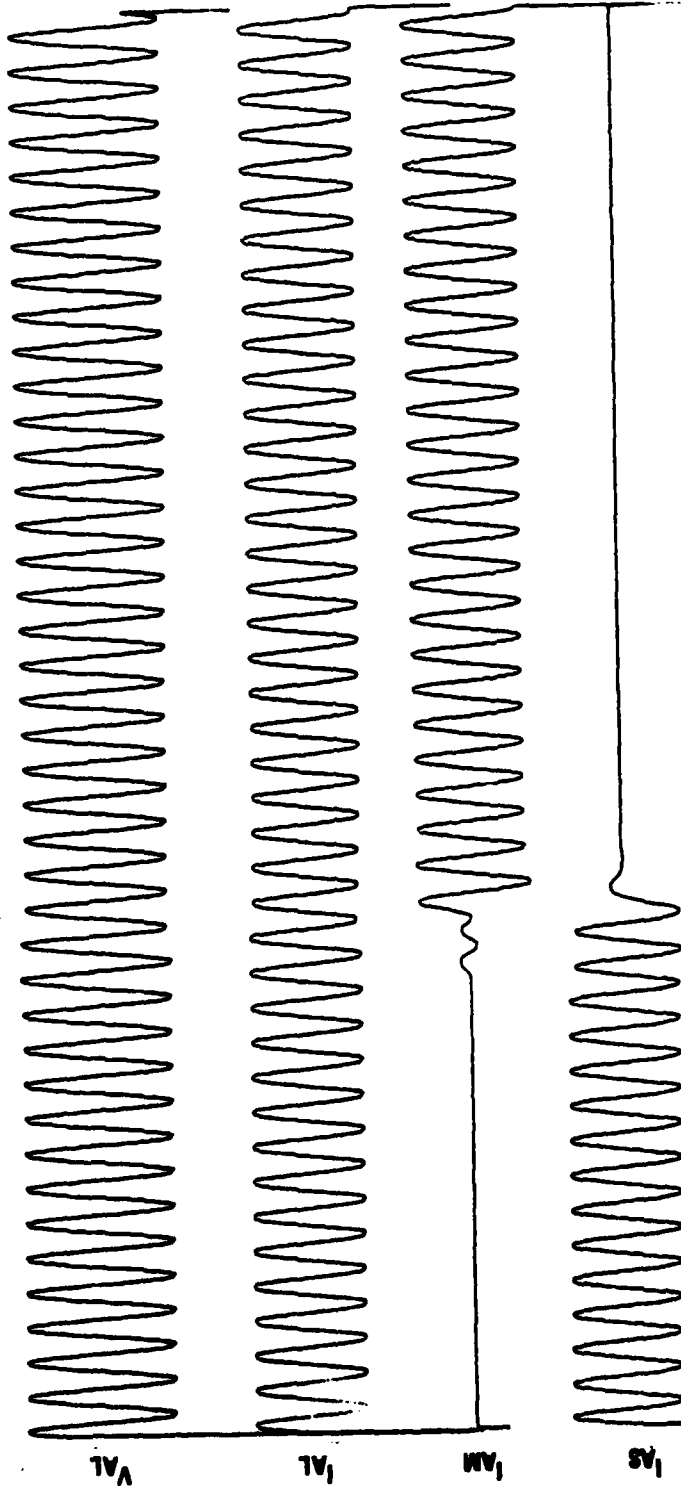
FIREFINDER TO FREQUENCY CHANGER TRANSFER

22 March 1982

FREQUENCY CHANGER TO FIREFINDER TRANSFER

TEST 3-22-03

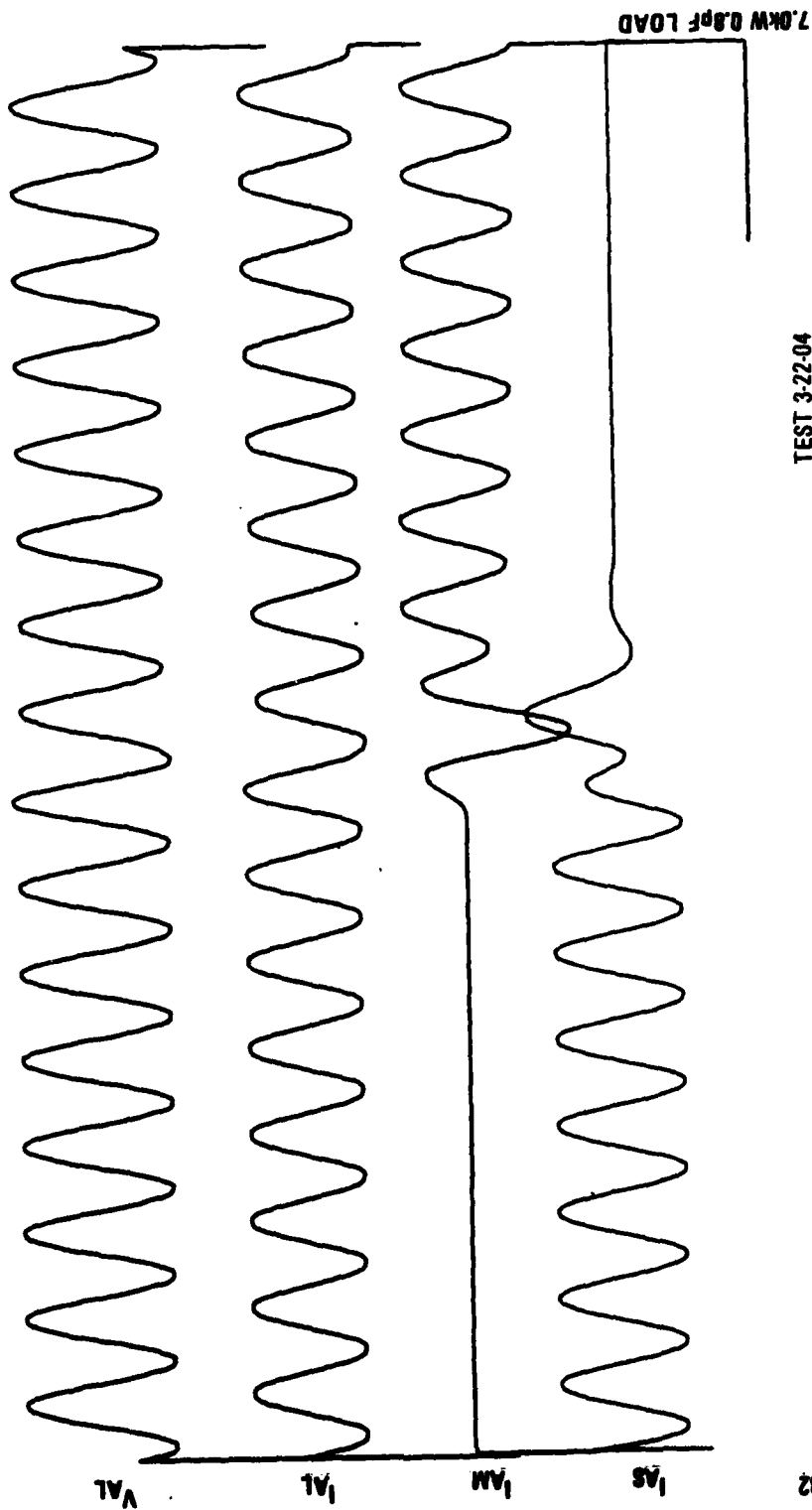
7.0KW 0.8PF LOAD



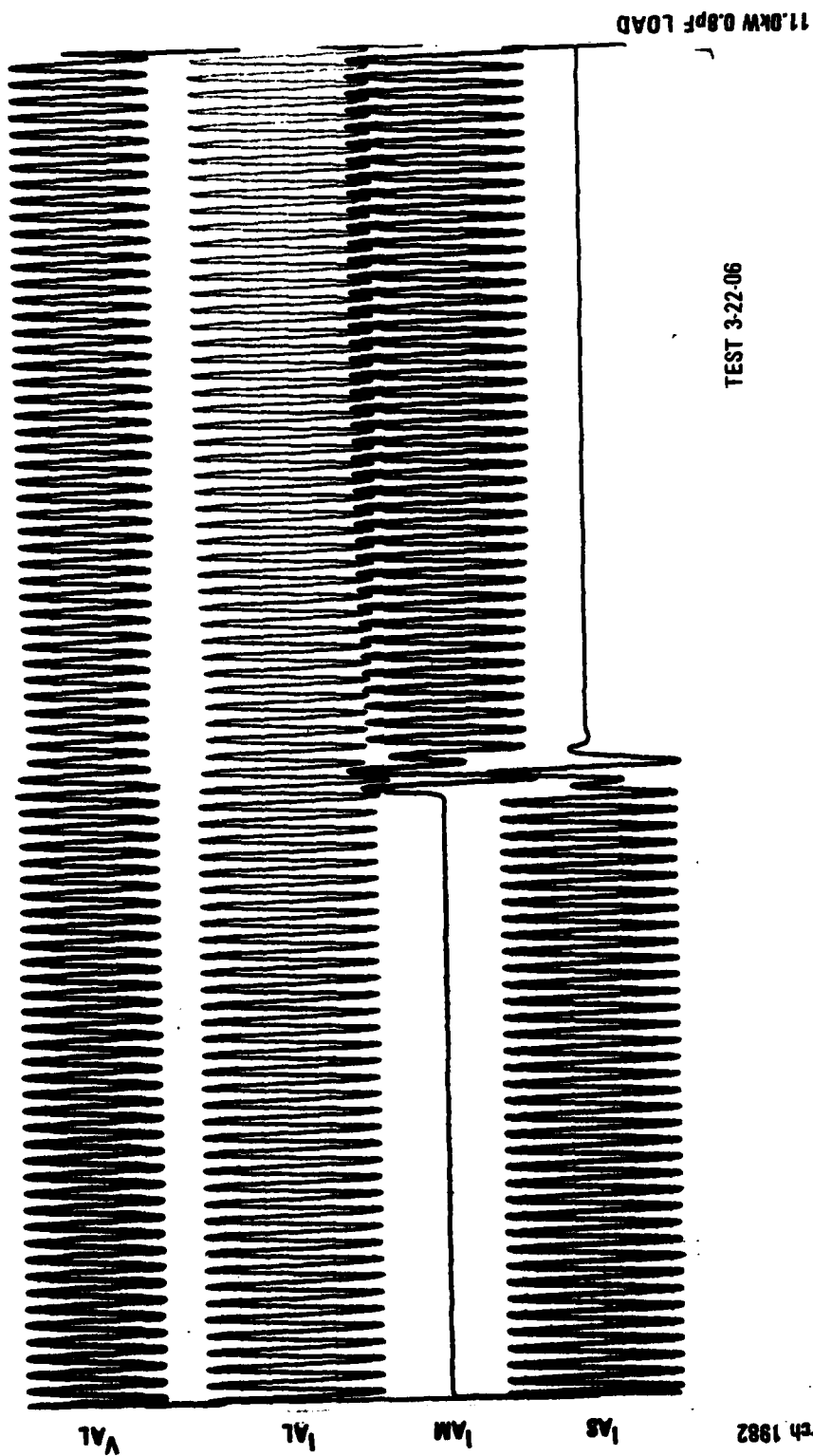
22 March 1982

FREQUENCY CHANGER TO FIREFINDER TRANSFER

TEST 3-22-04

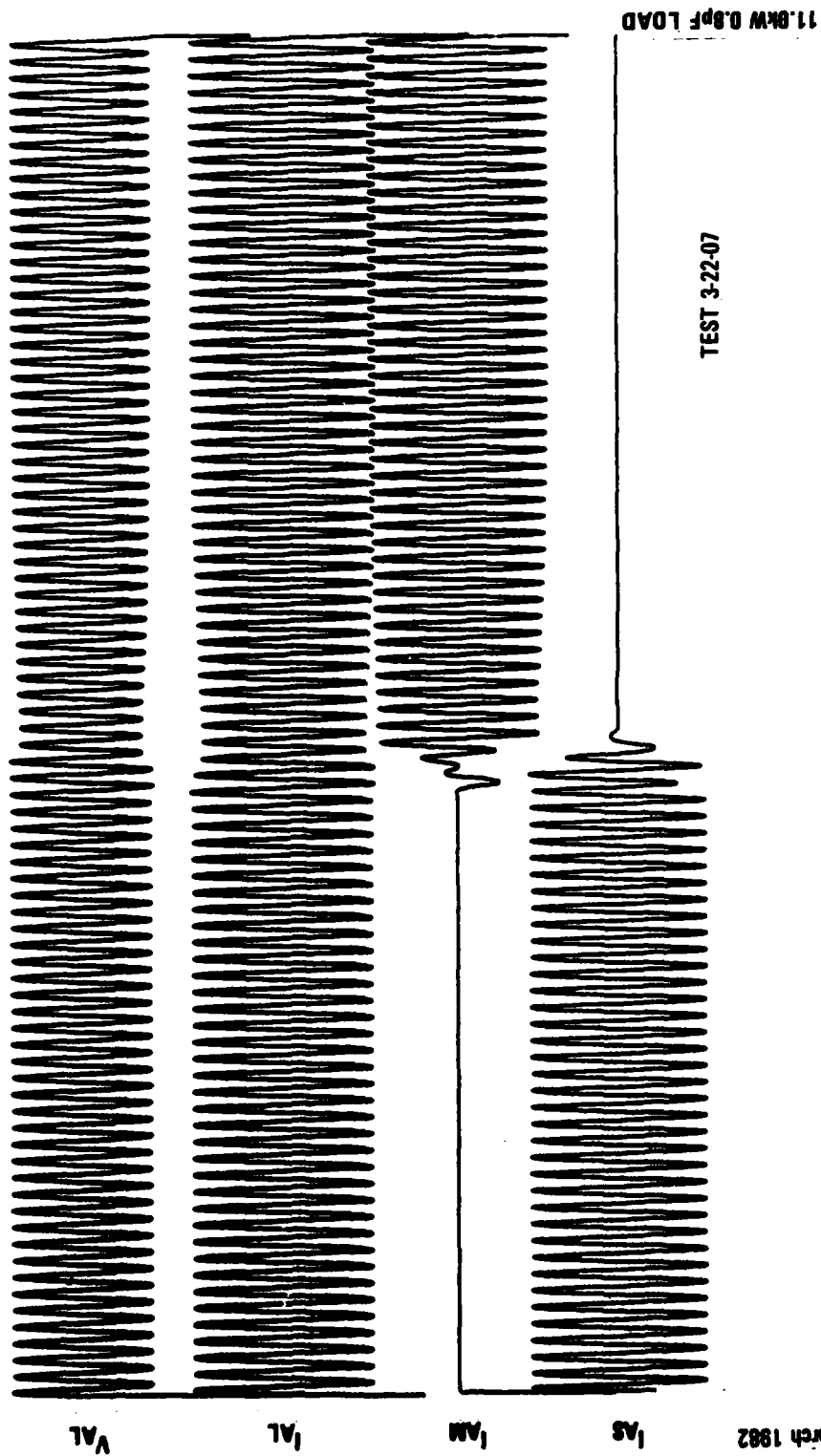


22 March 1982



FREQUENCY CHANGER TO FIREFINDER TRANSFER

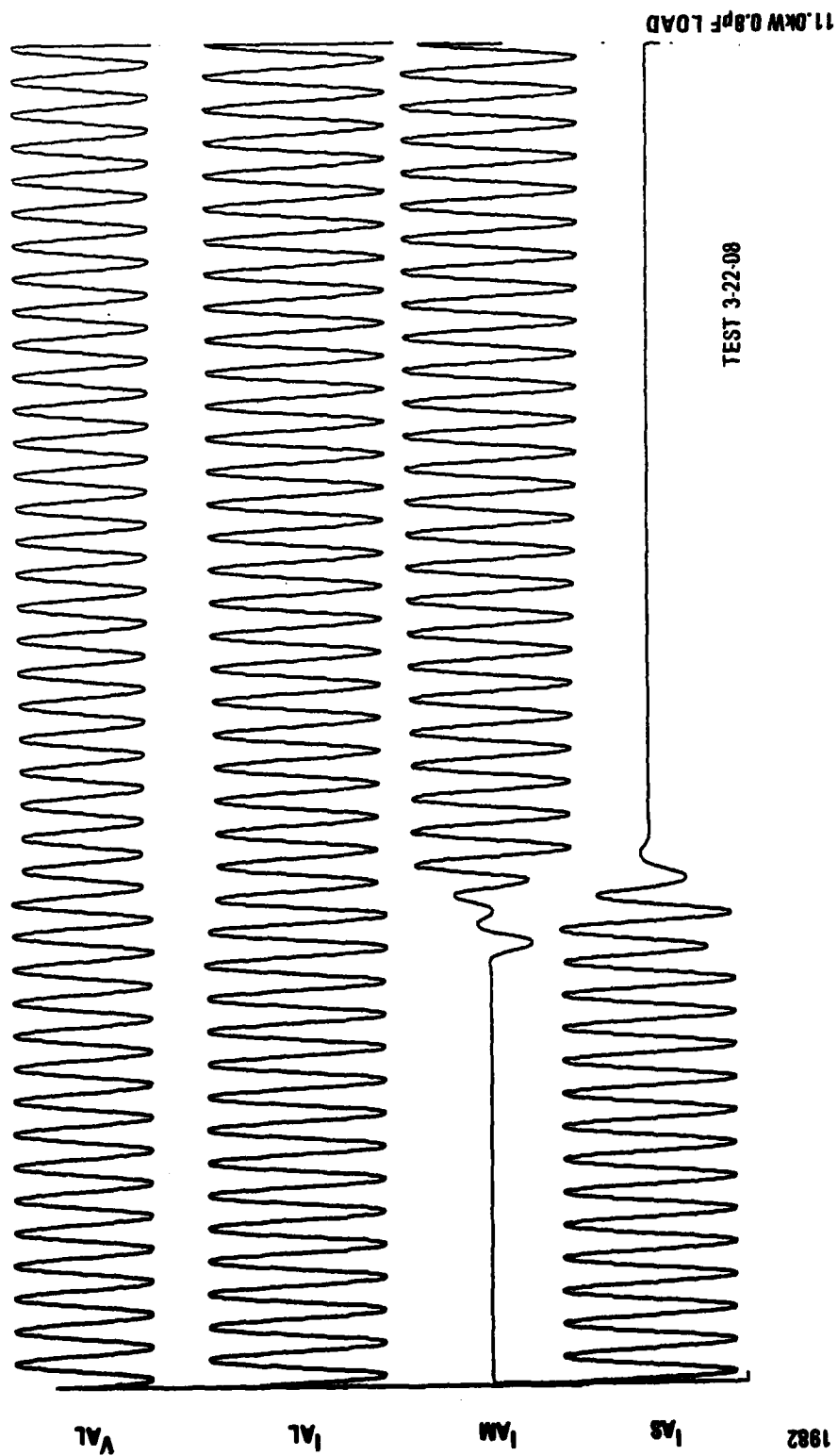
22 March 1962



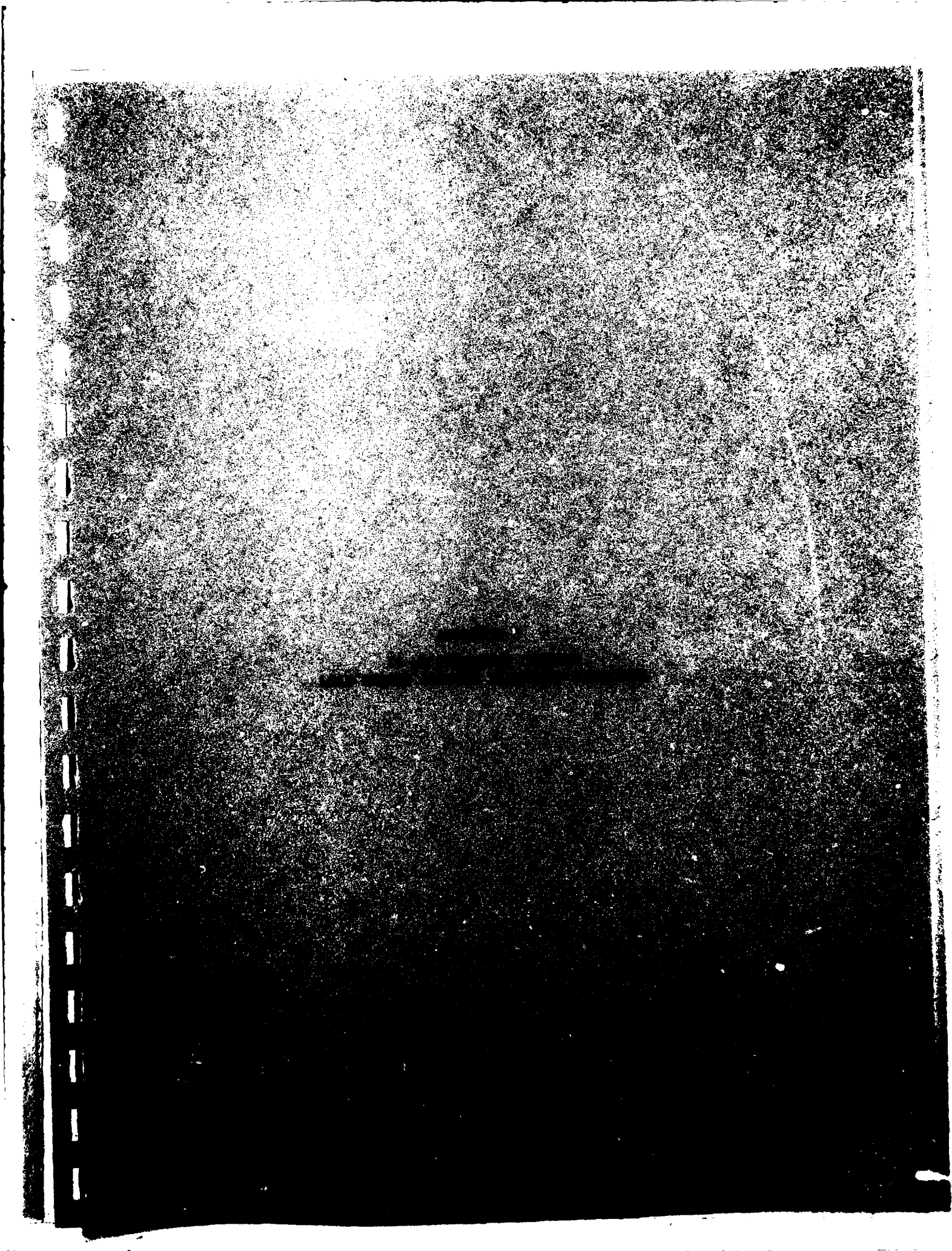
R82-127

B-9/10

22 March 1962



15kW FREQUENCY CHANGER TO FIREFINDER TRANSFER



**15 kW FREQUENCY CHANGER
LOAD CHANGE INDUCED TRANSIENT SIGNATURE**

On a power bus being driven by such power sources as motor-generator sets and/or frequency changers individually or in parallel, the load change - induced transient behavior of the sources is seen by the bus loads. This is obviously true in the case of a fixed source configuration operating varying loads. Not so obvious, but equally true, is the case of a fixed load with varying source configuration.

As an example of the later, consider the case where a fixed load is operating on a power bus. If a clean and instantaneous transfer of sources is made from a motor-generator set to a frequency changer, the load change-induced transient behavior of the frequency changer is seen by the load. In this case, the motor-generator set transient appears only at its output terminals after they are unloaded. However, the frequency changer is subjected nearly instantaneously to a no load to bus load transient. In this example, at this point in time, the frequency changer is the only source on the bus; so its transient performance governs the bus performance.

With this in mind, testing was performed on the frequency changer in a stand-alone mode to show its response to step load changers. Much testing of this nature was published in earlier test reports. For convenience and completeness of this report, the results of 1.0 per unit load transient testing are shown here. The upper curve shows the effect of a 15 kW 0.8 PF to no load transient on the phase A (L1 - L0) output voltage. The lower curve shows the effect of a no load to 15 kW 0.8 PF transient on the same output voltage.

12k - 43k - 0.68 μ F

22 March 1982

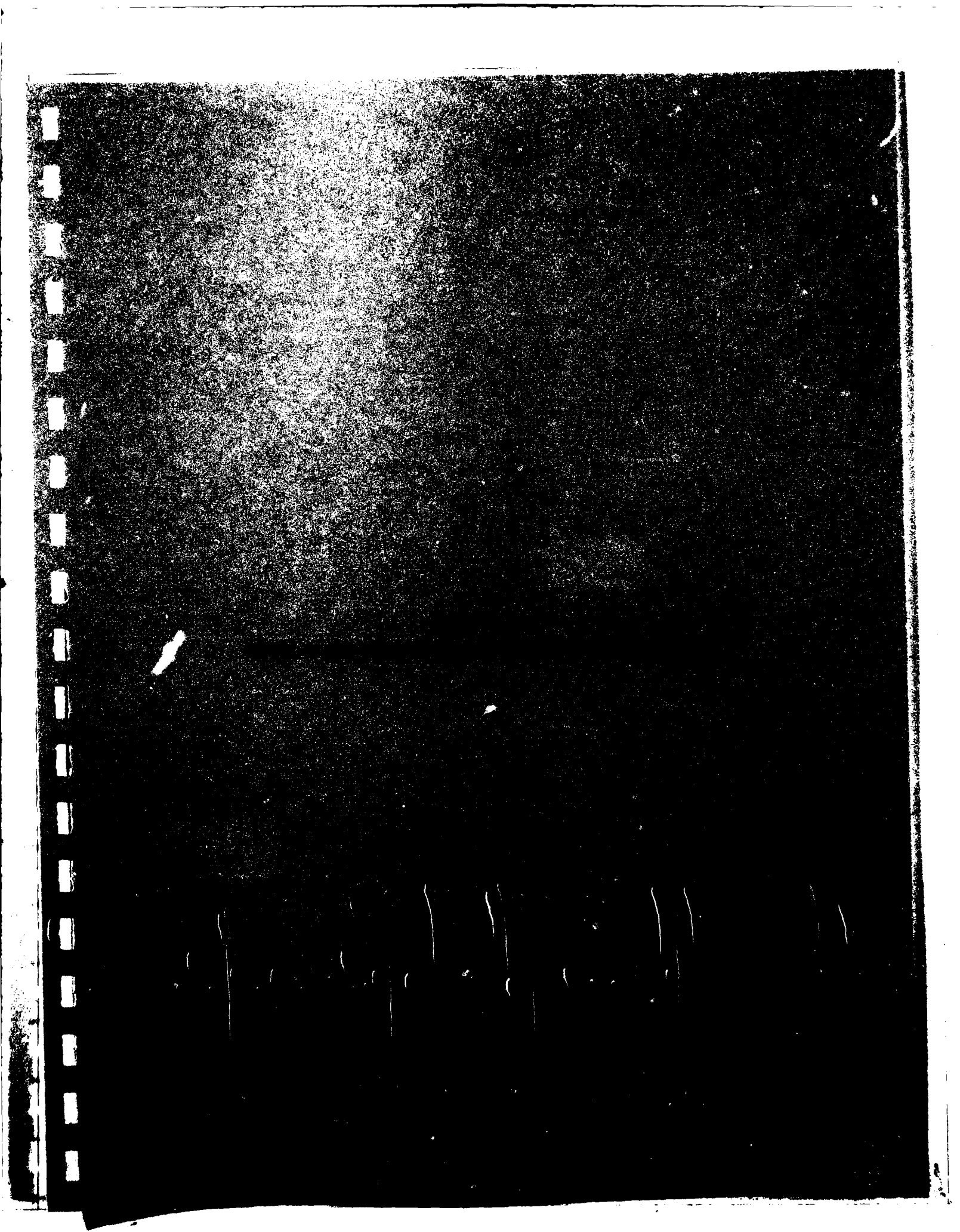
15kW $\leftarrow$ NL

15kW $\leftarrow$ NL

15kW 0.8pF LOAD

V_{0A-N}

15kW FREQUENCY CHANGER



EFFECT OF BUS FREQUENCY CHANGES DURING PARALLEL OPERATION

This testing was performed to demonstrate satisfactory operation when the 15 kW Frequency Changer is supplying power to a bus which has a large frequency transient. This might be expected when the Master source is a nonsynchronously driven M-G set and the bus is suddenly loaded.

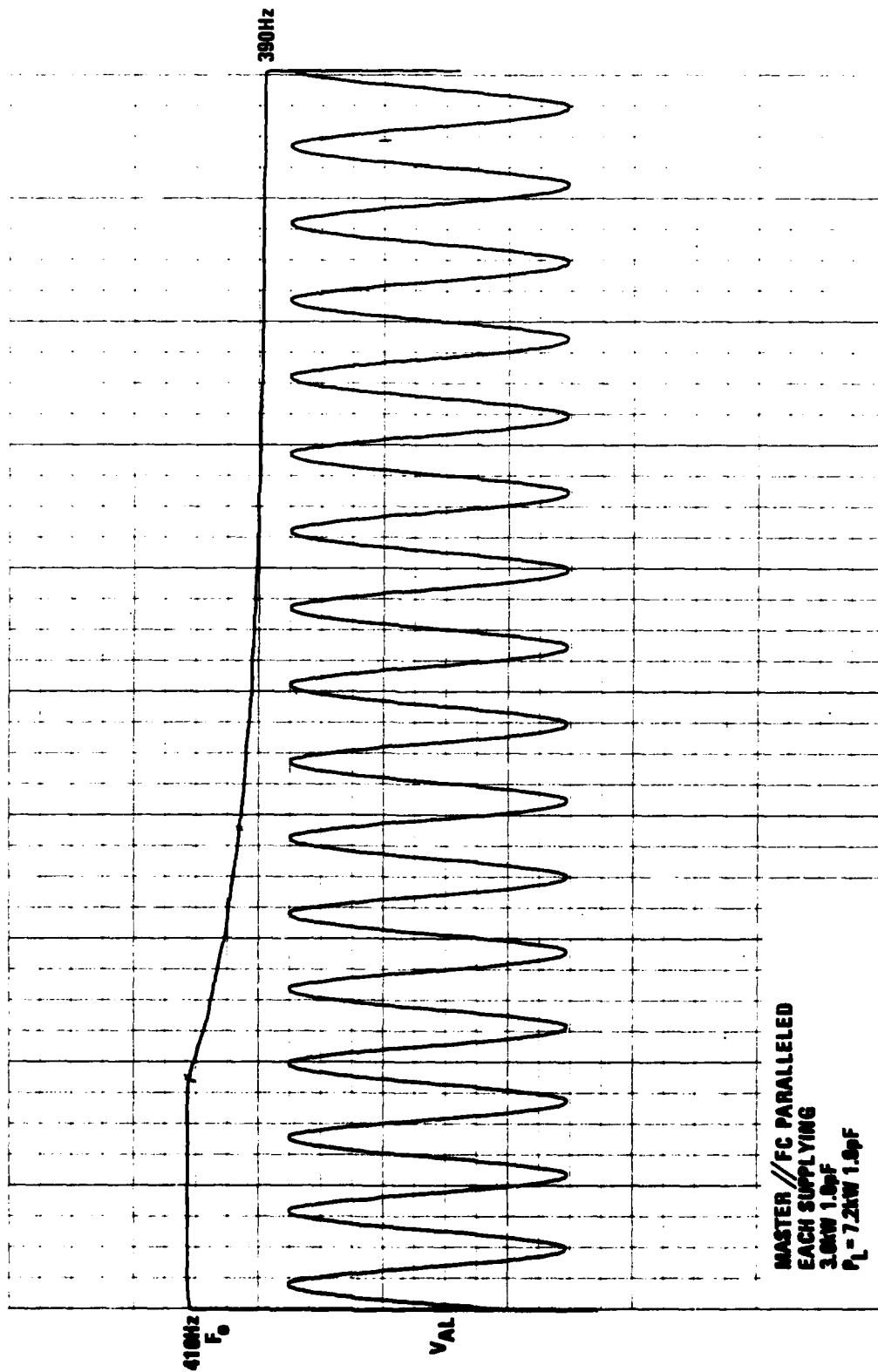
The Master for this test was the 10 kW Firefinder Generator Set (MEP D423A). It was modified for this test such that its operating frequency could be varied over the range of 390 Hz to 410 Hz. The generator set (Master) and the frequency changer (Slave) were fully paralleled and both supplying 3.6 kW to a 7.2 kW, unity PF, load. The phase A (L1 - L0) output voltage at the load was recorded.

In the first test, intended to simulate a typical worst case frequency transient, the Master frequency was varied exponentially from 410 Hz to 390 Hz with a time constant of approximately eight milliseconds. No problem was observed in the phase A voltage waveform.

In the second test, the Master frequency was stepped almost instantaneously from 410 Hz to 390 Hz. Here again, no problem was observed in the phase A voltage waveform. It can be reasonably concluded from these tests that the 15 kW Frequency Changer can be successfully paralleled with a bus having severe frequency transients. Excellent phase locking characteristics have been demonstrated.

D-2

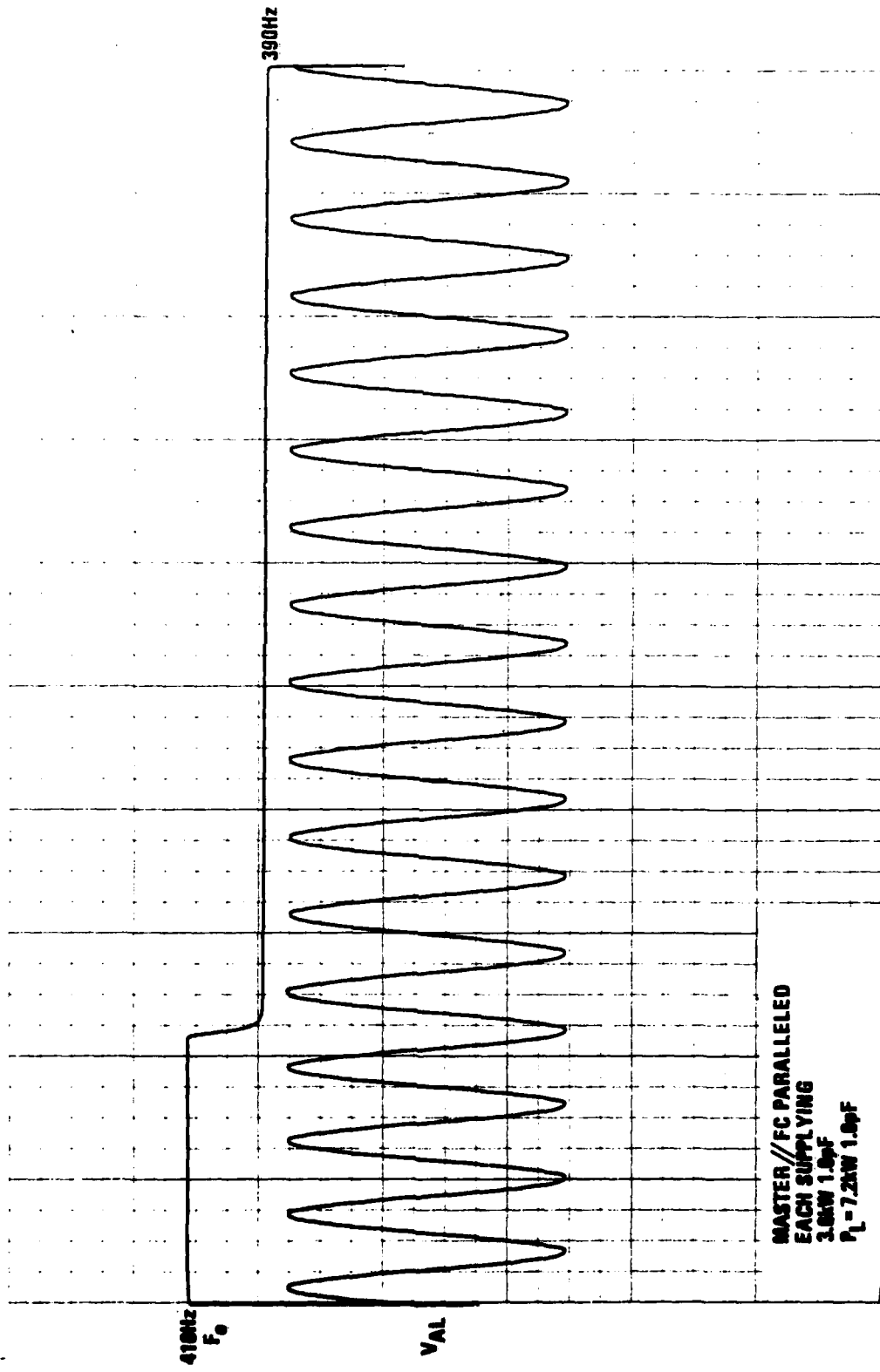
18 March 1962



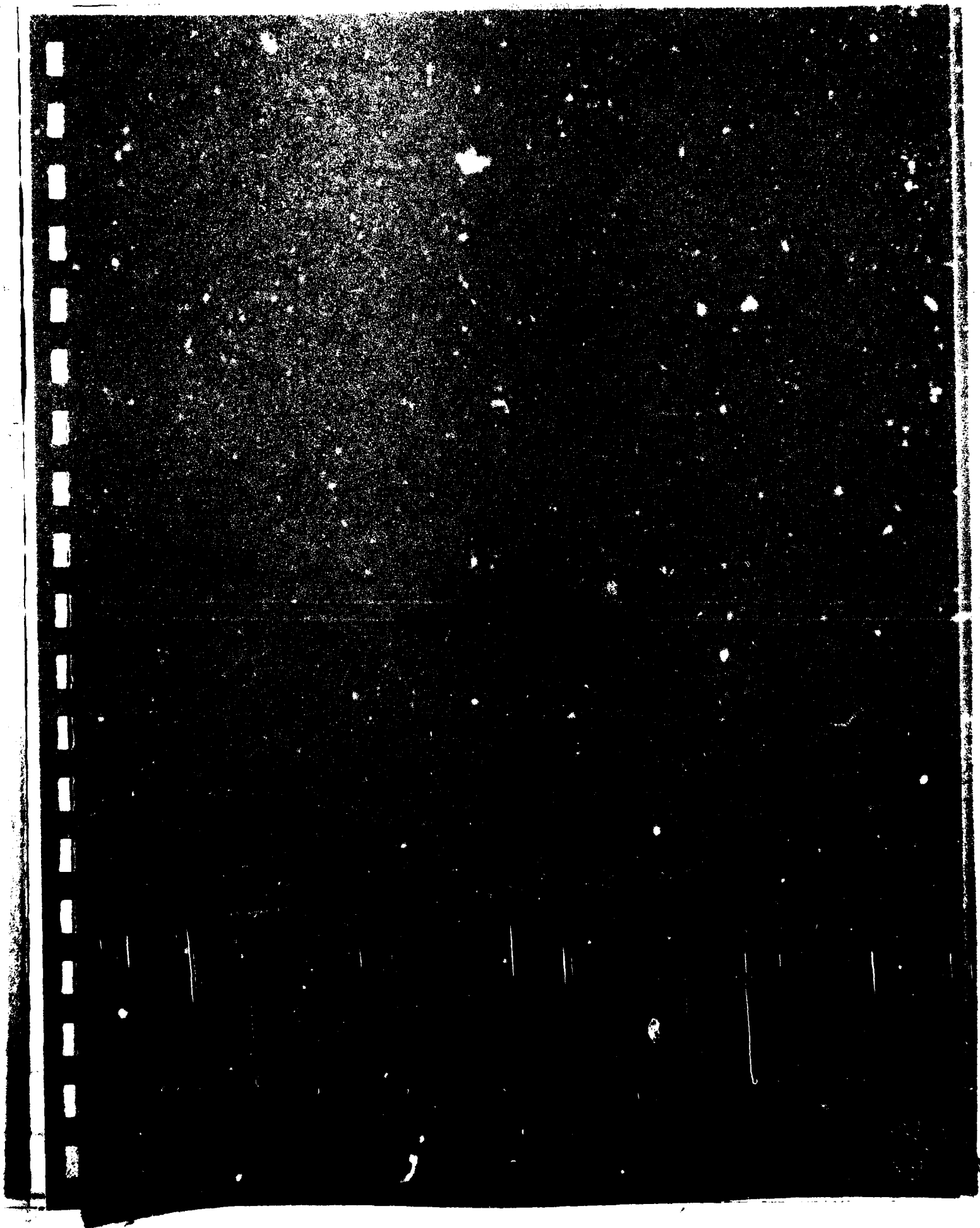
R82-127

18 March 1982

R82-127



D-3/4

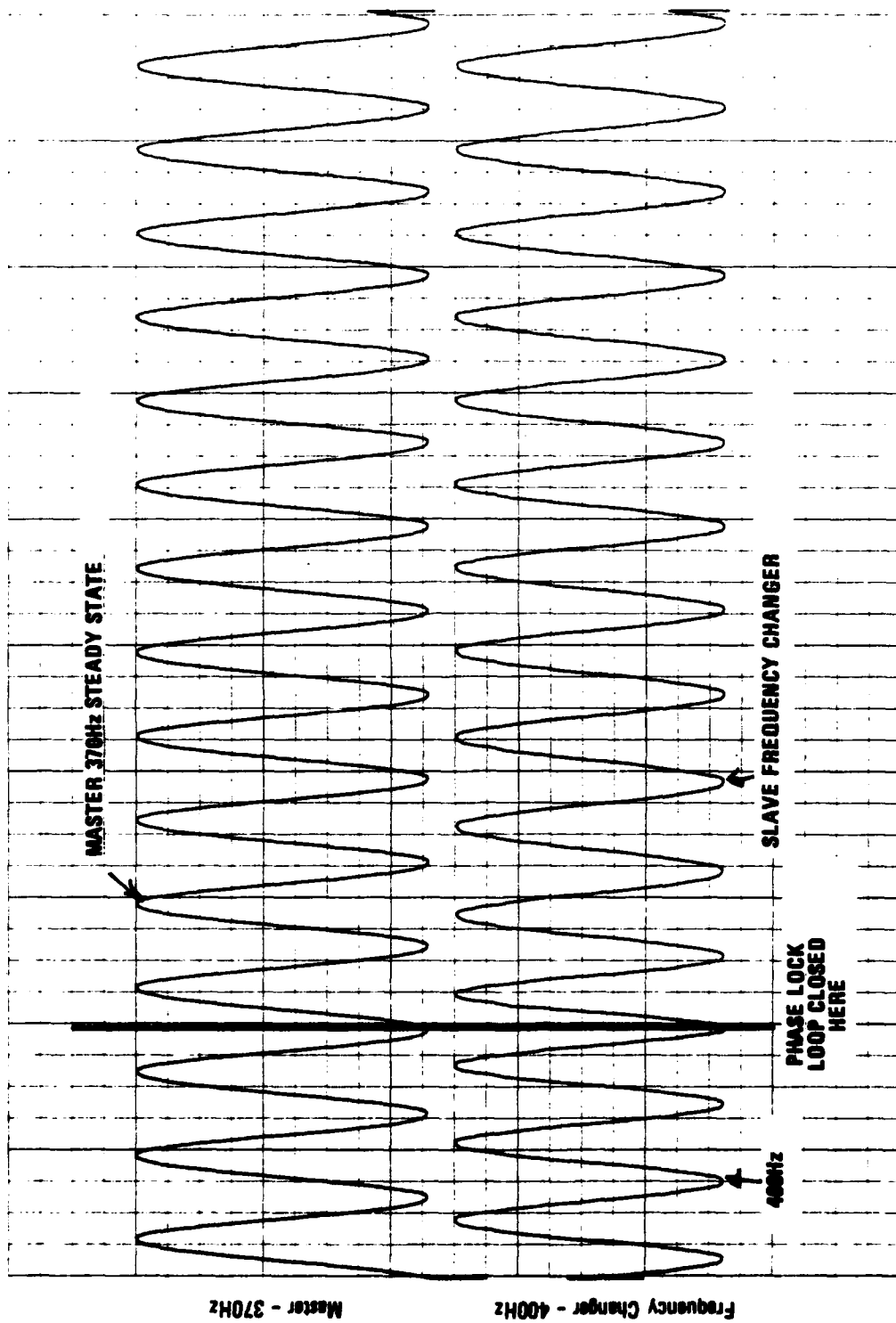


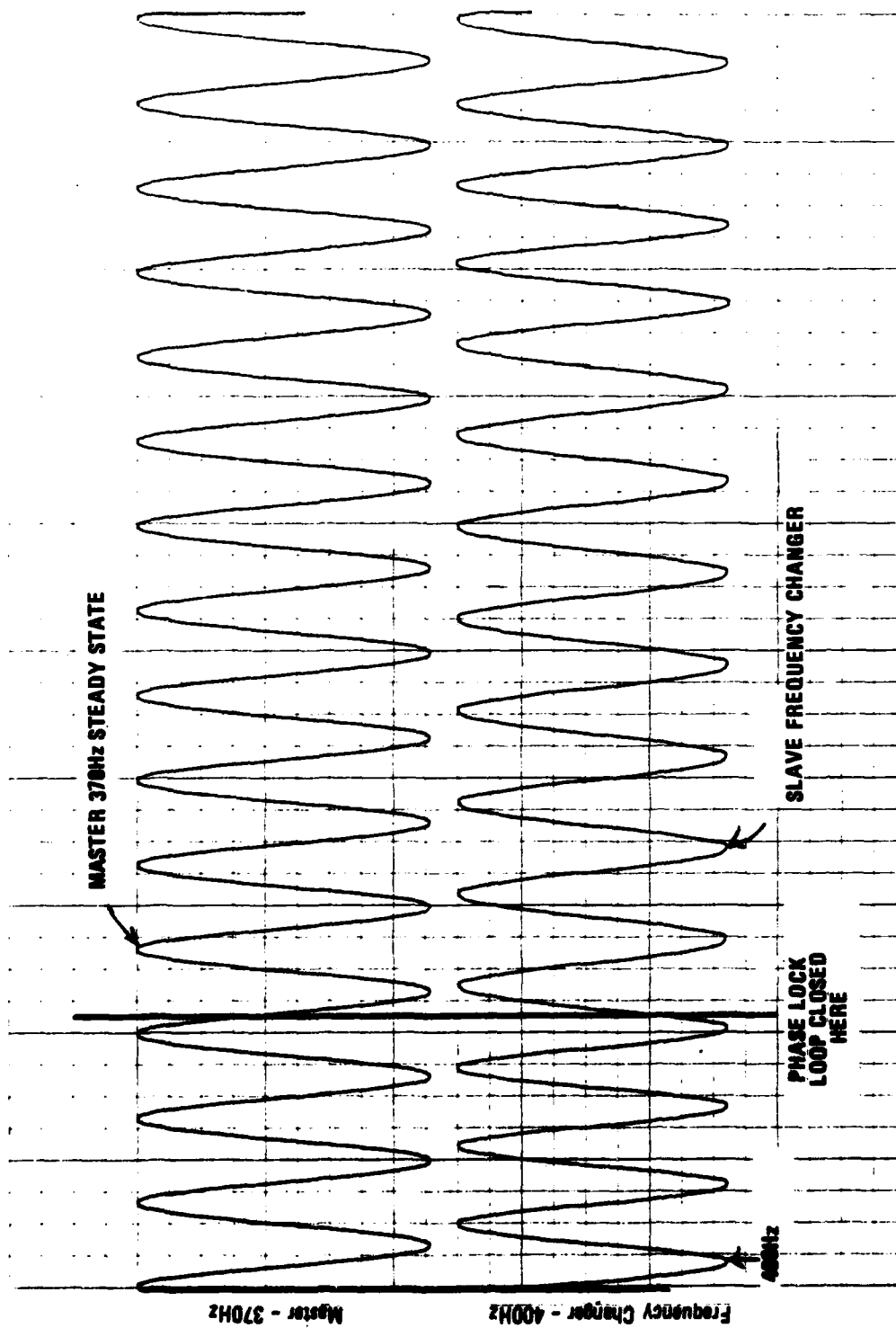
PHASE LOCK CAPTURE BEHAVIOR

This test was run to show the capture characteristics of the phase lock loop. A Master three phase generator was operated at a constant 370 Hz. Prior to closing the Phase Lock switch, the frequency changer operated at 400 Hz on local (crystal) frequency control. The switch was then closed and the frequency changer was made to capture the Master 370 Hz in frequency and phase.

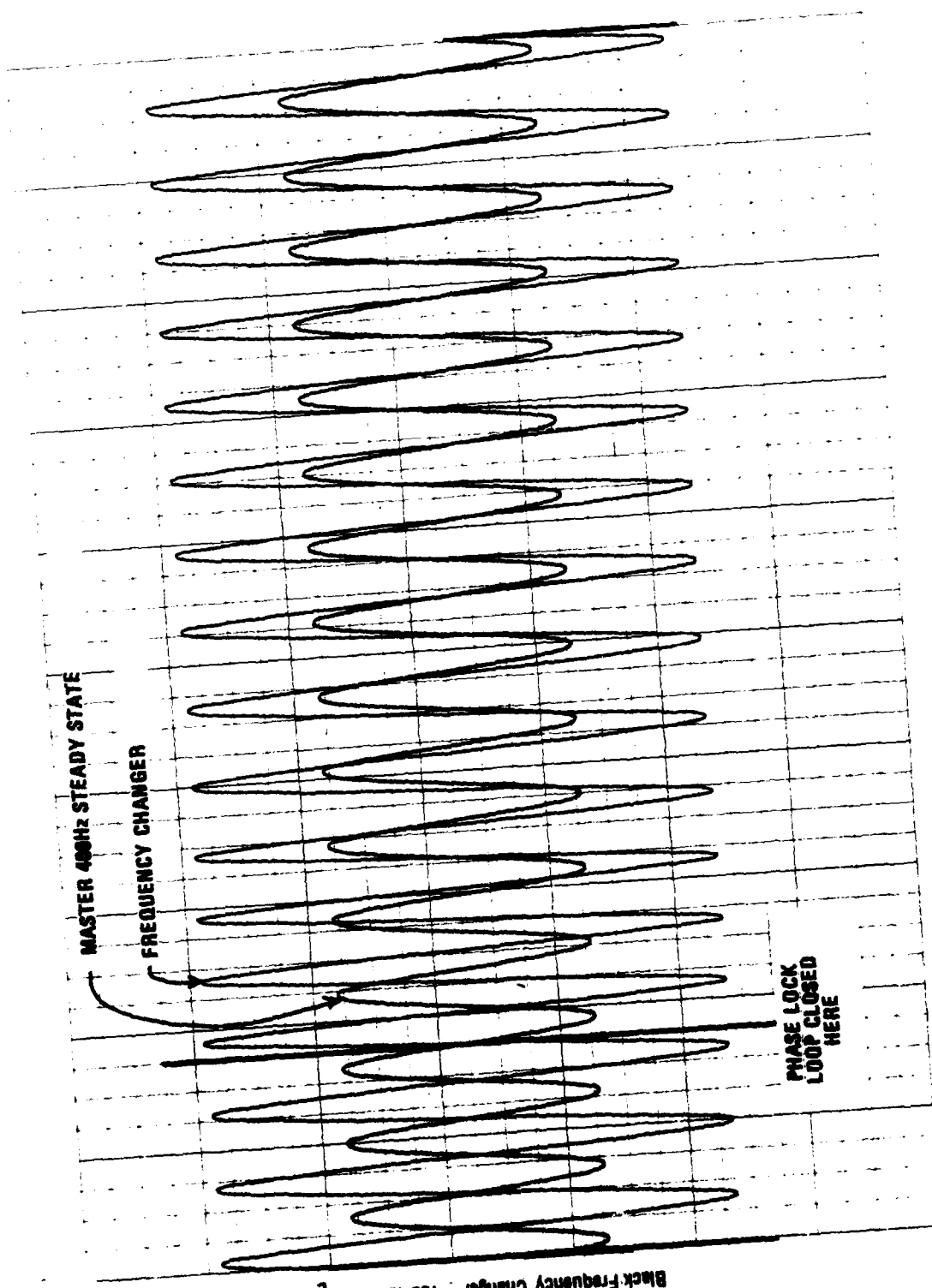
For the first test, at the time of closure the Master and the frequency changer were instantaneously nearly in phase. Frequency change and phase lock were accomplished smoothly in approximately three cycles. For the second test, at the time of closure, the Master and the frequency changer were instantaneously nearly 180 degrees out of phase. Again, frequency change and phase lock was accomplished smoothly. Full lock occurred in approximately ten cycles.

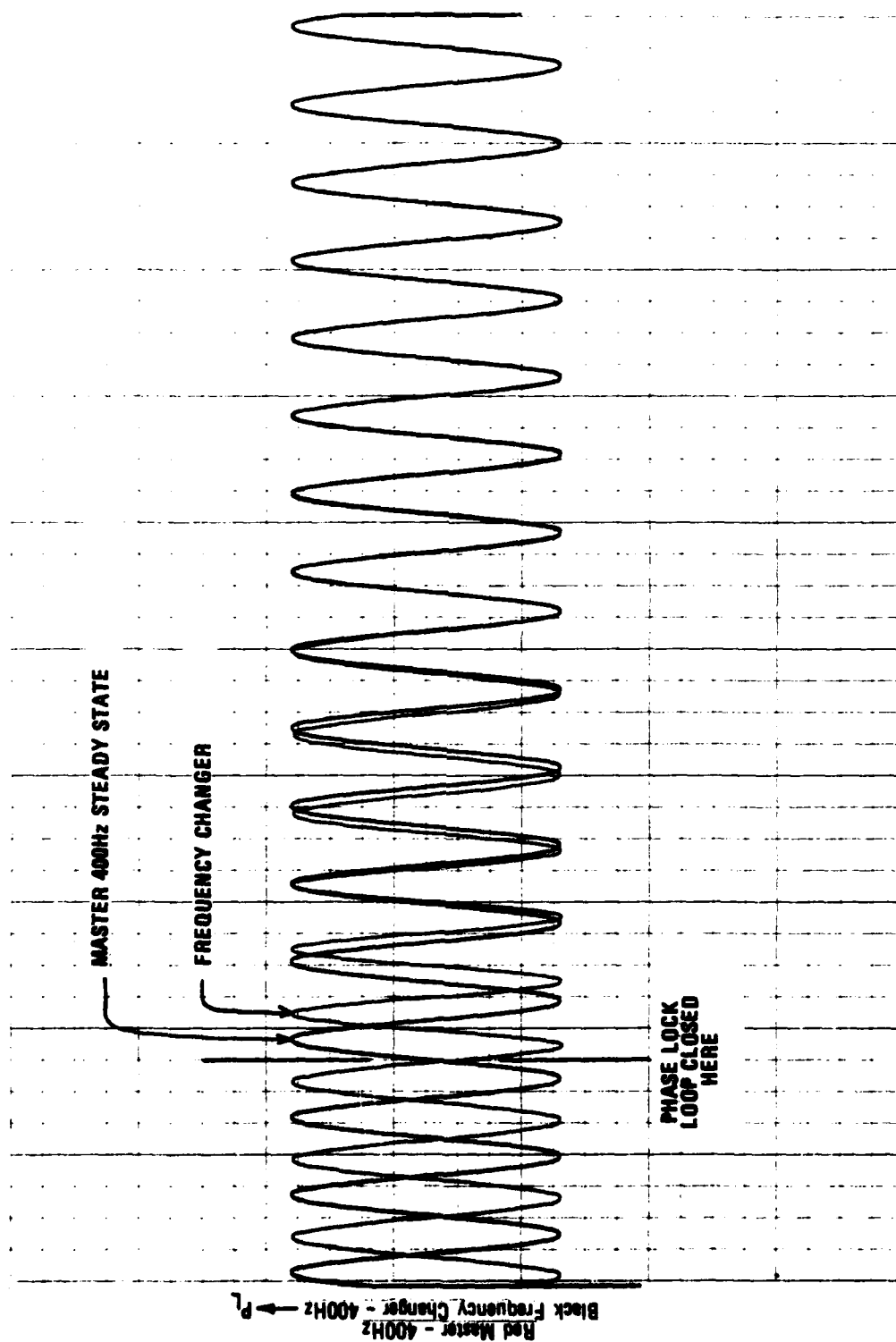
Test conditions for the third and fourth tests were like those of the second test except that the Master three-phase generator was replaced with a 10 kW Firefinder Generator Set (MEP D423A) operated at 400 Hz. The phase lock was in both cases accomplished smoothly. Full lock occurred in approximately eight cycles.

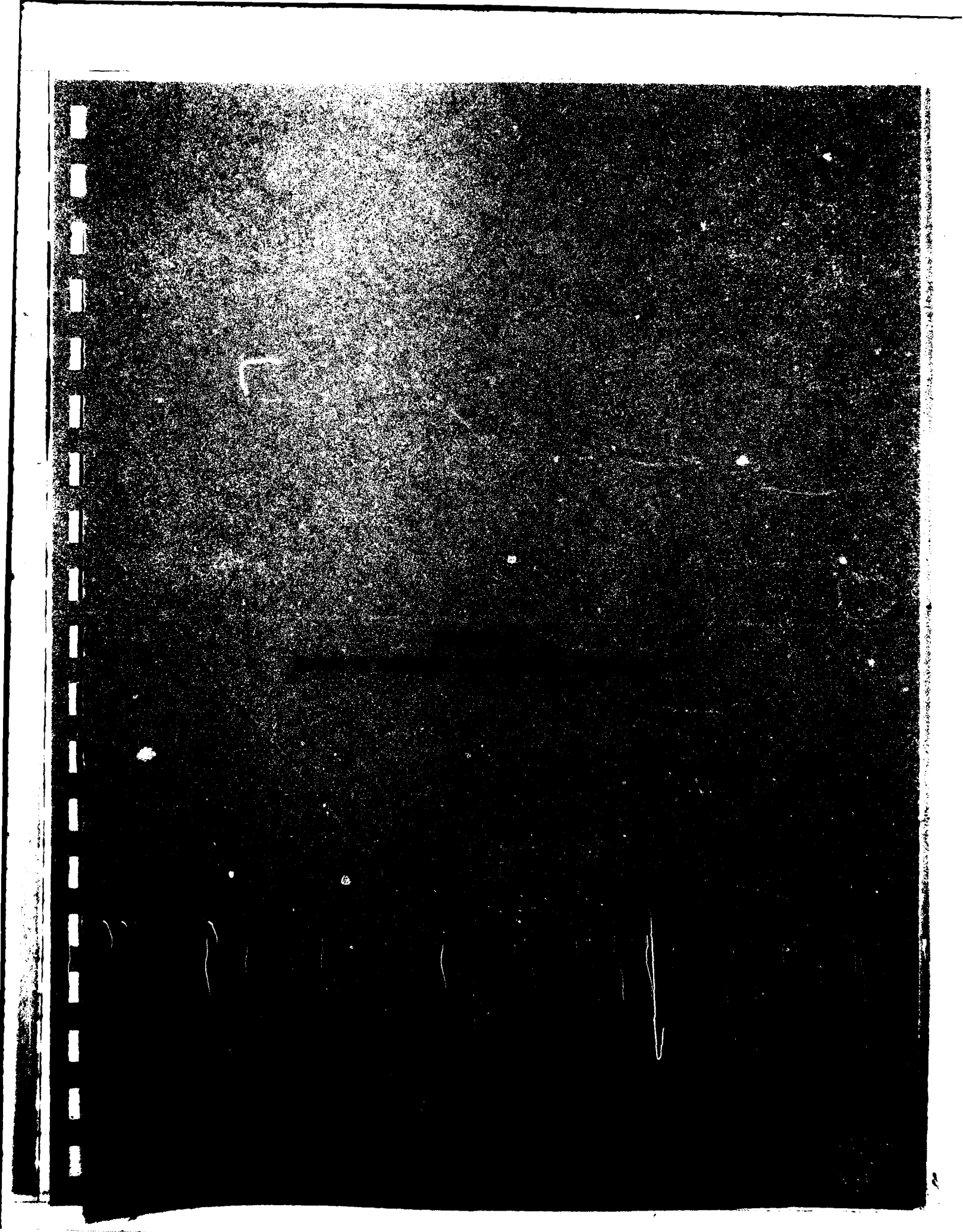




Red Master - 400Hz
Black Frequency Changer - 400Hz → P_L







EFFECT OF FREQUENCY TRANSIENTS ON PHASE LOCK

The paralleling controller phase lock circuit was tested to determine its response to a step change in frequency. For this testing the 15 kW Frequency Changer amplitude was operated on local control (Amplitude Lock was off). A three-phase oscillator, whose output frequency could be changed almost instantaneously relative to the 400 Hz nominal output, was used as a frequency reference for the Master inputs.

In the first test, the Master reference frequency was changed in a step fashion from 360 Hz to 440 Hz. In the second test, the Master reference frequency was changed in a step fashion from 440 Hz to 360 Hz. At 360 Hz, steady state, the frequency changer is seen to slightly lead the Master in phase. At 440 Hz, steady state, the frequency changer is seen to slightly lag the Master in phase. This steady state error is due primarily to the finite gain of the phase error loop in the paralleling controller. It is felt that this is an acceptable error.

It should be noted that for a step change the recovery period is approximately five cycles with a somewhat overdamped characteristic. There is no apparent overshoot. This response is felt to be acceptable.

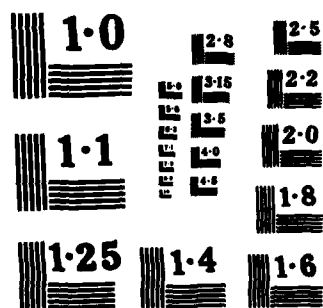
UNCLASSIFIED

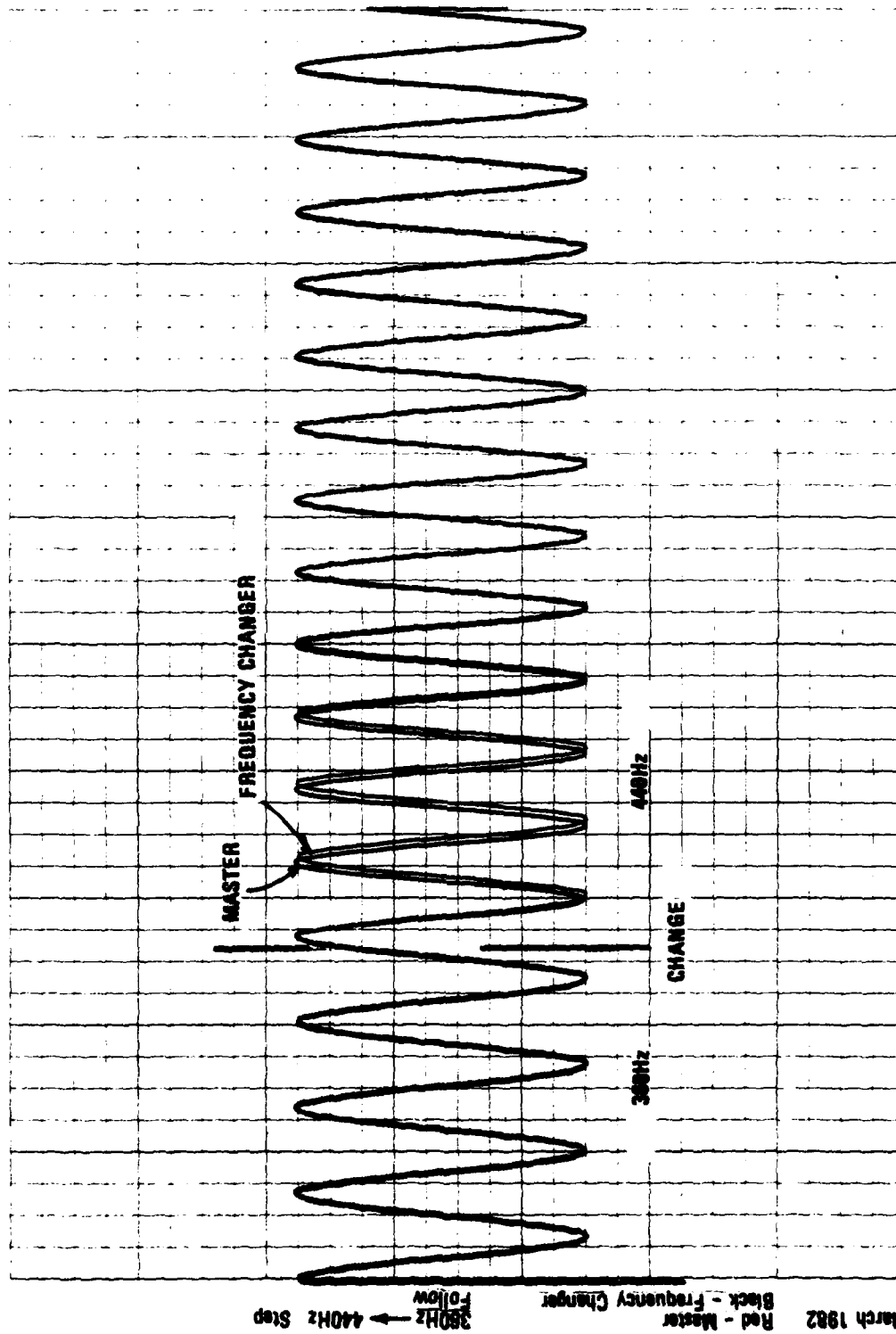
PROGRESS IN POWER DISTRIBUTION IN FISCAL YEAR 1982(U)
GENERAL MOTORS CORP GOLETA CA DELCO ELECTRONICS DIV
OCT 82 R82-127

F/G 10/2

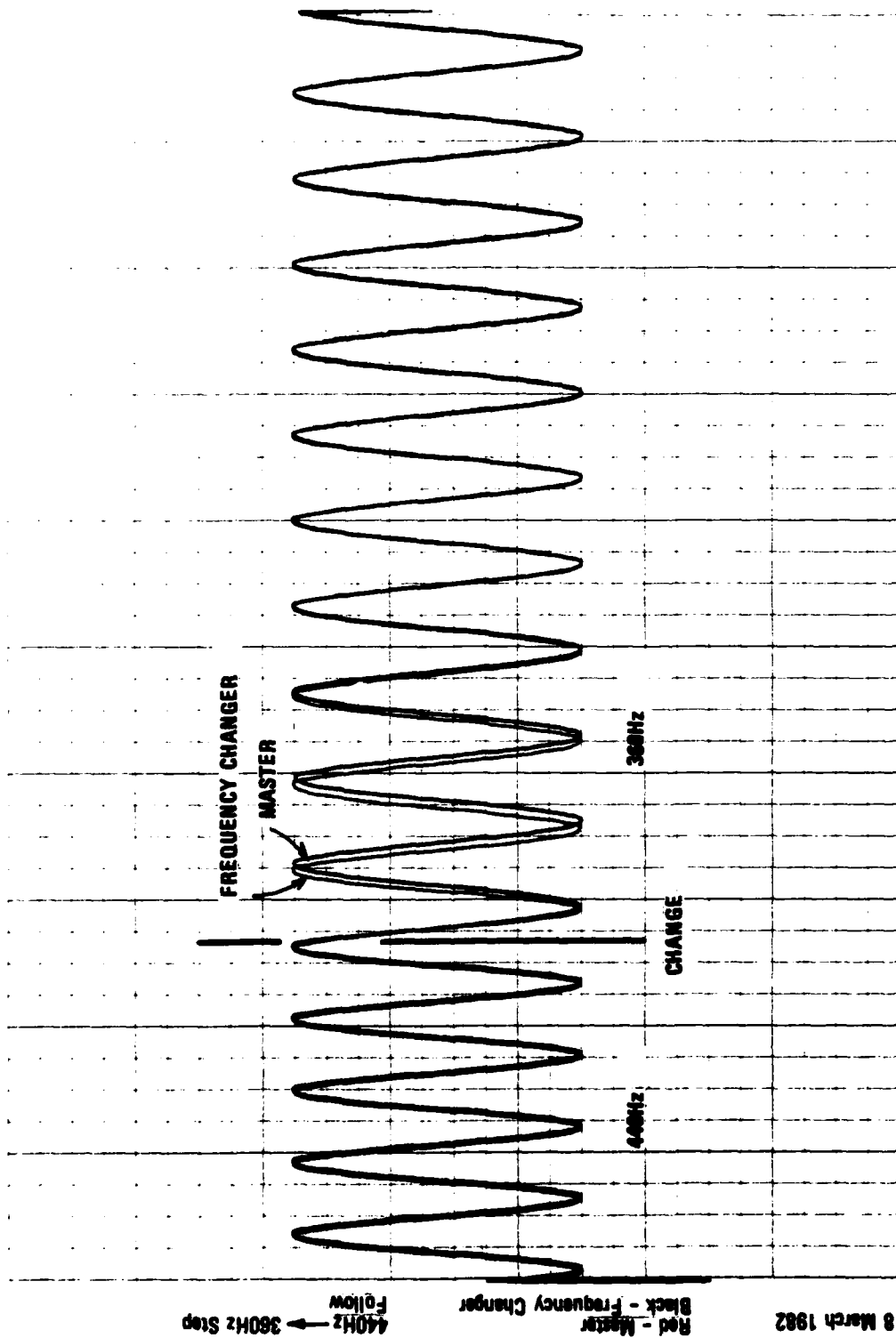
Ni

24





18 March 1982
 Red - Master
 Black - Frequency Changer
 380Hz - 440Hz Step Follow



18 March 1982

**15 kW FREQUENCY CHANGER INPUT CURRENT WAVEFORM
TESTING WITH ORIGINAL INPUT FILTER**

The 15 kW Frequency Changer, with the original single R-L-C input filter, was operated over a wide load range. The input current waveforms, THD, and harmonic components were recorded. Figure G-1 is a plot of some of the raw data, which appears in the following test records 01-03-01 through 01-03-08. Data were taken over the input current range of 10 to approximately 55 ARMS. This corresponds to a load range of approximately 10 to 110 percent from the converter portion (NL to 1.1 RL for the inverter portion).

EQUIP 15KW FREQ CHGR
 MFR DELCO
 MODEL NO. _____
 SERIAL NO. _____
 REF: _____
 BY _____
 TEST NO. SEE TEST REC
 DATE MARCH 01, 1982
 TEST REC 01-03-01
 THROUGH 01-03-08
 ORIGINAL
 INPUT FILTER



SANTA BARBARA, CALIFORNIA

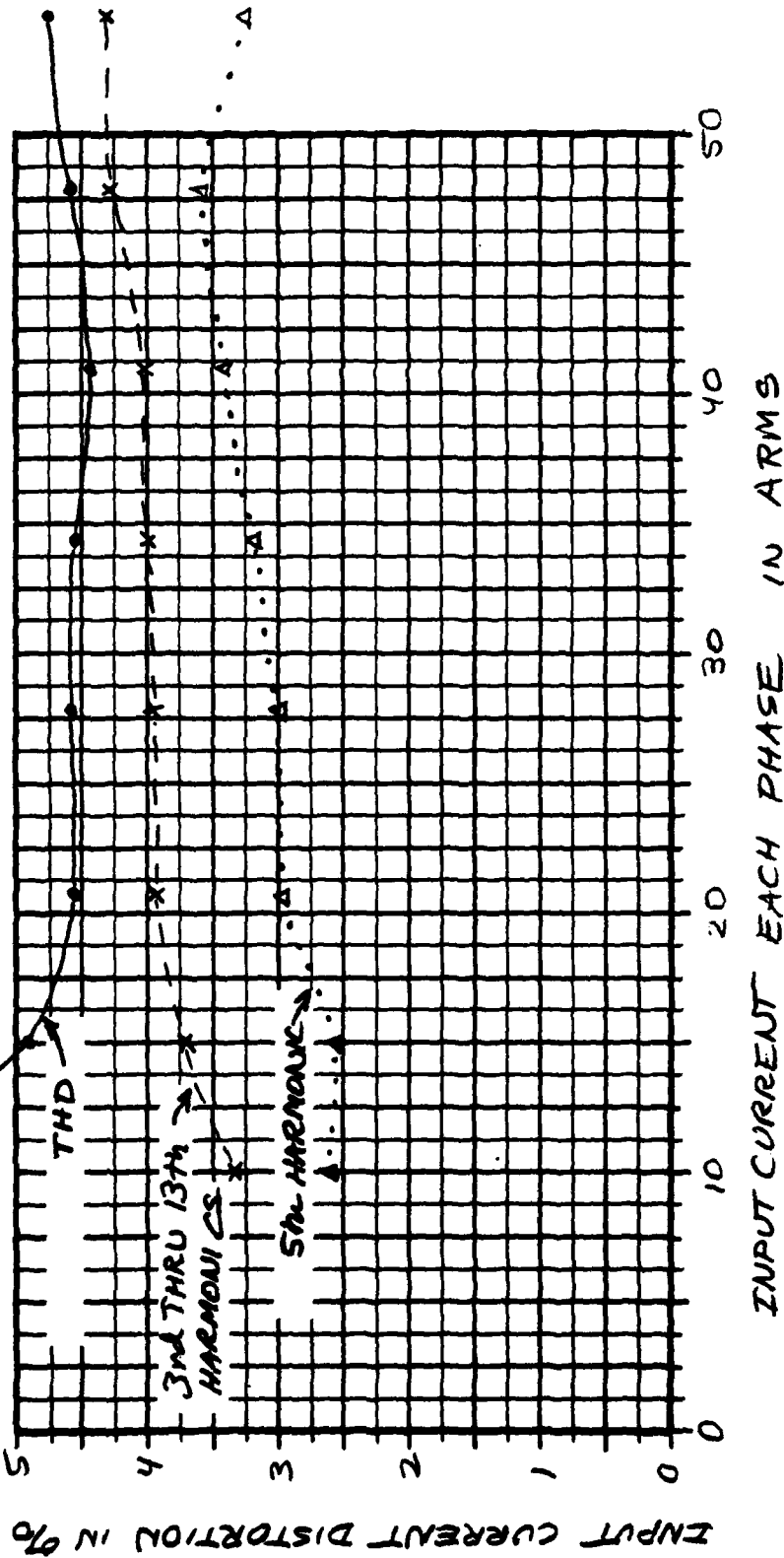


Figure G-1.

SSP9

EQUIP DESCRIPTION _____

TEST NO. 01-03-1

SHEET _____ OF _____

SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION INPUT V-I-PWRDATE 1-MAR-82

MFR _____

PROJ ENGR _____

MODEL NO. _____

TEST BY _____

SERIAL NO. _____

OBSERVER _____

400Hz OUTREF: 200T 15.5KW 0.8PF

(1) MEASUREMENT	(2) INST NO. (a)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) INPUT ϕ A VOLTAGE		<u>118.9</u>		V				
(a) ϕ A CURRENT		<u>53.90</u>		A				
(a) ϕ A PHASE ANGLE				deg				
(a) ϕ A POWER		<u>6392</u>		W				
(a) ϕ B VOLTAGE		<u>119.8</u>		V				
(a) ϕ B CURRENT		<u>55.32</u>		A				
(a) ϕ B PHASE ANGLE				deg				
(a) ϕ B POWER		<u>6593</u>		W				
(a) ϕ C VOLTAGE		<u>119.0</u>		V				
(a) ϕ C CURRENT		<u>53.64</u>		A				
(a) ϕ C PHASE ANGLE				deg				
(a) ϕ C POWER		<u>6339</u>		W				
(a) CONV FREQUENCY				Hz				
(a)		<u>19340</u>						

NOTE: LOAD BANK 1 SW 12.4.7 full LOAD BANK 2 SW 5.6.7 partialORIGINAL FILTER CONFIGURATION, NO EXTERNAL COMPONENTS

1

EQUIP DESCRIPTION



SANTA BARBARA, CALIFORNIA

TEST NO. 01-03-1

SHEET OF

TEST DESCRIPTION HARMONIC ANALYSIS

DATE 1-MAR-62

INSTR

PROJ ENGR

MODEL NO.

TEST BY

SERIAL NO.

OBSERVER

INPUT CURRENT

REF:

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
HARMONIC ANALYSIS		PIX NO.	
FUNDAMENTAL	Hz	100%	---
3rd		0.70 %	%
5th		3.25 %	%
7th		2.75 %	%
9th		0.20 %	%
11th		0.95 %	%
13th		---	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

NOTES

R62-127

4.36 90

308

EQUIP DESCRIPTION _____

TEST NO. 01-03-1

SHEET _____ OF _____

DATE _____

PROJ ENGR _____

TEST BY _____

OBSERVER _____

TEST DESCRIPTION INPUT CURRENT WAVEFORM

MFR _____

MODEL NO. _____

SERIAL NO. _____

REF: _____

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
INPUT ϕ A THD		4.42		4.42 %				
ϕ B THD		4.62		4.62 %				
ϕ C THD		4.75		4.75 %				
ϕ A WV ANALYSIS								
ϕ B WV ANALYSIS								
ϕ C WV ANALYSIS								
ϕ A DEV FACTOR				%				
ϕ B DEV FACTOR				%				
ϕ C DEV FACTOR				%				
ϕ A VMOD POS				V				
ϕ A VMOD NEG				V				
ϕ B VMOD POS				V				
ϕ B VMOD NEG				V				
ϕ C VMOD POS				V				
ϕ C VMOD NEG				V				

NOTES: _____

9 EQUIP DESCRIPTION

TEST NO. 01-03-1

SANTA BARBARA, CALIFORNIA

SHEET OF

TEST DESCRIPTION INPUT VOLTAGE WAVEFORM

DATE 1-11-82

INSTR

PROJ ENGR

MODEL NO.

TEST BY

SERIAL NO.

OBSERVER

REF:

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) INPUT ϕA THD		3.81		3.81 %				
(b) ϕB THD		3.88		3.88 %				
(c) ϕC THD		4.00		4.00 %				
(d) ϕA WV ANALYSIS								
(e) ϕB WV ANALYSIS								
(f) ϕC WV ANALYSIS								
(g) ϕA DEV FACTOR				%				
(h) ϕB DEV FACTOR				%				
(i) ϕC DEV FACTOR				%				
(j) ϕA VMOD POS				V				
(k) ϕA VMOD NEG				V				
(l) ϕB VMOD POS				V				
(m) ϕB VMOD NEG				V				
(n) ϕC VMOD POS				V				
(o) ϕC VMOD NEG				V				

NOTES

EQUIP DESCRIPTION _____

TEST NO. 01-03-2

SHEET _____ OF _____

DATE _____

PROJ ENGR _____

TEST BY _____

OBSERVER _____



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION INPUT V-I-PWR

MFGR _____

MODEL NO. _____

SERIAL NO. _____

REF: 2/2.3KW 0.8PF

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) INPUT ϕ A VOLTAGE		119.3		V				
(b) ϕ A CURRENT		47.22		A				
(c) ϕ A PHASE ANGLE				deg				
(d) ϕ A POWER		5605		W				
(e) ϕ B VOLTAGE		119.9		V				
(f) ϕ B CURRENT		48.39		A				
(g) ϕ B PHASE ANGLE				deg				
(h) ϕ B POWER		5753		W				
(i) ϕ C VOLTAGE		118.7		V				
(j) ϕ C CURRENT		46.76		A				
(k) ϕ C PHASE ANGLE				deg				
(l) ϕ C POWER		5508		W				
(m) CONV FREQUENCY		16870		Hz				
(n)								
(o)								

NOTES: _____

$$46.76/53.64 = 0.872$$

EQUIP DESCRIPTION _____

TEST NO. 01-03-2

SHEET _____ OF _____

DATE _____

PROJ ENGR _____

TEST BY _____

OBSERVER _____



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION HARMONIC ANALYSIS

MPGR _____

MODEL NO. _____

SERIAL NO. _____

TURB CHARGENT

REF: _____

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
HARMONIC ANALYSIS		PIX NO.	
FUNDAMENTAL	Hz	100%	—
3rd		0.50 %	%
5th		3.60 %	%
7th		2.20 %	%
9th		0.25 %	%
11th		0.55 %	%
13th		0.20 %	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

NOTES: _____

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

EQUIP DESCRIPTION _____

TEST NO. 01-03-2

SHEET _____ OF _____

DATE _____

PROJ ENGR _____

TEST BY _____

OBSERVER _____



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION INPUT CURRENT WAVEFORM

MFGR _____

MODEL NO. _____

SERIAL NO. _____

REF: _____

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) INPUT ϕ A THD		4.85	0.872	4.23 %				
(b) ϕ B THD		5.05	0.872	4.40 %				
(c) ϕ C THD		5.25	0.872	4.58 %				
(d) ϕ A WV ANALYSIS								
(e) ϕ B WV ANALYSIS								
(f) ϕ C WV ANALYSIS								
(g) ϕ A DEV FACTOR				%				
(h) ϕ B DEV FACTOR				%				
(i) ϕ C DEV FACTOR				%				
(j) ϕ A VMOD POS				V				
(k) ϕ A VMOD NEG				V				
(l) ϕ B VMOD POS				V				
(m) ϕ B VMOD NEG				V				
(n) ϕ C VMOD POS				V				
(o) ϕ C VMOD NEG				V				

NOTES: _____

EQUIP DESCRIPTION



SANTA BARBARA, CALIFORNIA

TEST NO. 01-03-3

SHEET

DATE _____

[illegible]

BS-300

MODEL NO.

SERIAL NO.

REF:

11.1 Kw O.BPF

[illegible]

NOTES

R82-127

$$39.80 / 59.64 = 0.742$$

EQUIP DESCRIPTION _____

TEST NO. 01-03-3

SHEET _____ OF _____

TEST DESCRIPTION HARMONIC ANALYSIS

DATE _____

MPGR _____

PROJ ENGR _____

MODEL NO. _____

TEST BY _____

SERIAL NO. _____

OBSERVER _____

REF: _____

INPUT CURRENT QC

SANTA BARBARA, CALIFORNIA

MEASUREMENT	INST. NO. (s)	MEAS.	SPEC.
HARMONIC ANALYSIS		PIX NO.	
FUNDAMENTAL	Hz	100%	—
3rd		0.40 %	%
5th		3.40 %	%
7th		2.00 %	%
9th		0.20 %	%
11th		0.60 %	%
13th		0.45 %	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

NOTES: _____

MEASUREMENT	INST. NO. (g)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

1.029%

EQUIP DESCRIPTION _____

TEST NO. 01-03-3

SANTA BARBARA, CALIFORNIA

SHEET _____ OF _____

TEST DESCRIPTION INPUT CURRENT WAVEFORM

DATE _____

INFO _____

PROJ ENGR _____

MODEL NO. _____

TEST BY _____

SERIAL NO. _____

OBSERVER _____

REF: _____

(1) MEASUREMENT	(2) INST NO.(4)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
INPUT ϕ A THD		5.42	0.742	4.02 %				
ϕ B THD		5.68	0.742	4.21 %				
ϕ C THD		5.98	0.742	4.44 %				
ϕ A WV ANALYSIS								
ϕ B WV ANALYSIS								
ϕ C WV ANALYSIS								
ϕ A DEV FACTOR				%				
ϕ B DEV FACTOR				%				
ϕ C DEV FACTOR				%				
ϕ A VMOD POS				V				
ϕ A VMOD NEG				V				
ϕ B VMOD POS				V				
ϕ B VMOD NEG				V				
ϕ C VMOD POS				V				
ϕ C VMOD NEG				V				

NOTES: _____



EQUIP DESCRIPTION _____

TEST NO. 01-03-4

SHEET _____ OF _____

TEST DESCRIPTION INPUT V-I-PWR

DATE _____

MFGR _____

PROJ ENGR _____

MODEL NO. _____

TEST BY _____

SERIAL NO. _____

OBSERVER _____

REF: _____

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) INPUT ϕ A VOLTAGE		120.4		V				
(b) ϕ A CURRENT		33.82		A				
(c) ϕ A PHASE ANGLE				deg				
(d) ϕ A POWER		4023		W				
(e) ϕ B VOLTAGE		120.6		V				
(f) ϕ B CURRENT		34.67		A				
(g) ϕ B PHASE ANGLE				deg				
(h) ϕ B POWER		4110		W				
(i) ϕ C VOLTAGE		119.6		V				
(j) ϕ C CURRENT		33.33		A				
(k) ϕ C PHASE ANGLE				deg				
(l) ϕ C POWER		3919		W				
(m) CONV FREQ		12060		Hz				
(n)								
(o)								

NOTES: _____

$$33.33 / 53.64 = 0.621$$

EQUIP DESCRIPTION _____

TEST NO. 01-03-4

SHEET _____

OF _____

DATE _____

PROJ ENGR _____

TEST BY _____

OBSERVER _____



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION HARMONIC ANALYSIS

MFG _____

MODEL NO. _____

SERIAL NO. _____

REF: _____

INPUT CURRENT ϕ C

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
HARMONIC ANALYSIS		P1X NO.	
FUNDAMENTAL	Hz	100%	—
3rd		0.25%	%
5th		3.20%	%
7th		2.20%	%
9th		0.10%	%
11th		0.80%	%
13th		0.35%	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

NOTES: _____

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

EQUIP DESCRIPTION _____

TEST NO. 01-03-4

SHEET _____ OF _____

DATE _____

PROJ ENGR _____

TEST BY _____

OBSERVER _____



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION INPUT CURRENT WAVEFORM

MFGR _____

MODEL NO. _____

SERIAL NO. _____

REF: _____

(1) MEASUREMENT	(2) INST NO. (s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
INPUT ϕ A THD		0.621	6.65	4.13 %				
ϕ B THD		0.621	6.90	4.28 %				
ϕ C THD		0.621	7.30	4.54 %				
ϕ A WV ANALYSIS								
ϕ B WV ANALYSIS								
ϕ C WV ANALYSIS								
ϕ A DEV FACTOR				%				
ϕ B DEV FACTOR				%				
ϕ C DEV FACTOR				%				
ϕ A VMOD POS				V				
ϕ A VMOD NEG				V				
ϕ B VMOD POS				V				
ϕ B VMOD NEG				V				
ϕ C VMOD POS				V				
ϕ C VMOD NEG				V				

NOTES: _____



EQUIP DESCRIPTION

SANTA BARBARA, CALIFORNIA

TEST NO. 01-03-5

SHEET OF

TEST DESCRIPTION INPUT V-I-PWR

DATE

INSTR

PROJ ENGR

MODEL NO.

TEST BY

SERIAL NO.

OBSERVER

REF:

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
INPUT ϕ A VOLTAGE		120.6		V				
ϕ A CURRENT		27.54		A				
ϕ A PHASE ANGLE				deg				
ϕ A POWER		3250		W				
ϕ B VOLTAGE		120.8		V				
ϕ B CURRENT		28.25		A				
ϕ B PHASE ANGLE				deg				
ϕ B POWER		3319		W				
ϕ C VOLTAGE		119.9		V				
ϕ C CURRENT		27.07		A				
ϕ C PHASE ANGLE				deg				
ϕ C POWER		3146		W				
CONV FREQUENCY		9720		Hz				

NOTES:

27.07 / 53.64 = 0.505

EQUIP DESCRIPTION _____

SANTA BARBARA, CALIFORNIA

TEST NO. 01-03-5

SHEET _____ OF _____

TEST DESCRIPTION HARMONIC ANALYSIS

DATE _____

INFR _____

PROJ ENGR _____

MODEL NO. _____

TEST BY _____

SERIAL NO. _____

OBSERVER _____

REF: _____

INPUT CURRENT ϕ C

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
HARMONIC ANALYSIS		PIX NO.	
FUNDAMENTAL	Hz	100%	—
3rd		0.25 %	%
5th		3.00 %	%
7th		2.30 %	%
9th		0.20 %	%
11th		1.00 %	%
13th		0.30 %	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

NOTE: _____

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

EQUIP DESCRIPTION _____

TEST NO. 01-03-S

SANTA BARBARA, CALIFORNIA

SHEET _____ OF _____

TEST DESCRIPTION INPUT CURRENT WAVEFORM

DATE _____

INFR _____

PROJ ENGR _____

MODEL NO. _____

TEST BY _____

SERIAL NO. _____

OBSERVER _____

REF: _____

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
INPUT ϕ A THD		8.12	0.505	4.10 %				
ϕ B THD		8.62	0.505	4.35 %				
ϕ C THD		9.08	0.505	4.58 %				
ϕ A WV ANALYSIS								
ϕ B WV ANALYSIS								
ϕ C WV ANALYSIS								
ϕ A DEV FACTOR				%				
ϕ B DEV FACTOR				%				
ϕ C DEV FACTOR				%				
ϕ A VMOD POS				V				
ϕ A VMOD NEG				V				
ϕ B VMOD POS				V				
ϕ B VMOD NEG				V				
ϕ C VMOD POS				V				
ϕ C VMOD NEG				V				

NOTES: _____

EQUIP DESCRIPTION _____

TEST NO. 01-03-6

SHEET _____ OF _____

SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION INPUT V-I-PWR

DATE _____

PROJ ENGR _____

TEST BY _____

OBSERVER _____

MFR _____

MODEL NO. _____

SERIAL NO. _____

REF: _____

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) INPUT ϕ A VOLTAGE		121.9		V				
(b) ϕ A CURRENT		20.94		A				
(c) ϕ A PHASE ANGLE				deg				
(d) ϕ A POWER		2440		W				
(e) ϕ B VOLTAGE		122.1		V				
(f) ϕ B CURRENT		21.58		A				
(g) ϕ B PHASE ANGLE				deg				
(h) ϕ B POWER		2488		W				
(i) ϕ C VOLTAGE		121.0		V				
(j) ϕ C CURRENT		20.54		A				
(k) ϕ C PHASE ANGLE				deg				
(l) ϕ C POWER		2346		W				
(m) CONV FREQUENCY		7280		Hz				
(n)								
(o)								

NOTES: _____

$$20.54 / 53.64 = 0.383$$

EQUIP DESCRIPTION

TEST NO. 01-03-6

SHEET OF

SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION HARMONIC ANALYSIS

DATE

INFR

PROJ ENGR

MODEL NO.

TEST BY

SERIAL NO.

OBSERVER

REF:

INPUT CURRENT φC

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
HARMONIC ANALYSIS		PIX NO.	
FUNDAMENTAL	Hz	100%	—
3rd		0.20 %	%
5th		2.95 %	%
7th		2.10 %	%
9th		0.20 %	%
11th		1.45 %	%
13th		0.30 %	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

NOTES

EQUIP DESCRIPTION _____

TEST NO. 01-03-6

SHEET _____ OF _____

DATE _____

PROJ ENGR _____

TEST BY _____

OBSERVER _____

TEST DESCRIPTION INPUT CURRENT WAVEFORM

MFGR _____

MODEL NO. _____

SERIAL NO. _____

REF: _____

(1) MEASUREMENT	(2) INST NO.(a)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
INPUT ϕ A THD		10.7	0.383	4.10 %				
ϕ B THD		11.6	0.383	4.44 %				
ϕ C THD		12.0	0.383	4.60 %				
ϕ A WV ANALYSIS								
ϕ B WV ANALYSIS								
ϕ C WV ANALYSIS								
ϕ A DEV FACTOR				%				
ϕ B DEV FACTOR				%				
ϕ C DEV FACTOR				%				
ϕ A VMOD POS				V				
ϕ A VMOD NEG				V				
ϕ B VMOD POS				V				
ϕ B VMOD NEG				V				
ϕ C VMOD POS				V				
ϕ C VMOD NEG				V				

NOTES: _____

EQUIP DESCRIPTION _____

TEST NO. 01-03-7

SHEET _____ OF _____

DATE _____

PROJ ENGR _____

TEST BY _____

OBSERVER _____



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION INPUT _____, V-I-PWR _____

MFGR _____

MODEL NO. _____

SERIAL NO. _____

REF: _____

(1) MEASUREMENT	(2) INST NO. (s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) INPUT ϕ A VOLTAGE		122.1		V				
(b) ϕ A CURRENT		14.90		A				
(c) ϕ A PHASE ANGLE				deg				
(d) ϕ A POWER		1643		W				
(e) ϕ B VOLTAGE		122.3		V				
(f) ϕ B CURRENT		15.54		A				
(g) ϕ B PHASE ANGLE				deg				
(h) ϕ B POWER		1680		W				
(i) ϕ C VOLTAGE		121.5		V				
(j) ϕ C CURRENT		14.63		A				
(k) ϕ C PHASE ANGLE				deg				
(l) ϕ C POWER		1556		W				
(m) CONV FREQUENCY		4890		Hz				
(n)								
(o)								

NOTES: _____

$$14.63/53.64 = 0.273$$



EQUIP DESCRIPTION _____

TEST NO. 01-03-7

SHEET _____ OF _____

SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION HARMONIC ANALYSISDATE 01-MAR-82

MFGR _____

PROJ ENGR _____

MODEL NO. _____

TEST BY _____

SERIAL NO. _____

OBSERVER _____

REF: _____

INPUT CURRENT DC

MEASUREMENT	INST. NO. (s)	MEAS.	SPEC.
HARMONIC ANALYSIS		PIX NO.	
FUNDAMENTAL		100%	—
3rd		0.30 %	%
5th		2.60 %	%
7th		2.10 %	%
9th	0.50	2.55 %	%
11th		1.60 %	%
13th		0.30 %	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

NOTES: _____

MEASUREMENT	INST. NO. (s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

EQUIP DESCRIPTION _____

TEST NO. 01-03-7

SHEET _____ OF _____

DATE _____

PROJ ENGR _____

TEST BY _____

OBSERVER _____



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION INPUT CURRENT WAVEFORM

INSTR _____

MODEL NO. _____

SERIAL NO. _____

REF: _____

(1) MEASUREMENT	(2) INST NO.(4)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
INPUT ϕ A THD		16.3	0.273	4.45 %				
ϕ B THD		16.9	0.273	4.61 %				
ϕ C THD		18.0	0.273	4.91 %				
ϕ A WV ANALYSIS								
ϕ B WV ANALYSIS								
ϕ C WV ANALYSIS								
ϕ A DEV FACTOR				%				
ϕ B DEV FACTOR				%				
ϕ C DEV FACTOR				%				
ϕ A VMOD POS				V				
ϕ A VMOD NEG				V				
ϕ B VMOD POS				V				
ϕ B VMOD NEG				V				
ϕ C VMOD POS				V				
ϕ C VMOD NEG				V				

NOTES: _____

EQUIP DESCRIPTION _____

TEST NO. 01-03-8

SHEET _____ OF _____

DATE _____

PROJ ENGR _____

TEST BY _____

OBSERVER _____



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION INPUT V-I-PWR

MFGR _____

MODEL NO. _____

SERIAL NO. _____

REF: NL

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) INPUT ϕ A VOLTAGE		122.6		V				
(b) ϕ A CURRENT		9.62		A				
(c) ϕ A PHASE ANGLE				deg				
(d) ϕ A POWER		847		W				
(e) ϕ B VOLTAGE		122.7		V				
(f) ϕ B CURRENT		10.23		A				
(g) ϕ B PHASE ANGLE				deg				
(h) ϕ B POWER		860		W				
(i) ϕ C VOLTAGE		121.7		V				
(j) ϕ C CURRENT		9.48		A				
(k) ϕ C PHASE ANGLE				deg				
(l) ϕ C POWER		767		W				
(m) CONV FREQUENCY		2480		Hz				
(n) _____								
(o) _____								

NOTES: _____

9

$$9.48/5364 = 0.177$$

EQUIP DESCRIPTION _____

TEST NO. 01-03-8

SHEET _____ OF _____

DATE 01-MAR-82

PROJ ENGR _____

TEST BY _____

OBSERVER _____



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION HARMONIC ANALYSIS

INFOR _____

MODEL NO. _____

SERIAL NO. _____

INPUT CURRENT ΦC

REF: _____

UL

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
HARMONIC ANALYSIS		PIX NO.	
FUNDAMENTAL	Hz	100%	—
3rd		— %	%
5th		2.65%	%
7th		1.50%	%
9th		0.35%	%
11th		1.30%	%
13th		0.35%	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

NOTES: _____

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

EQUIP DESCRIPTION _____

TEST NO. 01-03-B

SHEET _____ OF _____

TEST DESCRIPTION INPUT CURRENT WAVEFORM

DATE _____

PROJ ENGR _____

TEST BY _____

OBSERVER _____

MFGR _____

MODEL NO. _____

SERIAL NO. _____

REF: _____

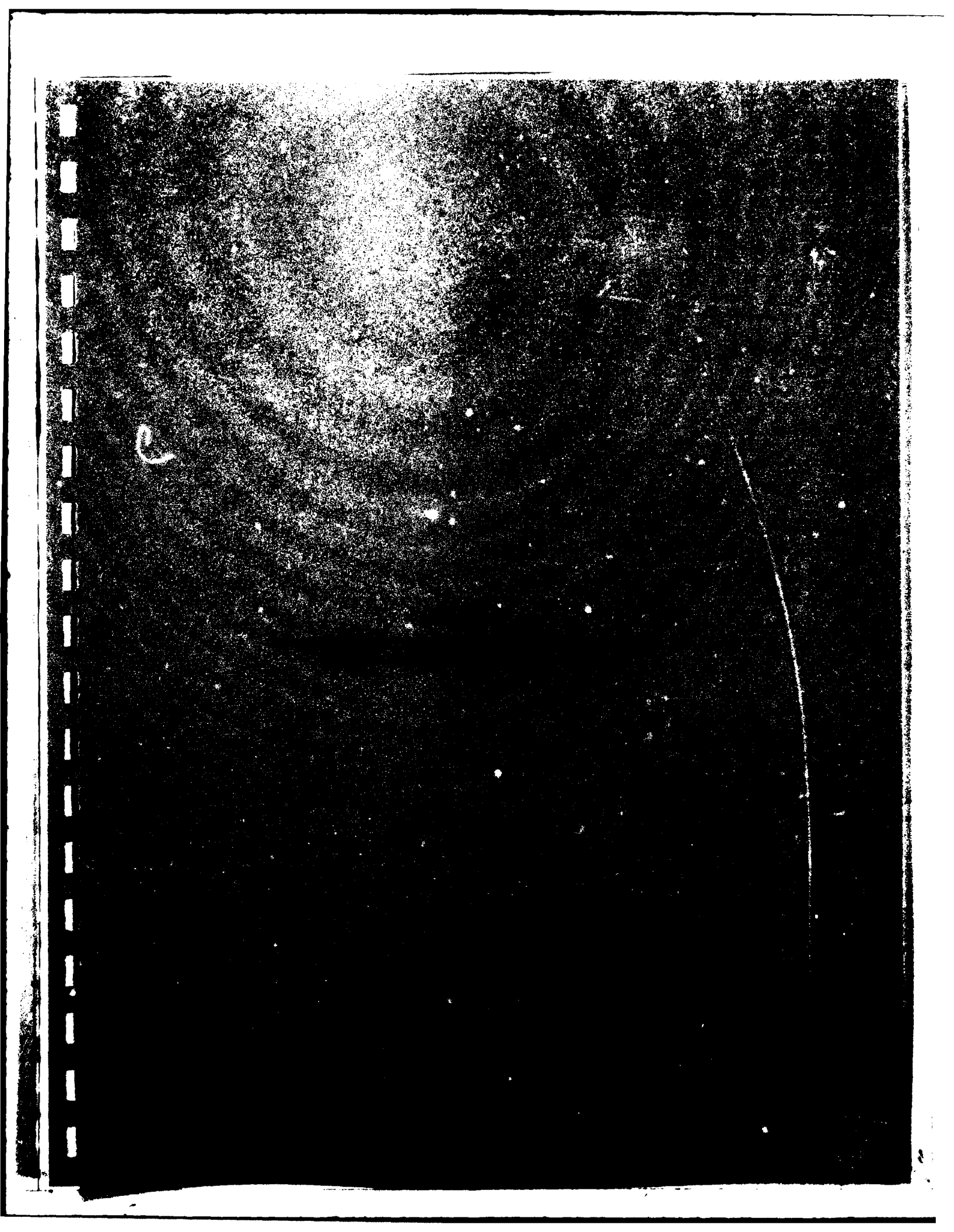
A/L



SANTA BARBARA, CALIFORNIA

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
INPUT ϕ A THD		32.0	0.177	5.66 %				
ϕ B THD		32.5	0.177	5.75 %				
ϕ C THD		34.5	0.177	6.10 %				
ϕ A WV ANALYSIS								
ϕ B WV ANALYSIS								
ϕ C WV ANALYSIS								
ϕ A DEV FACTOR				%				
ϕ B DEV FACTOR				%				
ϕ C DEV FACTOR				%				
ϕ A VMOD POS				V				
ϕ A VMOD NEG				V				
ϕ B VMOD POS				V				
ϕ B VMOD NEG				V				
ϕ C VMOD POS				V				
ϕ C VMOD NEG				V				

NOTES: _____



**15 kW FREQUENCY CHANGER INPUT CURRENT WAVEFORM
TESTING WITH AUGMENTED INPUT FILTER**

The 15 kW Frequency Changer - with the original single R-L-C input filter augmented with a second R-L-C stage located externally to the frequency changer for lack of space internally - was operated over a wide load range. The input current waveforms, THD, and harmonic components were recorded.

Figure H-1 is a plot of some of the raw data which appears in test records 24-05-01 and 25-05-01. Data were taken over the input current range of 10 to approximately 55 Arms. This corresponds to a load range of approximately 10 to 110 percent for the converter portion (NL to 1.1 RL for the inverter portion).

EQUIP 15KW FREED CHGRMFR DELCO

MODEL NO. _____

SERIAL NO. _____

REF: _____



SANTA BARBARA, CALIFORNIA

TEST NO. SEE TEST RECDATE MAY 24 1982

BY _____

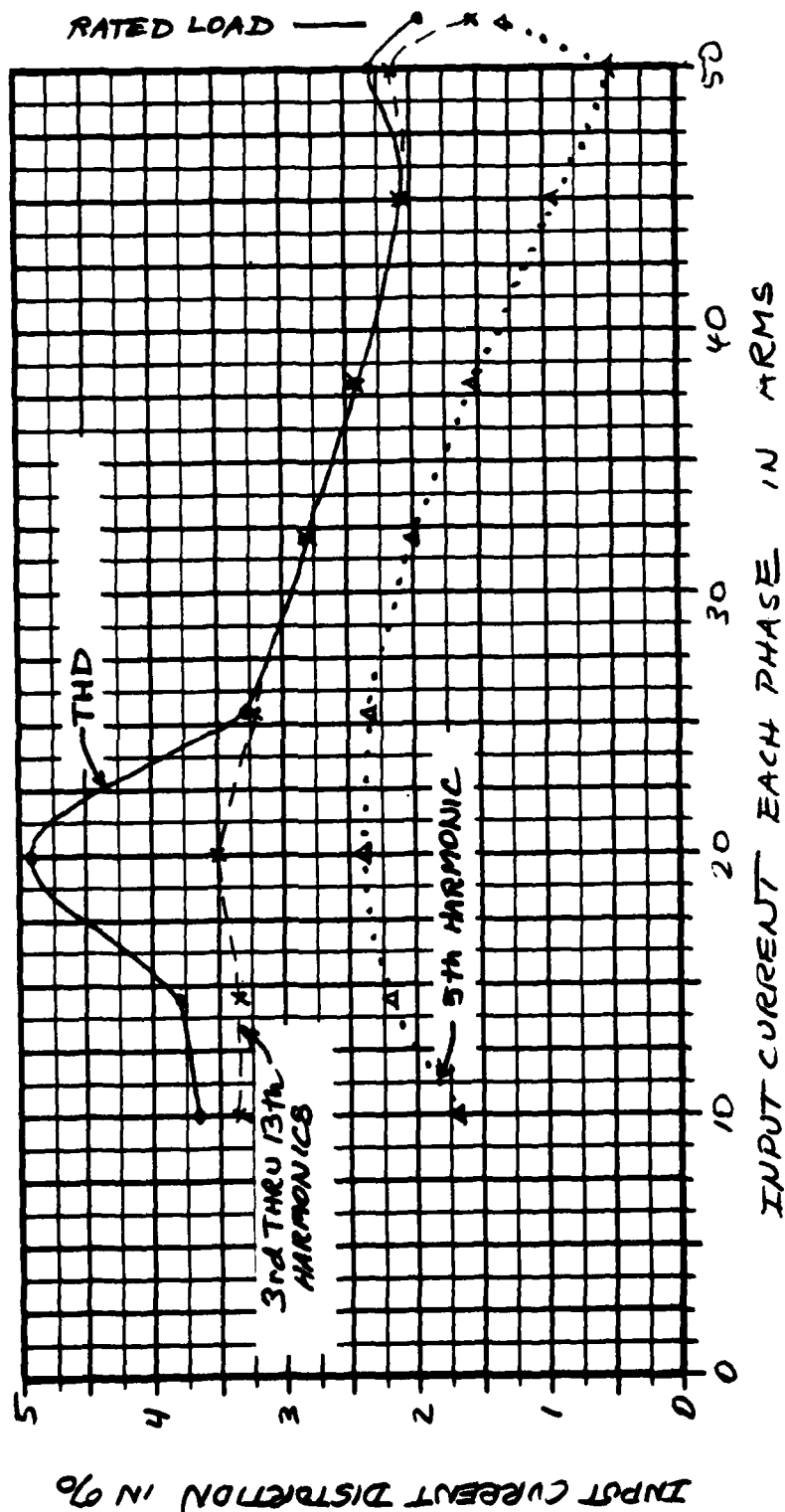
TEST REC 24-5-01Q. 25-5-01AUGMENTEDINPUT FILTER

Figure H-1.

EQUIP DESCRIPTION 15KW
GENERAL PURPOSE
FREQUENCY CHANGER
 MFR DELCO
 MODEL NO. _____
 SERIAL NO. _____



SANTA BARBARA, CALIFORNIA

TEST NO. 24-5-01
 SHEET _____ OF _____
 DATE 24-MAY-1982
 PROJ ENGR _____
 TEST BY C.B. Barrett
 OBSERVER _____

TEST DESCRIPTION INPUT V-I-PWR
DRIVER INPUT
TESTS
 REF: 17.3KW

(1) MEASUREMENT	(2) INST NO. (a)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) INPUT ϕ A VOLTAGE		120.7		120.7 V				
(b) ϕ A CURRENT		52.25		52.25 A				
(c) ϕ A PHASE ANGLE		—		— ϕ	PF = 0.998			
(d) ϕ A POWER		6297		6297 W				
(e) ϕ B VOLTAGE		120.6		120.6 V				
(f) ϕ B CURRENT		53.32		53.32 A				
(g) ϕ B PHASE ANGLE		—		— ϕ	PF = 0.998			
(h) ϕ B POWER		6417		6417 W				
(i) ϕ C VOLTAGE		120.0		120.0 V				
(j) ϕ C CURRENT		52.54		52.54 A				
(k) ϕ C PHASE ANGLE		—		— ϕ	PF = 0.998			
(l) ϕ C POWER		6295		6295 W				
(m) CORN FREQUENCY		—		— Hz				
(n) TOTAL INPUT POWER		19009		19009 W				
(o) TOTAL OUTPUT POWER		417300		417300 W				

NOTES: ABOVE READINGS TAKEN USING YEW 2505 / YEW 2514-47

PACAL WATTMETER

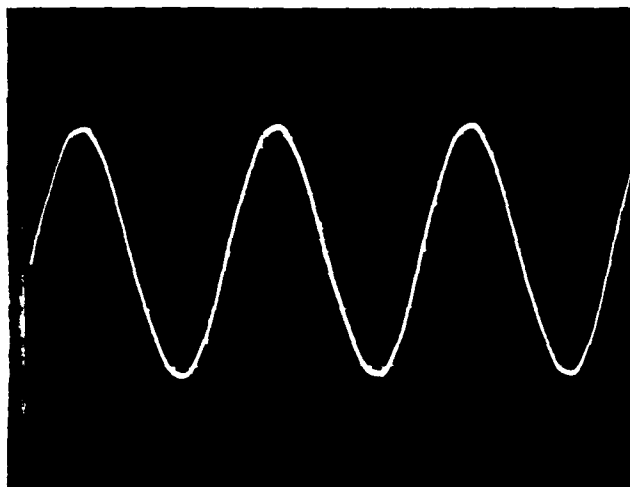
(c) PF = $\frac{d}{a \times b}$

(g) PF = $\frac{b}{a \times f}$

(k) PF = $\frac{1}{i \times j}$



SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION L-N VOLTAGE
WAVEFORMS

V1 V ϕ A L-N (UNCAL)

V2 THD = 1.43%

V3 CONV NOT OPERATING

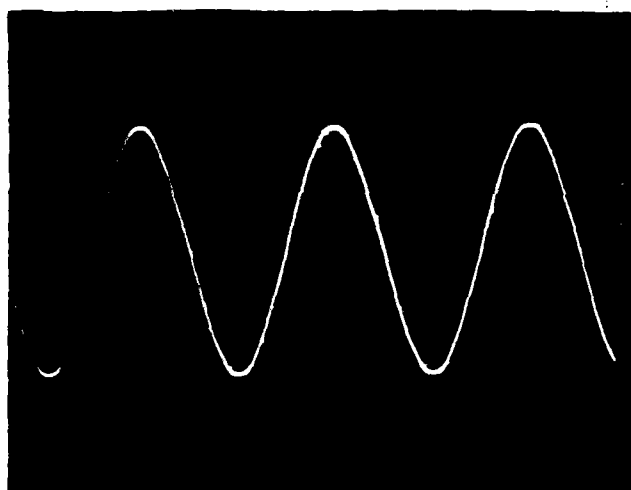
V4 _____

H1 _____

H2 _____

TEST NO. _____

PIX NO. _____



V1 V ϕ B L-N

V2 THD = 1.46%

V3 CONV NOT OPERATING

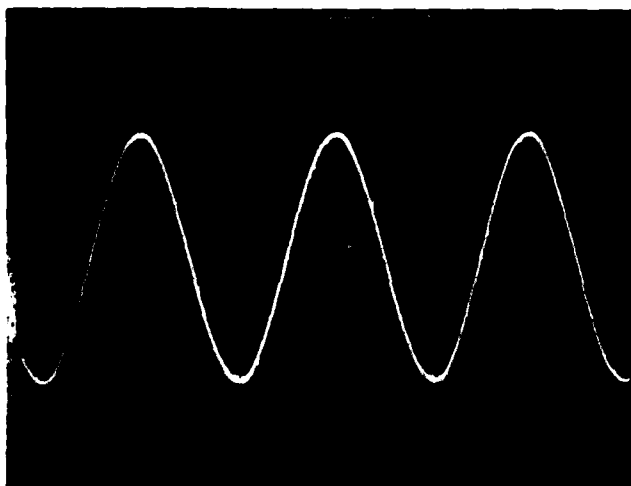
V4 _____

H1 _____

H2 _____

TEST NO. _____

PIX NO. _____



V1 V ϕ C L-N

V2 THD = 0.78%

V3 CONV NOT OPERATING

V4 _____

H1 _____

H2 _____

TEST NO. _____

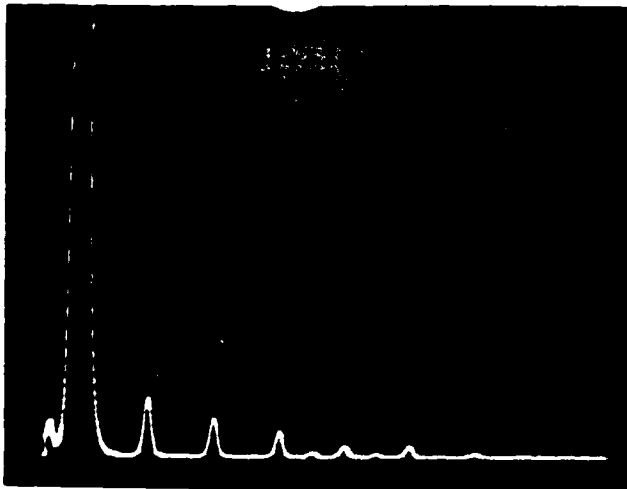
PIX NO. _____

R83-127

SSP1



SANTA BARBARA, CALIFORNIA

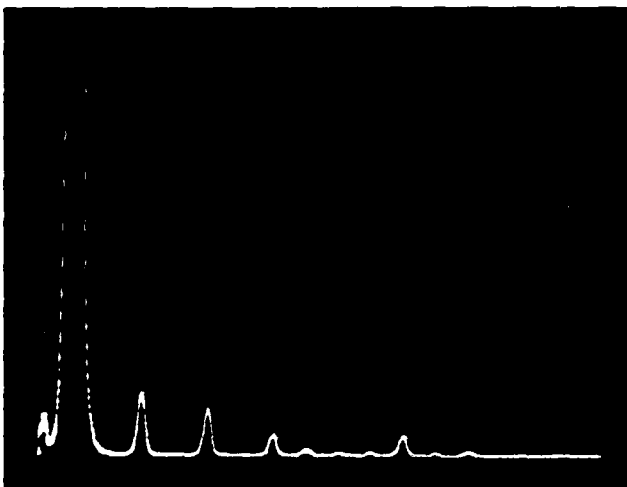


TEST DESCRIPTION L-N VOLTAGE
DISTORTION COMPONENTS

V1 V ϕ A L-N (THD=1.43%)
V2 DISTORTION 1% / DIV
V3 CONV NOT
V4 OPERATING
H1 100 Hz / DIV
H2

TEST NO. _____

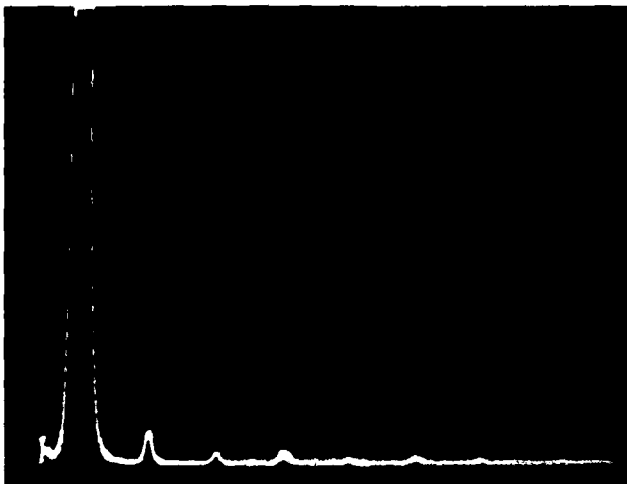
PIX NO. _____



V1 V ϕ B (THD=1.46%)
V2 _____
V3 _____
V4 _____
H1 _____
H2 _____

TEST NO. _____

PIX NO. _____



V1 V ϕ C (THD=0.78%)
V2 _____
V3 _____
V4 _____
H1 _____
H2 _____

TEST NO. _____

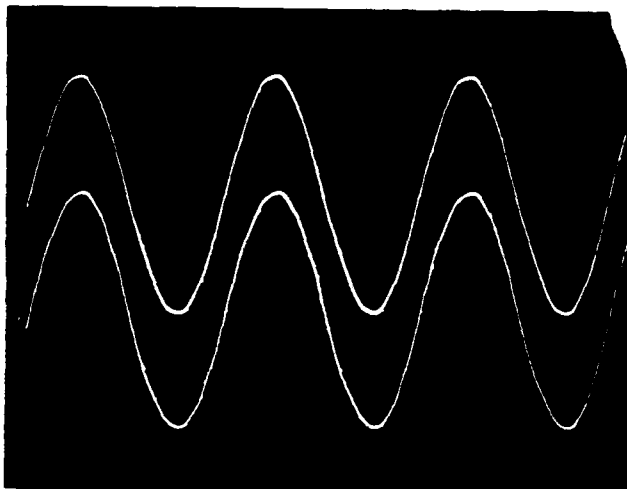
PIX NO. _____

H-8

SSP1



SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION L-N VOLTAGE
& CURRENT WAVEFORMS

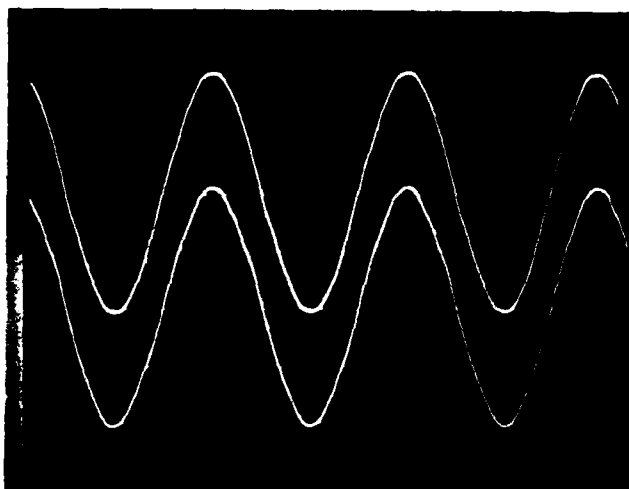
V1 V ϕ A L-N THD=1.22%
V2 I ϕ A THD=2.32%
V3 CONVERTER INPUT
V4 POWER = 19 KW

H1 _____

H2 _____

TEST NO. _____

PIX NO. 1



V1 V ϕ B L-N THD=1.50%
V2 I ϕ B THD=1.90%

V3 _____

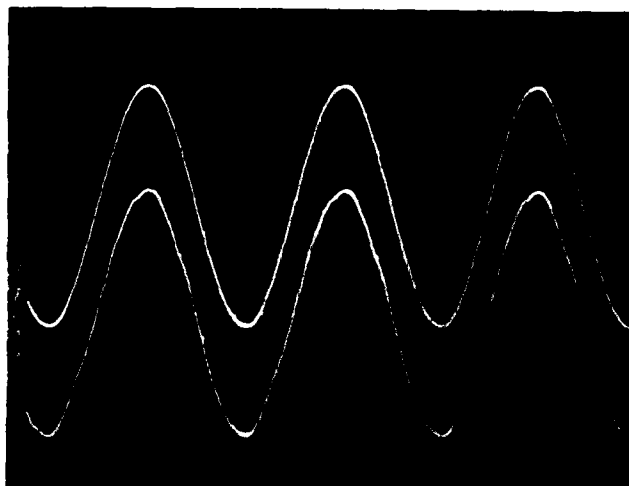
V4 _____

H1 _____

H2 _____

TEST NO. _____

PIX NO. 2



V1 V ϕ C L-N THD=0.85%
V2 I ϕ C THD=2.22%

V3 _____

V4 _____

H1 _____

H2 _____

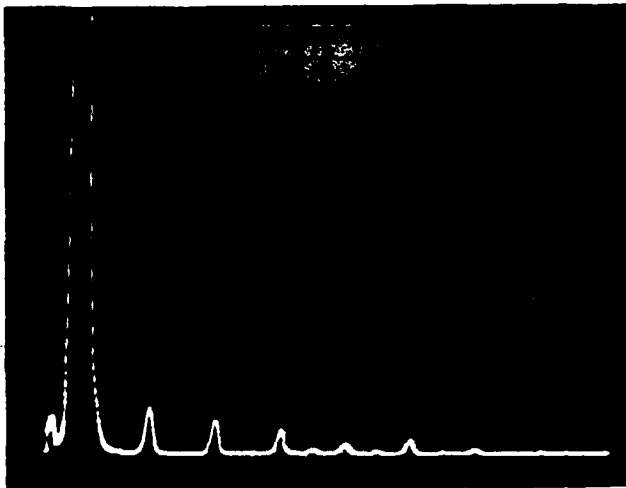
TEST NO. _____

PIX NO. 3

- R82-127



SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION L-N VOLTAGE

DISTORTION COMPONENTS

V1 V ϕ A L-N (THD=1.22%)

V2 DISTORTION 10% DIV

V3 CONV INPUT 19KW

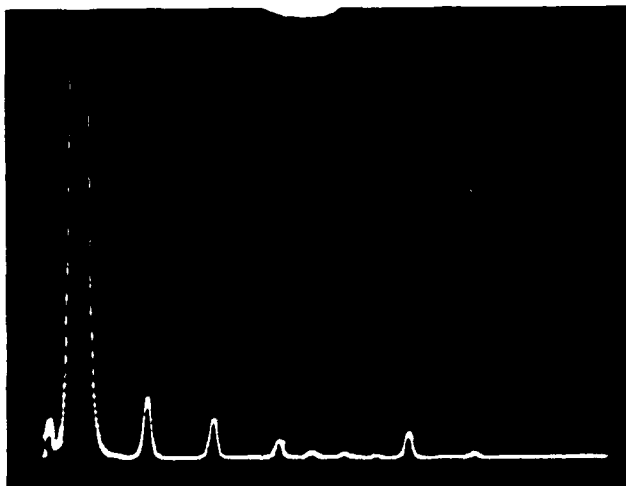
V4 _____

H1 100 HZ / DIV

H2 _____

TEST NO. _____

PIX NO. _____



V1 V ϕ B L-N (THD=1.50%)

V2 _____

V3 _____

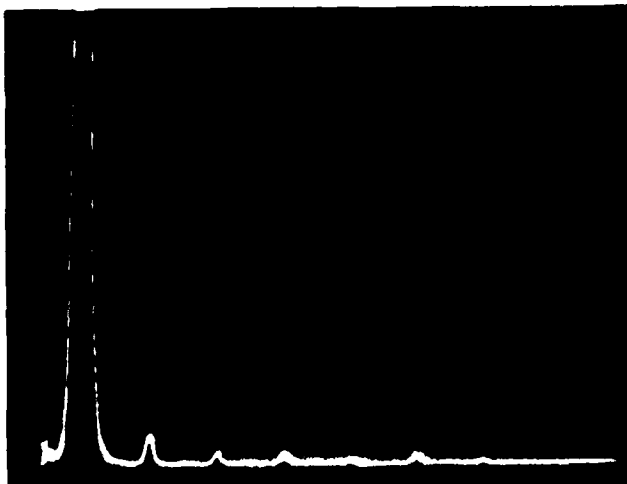
V4 _____

H1 _____

H2 _____

TEST NO. _____

PIX NO. _____



V1 V ϕ C L-N (THD=0.85%)

V2 _____

V3 _____

V4 _____

H1 _____

H2 _____

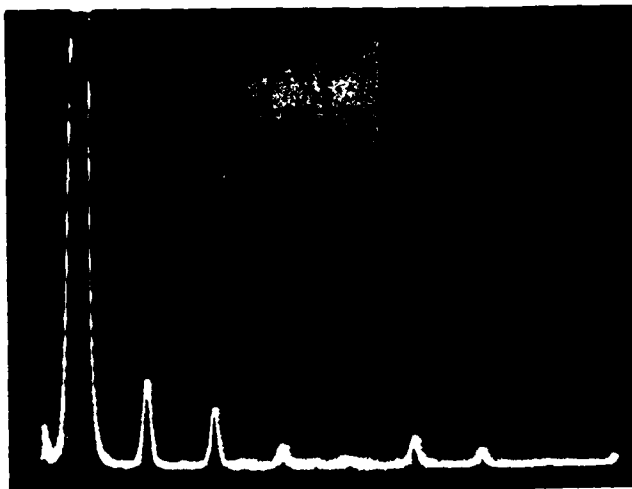
TEST NO. _____

PIX NO. _____

R82-127

H-7

3371



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION INPUT CURRENT
DISTORTION COMPONENTS

V1 $I\phi A$ (THD=2.32%)

V2 DISTORTION 1% / DIV

V3 CONV INPUT 19 KW

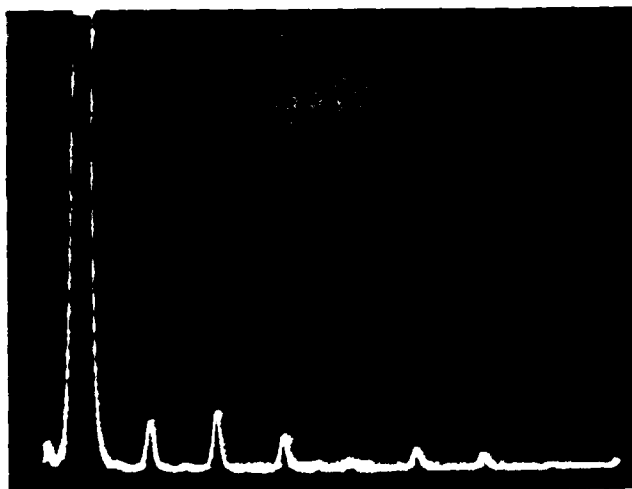
V4 _____

H1 100 Hz / DIV

H2 _____

TEST NO. _____

PIX NO. _____



V1 $I\phi B$ (THD=1.90%)

V2 _____

V3 _____

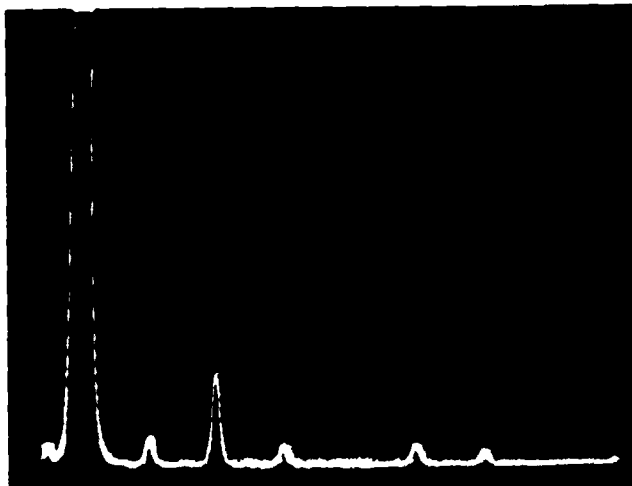
V4 _____

H1 _____

H2 _____

TEST NO. _____

PIX NO. _____



V1 $I\phi C$ (THD=2.22%)

V2 _____

V3 _____

V4 _____

H1 _____

H2 _____

TEST NO. _____

PIX NO. _____

R82-127

SSP

EQUIP DESCRIPTION 15KW
GENERAL PURPOSE
FREQ CHARGER

MFRS DELCO

MODEL NO. _____

SERIAL NO. _____

TEST DESCRIPTION INPUT , V-I-PWRINPUT CURRENTHARMONIC TESTS

REF: _____

TEST NO. 25-5-01SHEET 1 OF 9DATE 25 MAY 82

PROJ ENGR _____

TEST BY C. G. B. B. B.

OBSERVER _____



SANTA BARBARA, CALIFORNIA

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) INPUT ϕ A VOLTAGE		120		V				
(b) ϕ A CURRENT		50.40	down	A				
(c) ϕ A PHASE ANGLE				deg				
(d) ϕ A POWER				W				
(e) ϕ B VOLTAGE				V				
(f) ϕ B CURRENT				A				
(g) ϕ B PHASE ANGLE				deg				
(h) ϕ B POWER				W				
(i) ϕ C VOLTAGE				V				
(j) ϕ C CURRENT		50.46	down	A				
(k) ϕ C PHASE ANGLE				deg				
(l) ϕ C POWER				W				
(m) CONV FREQUENCY				Hz				
(n) TOTAL POWER INPUT		18.1KW	down to 2KW					

NOTES: I ϕ A and I ϕ C examined at different power levels
LINE VOLTAGE DISTORTION w/o CONVERTER IS RATHER HIGH
AT THIS TIME $\approx 20\%$ THD
ADD'D INPUT FILTER FOR THIS TEST SAME AS 26-02-01
L=650uH, R=15 Ω , C=10uF (line to line)

TEST DESCRIPTION:

SERIAL NO.

REF:

[illegible]

NOTES:

EQUIP DESCRIPTION _____

TEST NO. 25-S-01SHEET 3 OF 9

DATE _____

PROJ ENGR _____

TEST BY _____

OBSERVER _____

TEST DESCRIPTION _____

MFR _____

MODEL NO. _____

SERIAL NO. _____

REF: _____



SANTA BARBARA, CALIFORNIA

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED T&D	(4) CORR FACTOR	(5) MEASURED T&D	(6) CALCULATIONS/OTHER WORKING MEAS.	(7) PIX NO.	(8) PERE THD 5-2	(9) SPEC LIMIT
(a) IFC 50.46 ARMS		1.32	50.46/a	1.32	0.80%, 3rd		1.26	1.144444444
(b) 45.30 ARMS		1.48	45.30/a	1.33	1.00%, 5th		1.34	
(c) 38.33 ARMS		2.42	38.33/a	1.84	1.55%, 5th		1.80	
(d) 32.03 ARMS		3.75	32.03/a	2.38	2.15%, 5th		2.39	
(e) 25.78 ARMS		5.90	25.78/a	3.01	2.60%, 5th		2.96	
(f) 19.80 ARMS		13.2	19.80/a	5.18	2.95%, 5th		3.43	
(g) 14.19 ARMS		14.5	14.19/a	4.08	3.00%, 5th		3.48	3.00%
(h) 10.14 ARMS		20.5	10.14/a	4.12	2.65%, 5th		3.68	
(i)								
(j)								
(k)								
(l)								
(m)								
(n)								
(o)								

NOTES: _____



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION

V1 $I_{\phi A}$ 50.40 ARMS

V2

V3 1% / DIV

V4

H1 100 Hz / DIV

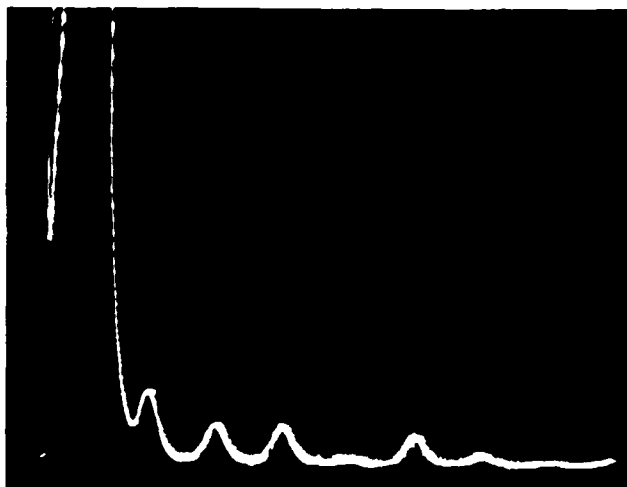
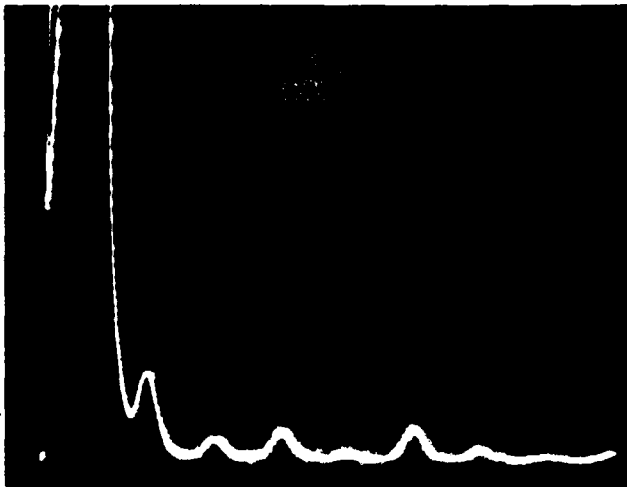
H2

TEST NO. 25-5-01

PIX NO.

TAD = 2.19

File



V1 $I_{\phi A}$ 45.05 ARMS

V2 (REF 50.40)

V3 1% / DIV

V4

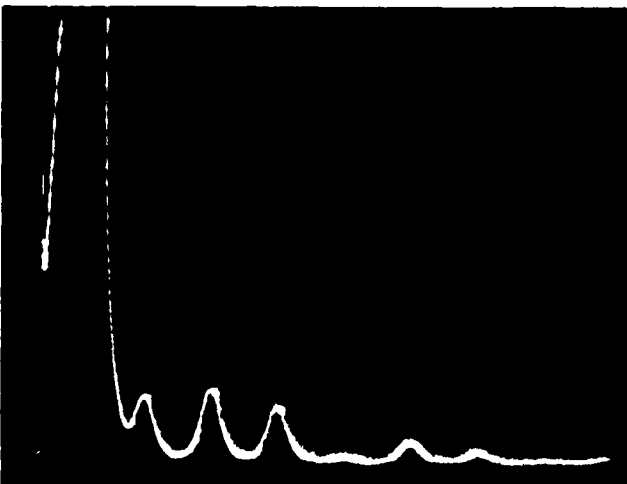
H1

H2

TEST NO.

PIX NO.

TAD = 2.12



V1 $I_{\phi A}$ 38.32 ARMS

V2 (REF 50.40 FS)

V3 1% / DIV

V4

H1

H2

TEST NO.

PIX NO.

TAD = 2.45

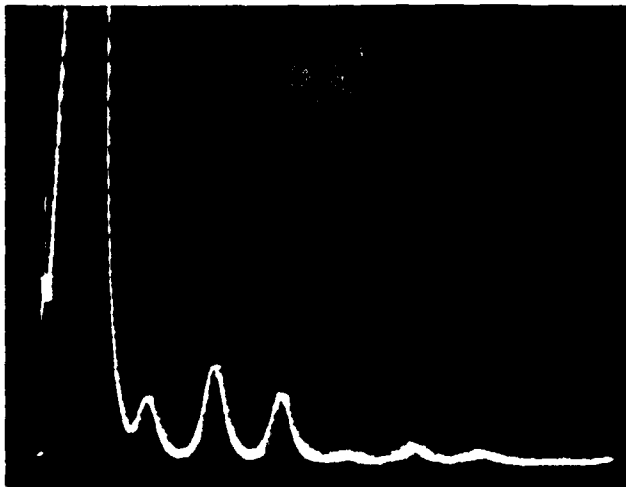
R82-127

SSP



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION



V1 I_{φA} 32.03 ARMS

V2 (REF 50.40A FS)

V3 1070/DIV

V4

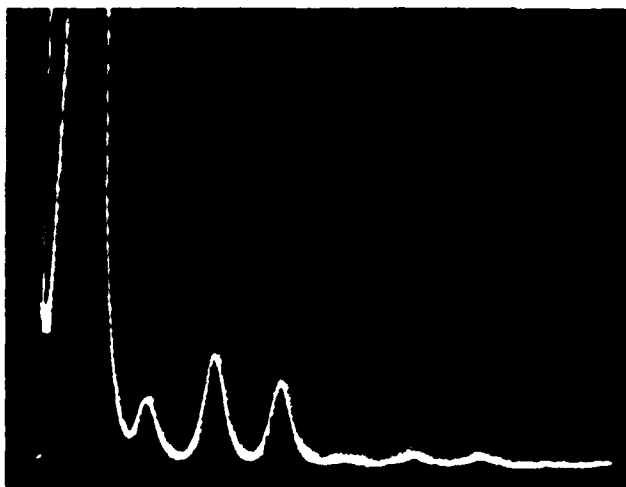
H1 200 Hz/DIV

H2

TEST NO. 25-5-01

PIX NO.

THD = 2.87%



V1 I_{φA} 25.88 ARMS

V2 (REF 50.40A FS)

V3 1070/DIV

V4

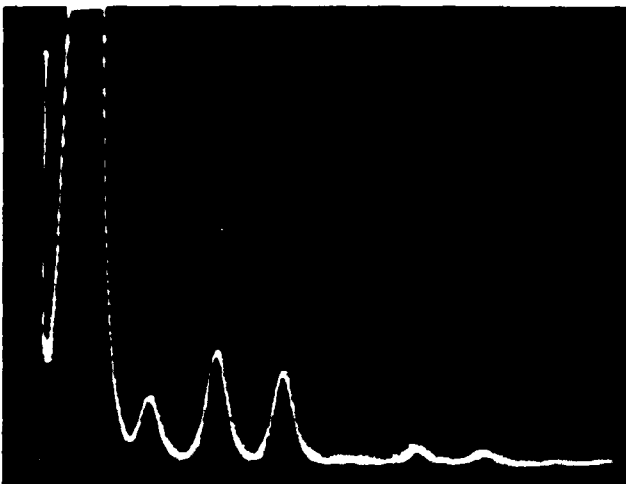
H1

H2

TEST NO.

PIX NO.

THD = 2.1%



V1 I_{φA} 19.92 ARMS

V2 (REF 50.40A FS)

V3 1070/DIV

V4

H1

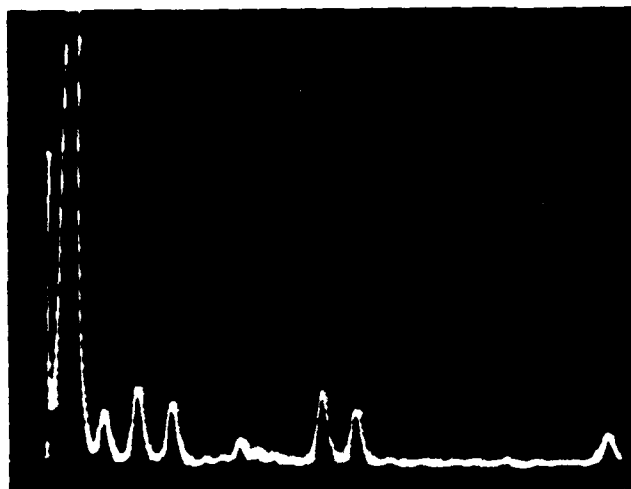
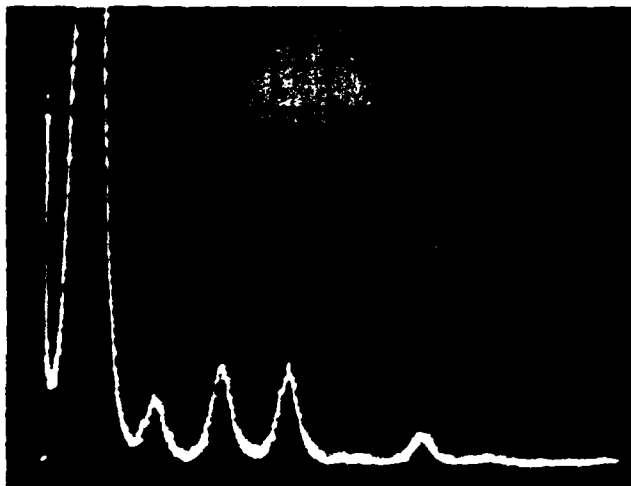
H2

TEST NO.

PIX NO.

H-13

SEP1



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION _____

V1 T₀A 14.29 ARMS

V2 (REF 50.40 AFS)

V3 100/DIV

V4 _____

H1 _____

H2 _____

TEST NO. 25-5-01

PIX NO. _____

- - - - - 3.33

V1 T₀A 10.10 ARMS

V2 (REF 50.40 AFS)

V3 100/DIV

V4 _____

H1 200 Hz / DIV

H2 _____

TEST NO. _____

PIX NO. _____

- - - - - 3.34

V1 _____

V2 _____

V3 _____

V4 _____

H1 _____

H2 _____

TEST NO. _____

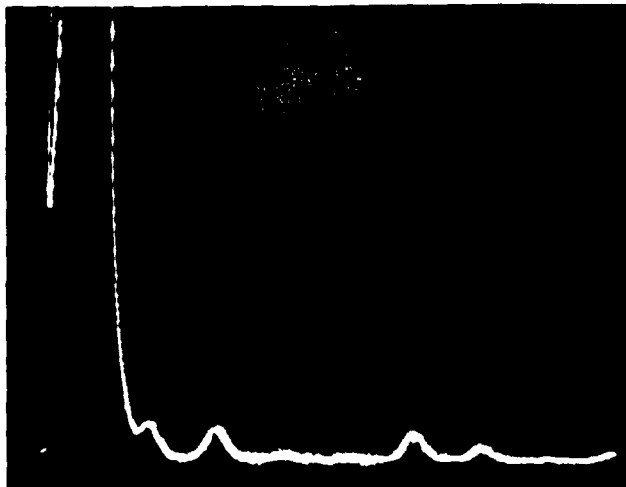
PIX NO. _____

R82-127

SSP1



SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION

V1 I_{φC} 50.46 ARMS

V2 50.46 A = FS

V3 100 / DIV

V4

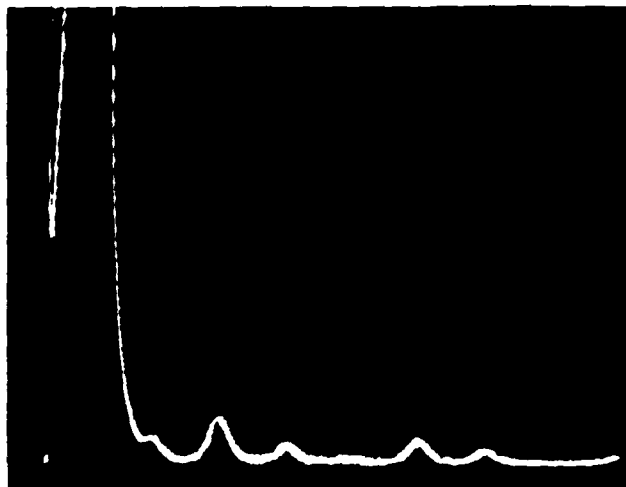
H1 100 Hz / DIV

H2

TEST NO. 25-5-01

PIX NO.

R² THD = 1.26



V1 I_{φC} 4530 ARMS

V2 (REF 50.46 A FS)

V3 100 / DIV

V4

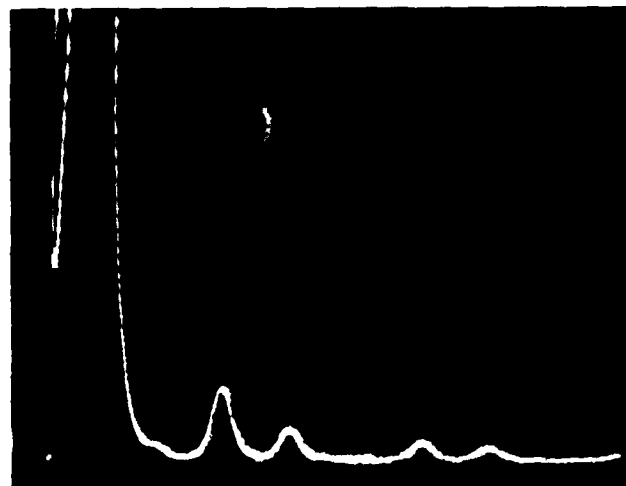
H1

H2

TEST NO.

PIX NO.

THD = 1.31



V1 I_{φC} 38.33 ARMS

V2 (REF 50.46 A FS)

V3 100 / DIV

V4

H1

H2

TEST NO.

PIX NO.

H-15

THD = 1.80

SSP1



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION

V1 I_{DC} 32.03 ARMS

V2 (REF 50.46 A FS)

V3 10% DIV

V4

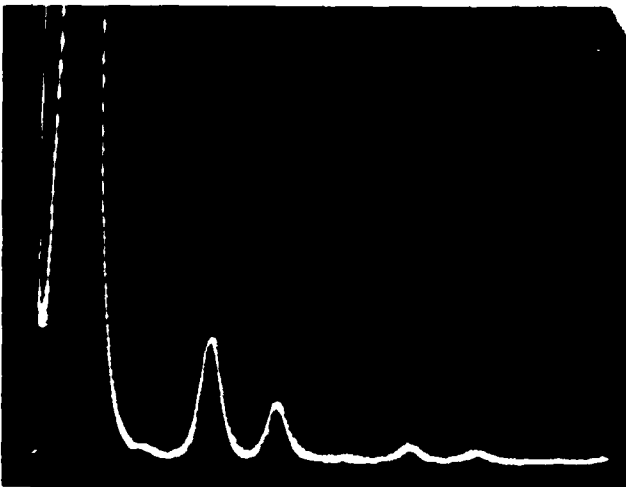
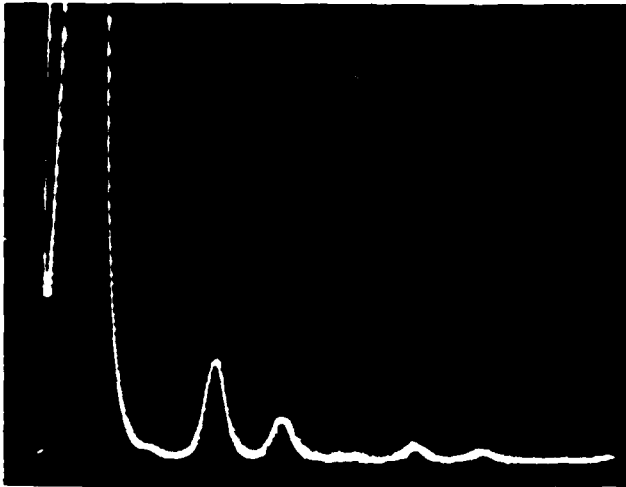
H1 100 Hz DIV

H2

TEST NO. 25-5-01

PIX NO.

THD = 2.39



V1 I_{DC} 25.78 ARMS

V2 (REF 50.46 A FS)

V3 10% DIV

V4

H1

H2

TEST NO.

PIX NO.

THD = 2.96



V1 I_{DC} 19.80 ARMS

V2 (REF 50.46 A FS)

V3 10% DIV

V4

H1

H2

TEST NO.

PIX NO.

THD = 3.43

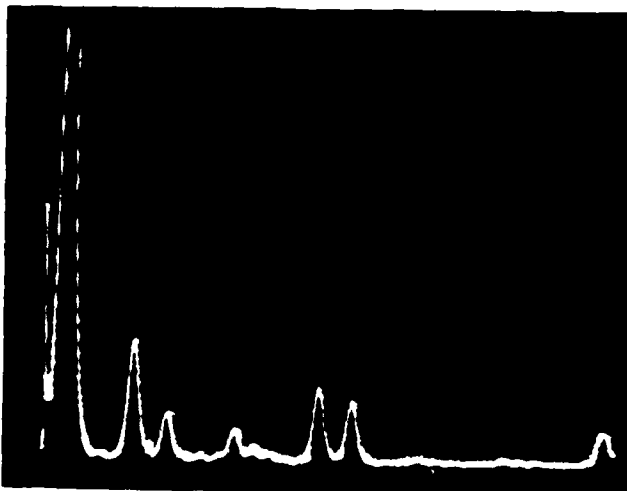
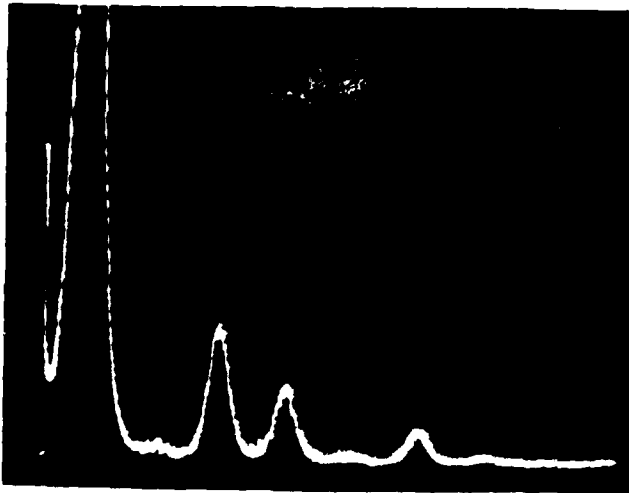
R82-127

SSP1

H-16



SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION

V1 $I_{\phi c}$ 14.9 ARMS
V2 (ref. 50.46 A FS)
V3 1070 / DIV
V4
H1 100 Hz / DIV
H2

TEST NO. 25-5-01

PIX NO.

THD = 3.48

V1 $I_{\phi c}$ 10.14 ARMS
V2 (ref. 50.46 A FS)
V3 1070 / DIV
V4
H1 200 Hz / DIV
H2

TEST NO.

PIX NO.

THD = 3.48

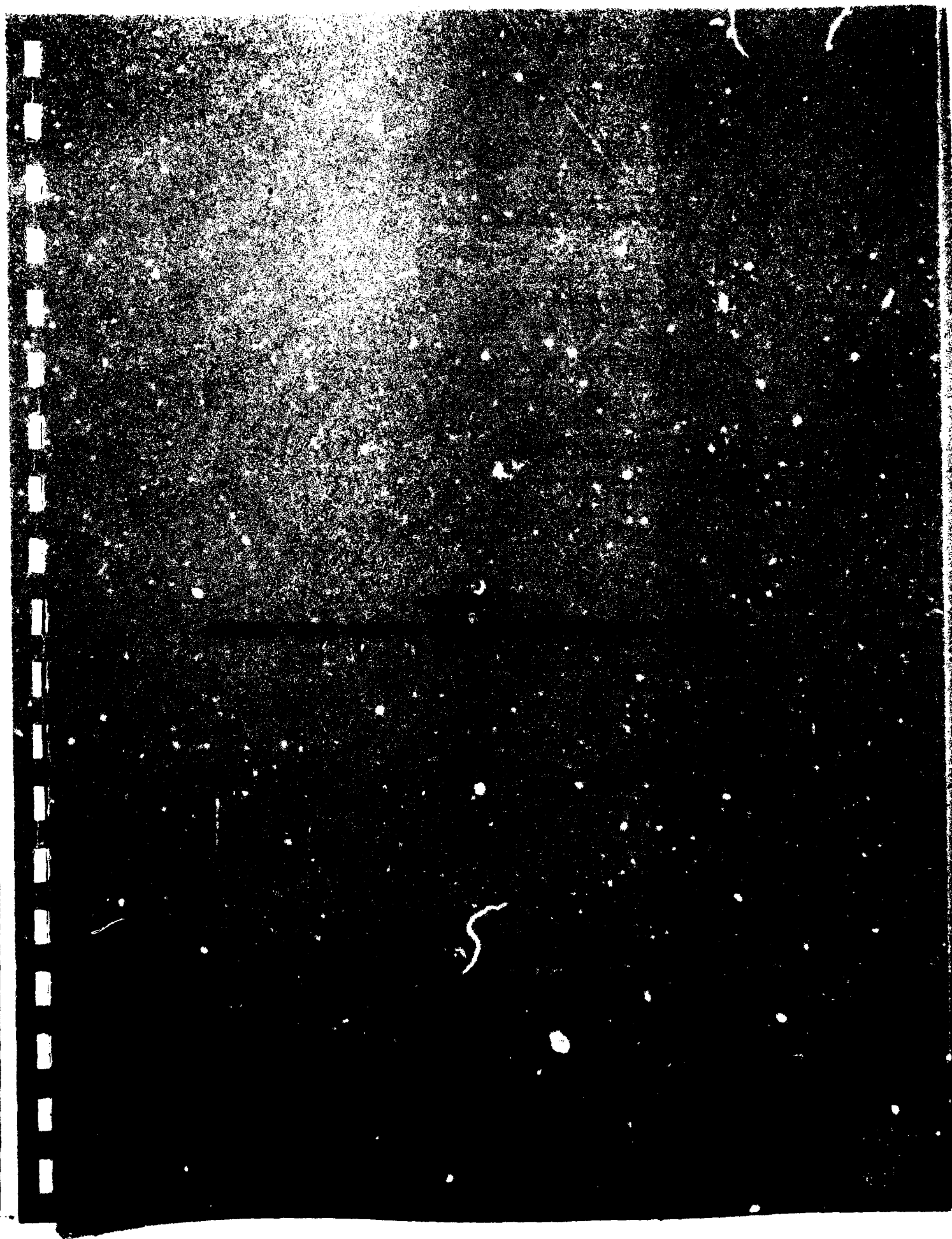
V1
V2
V3
V4
H1
H2

TEST NO.

PIX NO.

H-17/18

SEP1



INVERTER OUTPUT WAVEFORM DEGRADATION WITH NONLINEAR LOADING

The Delco inverter, similar to that used in the 15 kW Frequency Changer, was tested to determine the nature of the output waveform degradation which occurs when specific nonlinear loads are applied. A part of this effort involved running comparative testing on a conventional motor driven alternator (MG) set.

A substitution was made for the 15 kW Frequency Changer, which at this writing, malfunctions with transient overloads - such as is characteristic of some of the nonlinear loads used in these tests. Substituted was the 10 kW Firefinder Generator Set, MEP D423A. The MG set used is a 12.5 kVA, 400 Hz MG set manufactured by Electric Machinery Manufacturing Company.

Loading for all tests was at the 10 kW level and was inherently equal on all the phases of the two units tested. In no case was there any component of normal linear nature; rather, total loading was nonlinear and produced by different rectifier circuits.

In test 17-06-01 the MG set was used to drive a three-phase, full wave rectifier bridge (not to be confused with three single full wave bridges) and a resistive load. For test 16-06-01, the Delco inverter was used with the same nonlinear load. There was little waveform degradation when the Delco inverter was used and the total harmonic distortion (THD) of its output was approximately 3 percent. The MG set produced approximately 12 percent THD.

In test 17-06-04, the MG set was used to drive the same rectifier bridge with small inductance, large capacitance filter ahead of the 10 kW resistive load. There was some waveform degradation in test 17-06-02, to approximately 5 percent THD when the Delco inverter was used with this (a very common type) of nonlinear load. The MG set produced about 12 percent THD with this load.

In test 17-06-05, the MG set was used to drive the same rectifier bridge with a large inductance (nearly critical), large capacitance filter ahead of the 10 kW resistive load. The Delco inverter, in test 17-06-03, displayed approximately 3.5 percent THD while the MG set displayed approximately 12 percent THD.



SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 12.5KVA,
400H2, 120/208V
M-G Set
 MFR Electric Machinery Mfg. Co.
 MODEL NO. _____
 SERIAL NO. 1Q144072/3

TEST NO. 17-06-01
 SHEET 1 OF 5
 DATE 17-JUN-82
 PROJ ENGR A.H. BARRETT
 TEST BY _____
 OBSERVER _____

TEST DESCRIPTION M-G SET
OUTPAT WAVEFORM WITH
NON-LINEAR LOADING
 REF: OKW

(1) MEASUREMENT	(2) INST NO. (a)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) <u>V_{ΦA} (LINE RMS)</u>	<u>25447</u>	<u>122.5</u>		<u>12.8 V RMS</u>		<u>1, 4, 5</u>		
(b) <u>V_{ΦB}</u>	<u>25447</u>	<u>125.0</u>		<u>125.0 V RMS</u>		<u>2</u>		
(c) <u>V_{ΦC}</u>		<u>124.7</u>		<u>124.7 V RMS</u>		<u>3</u>		
(d) <u>I_{ΦA}</u>		<u>28.04</u>		<u>28.04 ARMS</u>		<u>1, 6, 7</u>		
(e) <u>I_{ΦB}</u>		<u>28.14</u>		<u>28.14 ARMS</u>		<u>2</u>		
(f) <u>I_{ΦC}</u>		<u>28.63</u>		<u>28.63 ARMS</u>		<u>3</u>		
(g) <u>P_{ΦA}</u>		<u>3247</u>		<u>3247 W</u>	<u>PF = 0.943</u>			
(h) <u>P_{ΦB}</u>		<u>3326</u>		<u>3326 W</u>	<u>PF = 0.962</u>			
(i) <u>P_{ΦC}</u>		<u>3385</u>		<u>3385 W</u>	<u>PF = 0.948</u>			
(j) <u>P_{TOT}</u>		<u>9960</u>		<u>9960 W</u>				
(k) <u>V_{ΦA} THD</u>	<u>459A</u>	<u>12.2</u>		<u>12.2 %</u>		<u>4, 5</u>		
(l) <u>V_{ΦB} THD</u>		<u>9.6</u>		<u>9.6 %</u>				
(m) <u>V_{ΦC} THD</u>		<u>9.2</u>		<u>9.2 %</u>				
(n) <u>I_{ΦA} THD</u>		<u>22.2</u>		<u>22.2 %</u>		<u>6, 7</u>		
(o) <u>I_{ΦB} THD</u>		<u>23.6</u>		<u>23.6 %</u>				

NOTES: LOAD CONFIGURATION: 3Φ FULL WAVE BRIDGE WITH
PURE RESISTIVE LOAD

EQUIP DESCRIPTION 12.5 KVA,400 Hz, 120/208 VM-G SETMFR Electric Machinery Mfg Co.

MODEL NO. _____

SERIAL NO. 10444072/3

REF: _____

TEST NO. 17-06-01SHEET 2 OF 5DATE 17-JUN-82PROJ ENGR A.H. BARRETT

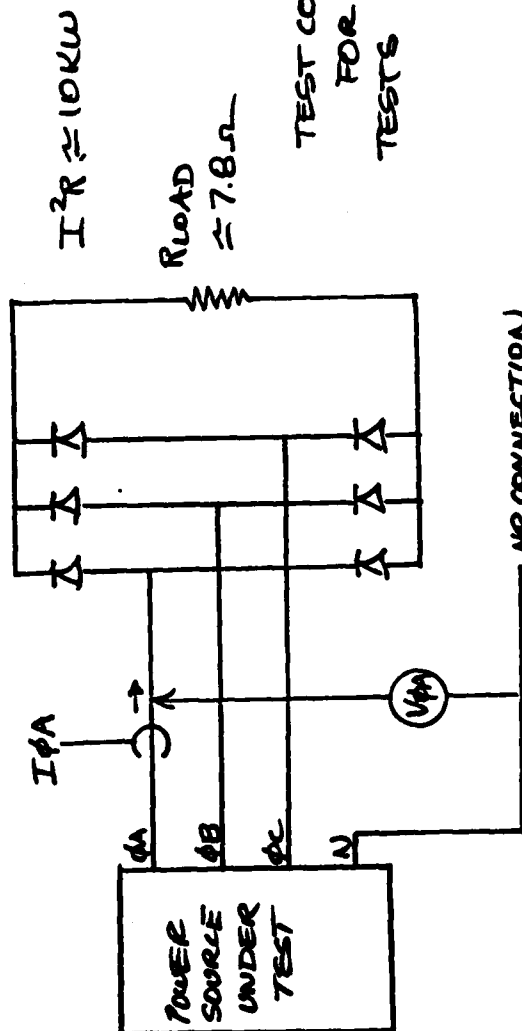
TEST BY _____

OBSERVER _____

SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION M-G SETOUTPUT WAVEFORM WITHNON-LINEAR LOADINGS

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) <u>I_{dc} THD</u>	<u>HP 339A</u>	<u>21.8</u>		<u>81.89%</u>				

3 ϕ
FULL WAVE
BRIDGE

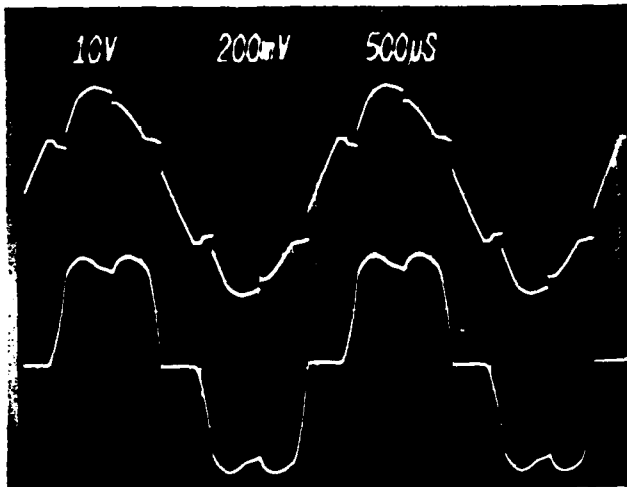
TEST CONFIGURATION

FOR

TESTS 16-06-0117-06-01



SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION _____

V1 V ϕ A 100V/DIV

V2 I ϕ A 20A/DIV

V3 _____

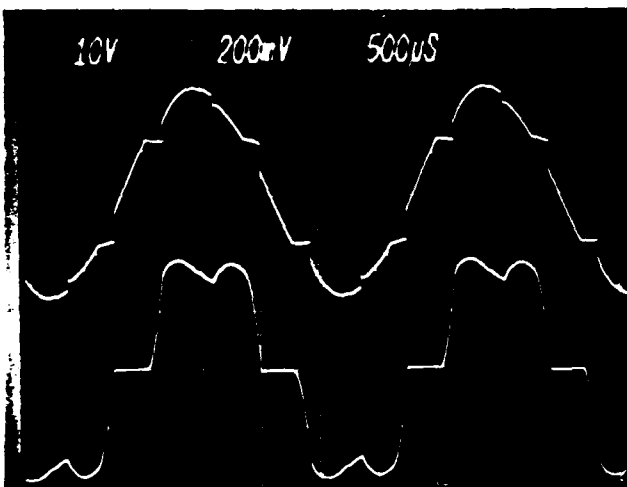
V4 _____

H1 500 μ s /DIV

H2 _____

TEST NO. 17-06-01

PIX NO. 1



V1 V ϕ B 100V/DIV

V2 I ϕ B 20A/DIV

V3 _____

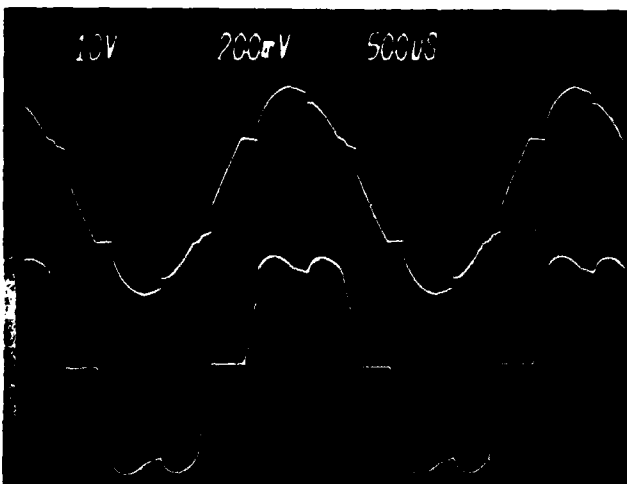
V4 _____

H1 500 μ s /DIV

H2 _____

TEST NO. 17-06-01

PIX NO. 2



V1 V ϕ C 100V/DIV

V2 I ϕ C 20A/DIV

V3 _____

V4 _____

H1 500 μ s /DIV

H2 _____

TEST NO. 17-06-01

PIX NO. 3

R82-127



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION _____

V1 SPECTRUM VOA

V2 10% DIV

V3 _____

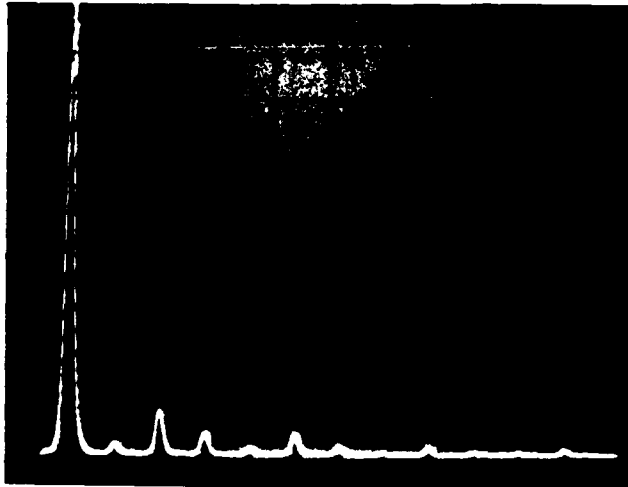
V4 _____

H1 1 KHz DIV

H2 _____

TEST NO. 17-06-01

PIX NO. 4



V1 SPECTRUM VOA

V2 10% DIV

V3 _____

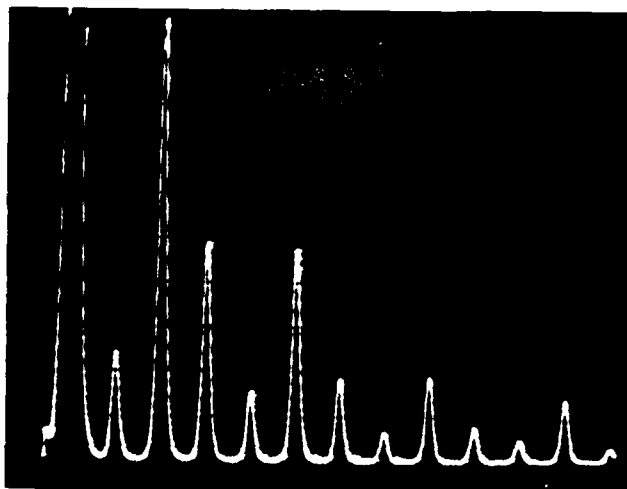
V4 _____

H1 1 KHz DIV

H2 _____

TEST NO. 17-06-01

PIX NO. 5



V1 SPECTRUM FOA

V2 10% DIV

V3 _____

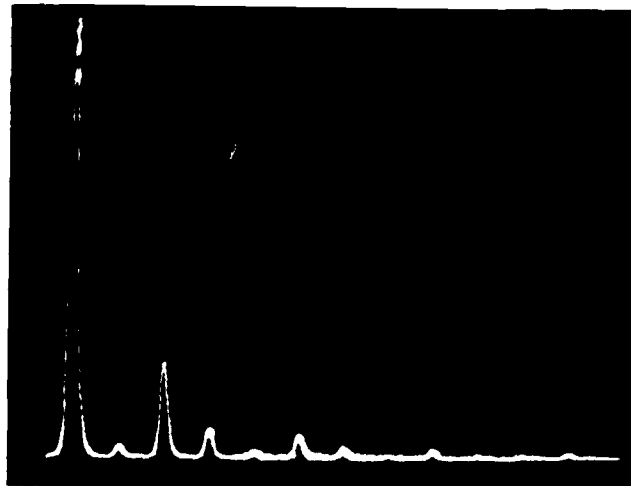
V4 _____

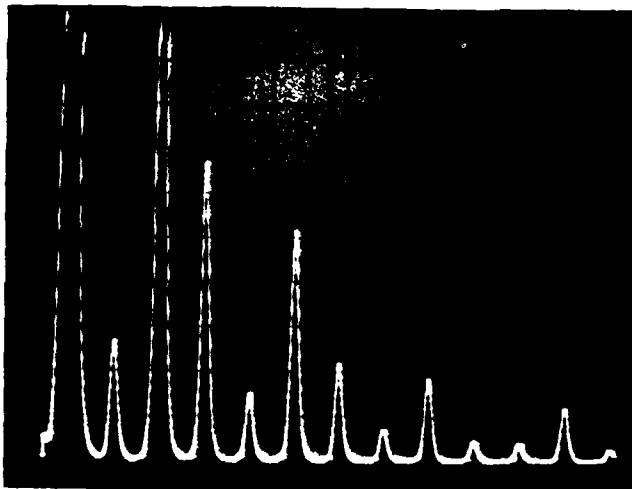
H1 1 KHz

H2 _____

TEST NO. 17-06-01

PIX NO. 6





SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION _____

V1 SPECTRUM IDA

V2 170/DIV

V3 _____

V4 _____

H1 1 KHz

H2 _____

TEST NO. 17-06-01

PIX NO. 7

V1 _____

V2 _____

V3 _____

V4 _____

H1 _____

H2 _____

TEST NO. _____

PIX NO. _____

V1 _____

V2 _____

V3 _____

V4 _____

H1 _____

H2 _____

TEST NO. _____

PIX NO. _____

R82-127

EQUIP DESCRIPTION 10KW
FIREFINDER PCU /
TURBINE / RT
 MFR DELCO
 MODEL NO. 1B1U D423A
 SERIAL NO. TEST BED UNIT 1

TEST NO. 16-06-01
 SHEET 1 OF 4
 DATE 16-JUN-82
 PROJ ENGR A.H. BARRETT
 TEST BY _____
 OBSERVER _____



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION INVERTER
OUTPUT WAVEFORM WITH
NON-LINEAR LOADS

REF: PKU

(1) MEASUREMENT	(2) INST NO. (a)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) $V_{\phi A}$ TRUE RMS	YEW 2504	122.0		122.0 VRMS		1,4		
(b) $V_{\phi B}$	2504-1	121.9		121.9 VRMS		2		
(c) $V_{\phi C}$		121.9		121.9 VRMS		3		
(d) $I_{\phi A}$		28.83		28.83 ARMS		1,5		
(e) $I_{\phi B}$		28.83		28.83 ARMS		2		
(f) $I_{\phi C}$		28.82		28.82 ARMS		3		
(g) $P_{\phi A}$		3354		3354 W	PF = 0.954			
(h) $P_{\phi B}$		3353		3353 W	PF = 0.954			
(i) $P_{\phi C}$		3349		3349 W	PF = 0.953			
(j) P_{TOT}		10060		10060 W				
(k) $V_{\phi A}$ THD	HPA 2.90	2.90		2.98%		4		
(l) $V_{\phi B}$ THD		2.91		2.91%				
(m) $V_{\phi C}$ THD		2.91		2.91%				
(n) $I_{\phi A}$ THD		27.4		27.4%		5		
(o) $I_{\phi B}$ THD		27.6		27.6%				

NOTES: LOAD CONFIGURATION 3 ϕ FULL WAVE BRIDGE WITH
PURE RESISTIVE LOAD

EQUIP DESCRIPTION 10KW
ENGINEER PCU/
TURBINE/ALT
 MFR DELCO
 MODEL NO. D423A
 SERIAL NO. TEST BED UNIT 1



SANTA BARBARA, CALIFORNIA

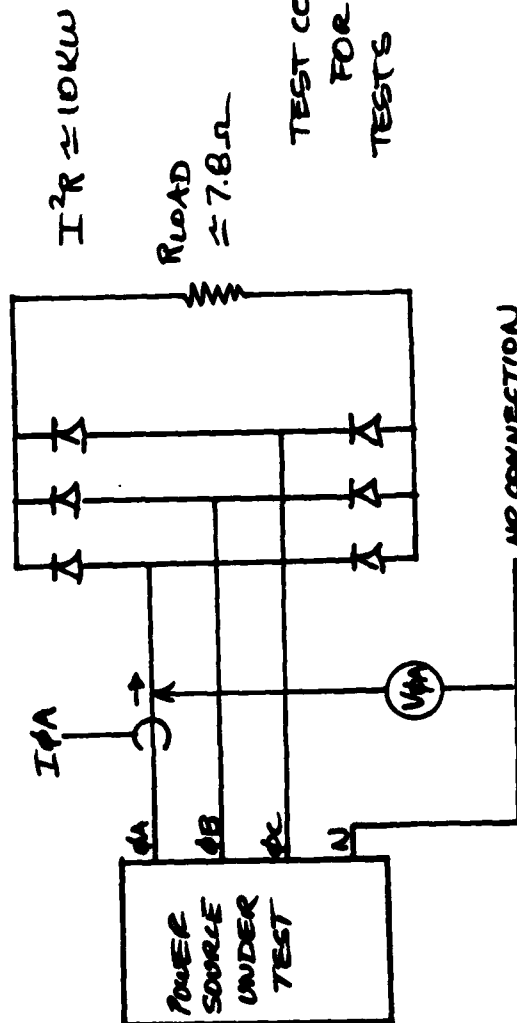
TEST DESCRIPTION INVERTER
OUTPUT WAVEFORM WITH
NON-LINEAR LOADING

TEST NO. 16-06-01
 SHEET 2 OF 4
 DATE 16-JUN-82
 PROJ ENGR A.H. BARRETT
 TEST BY _____
 OBSERVER _____

REF:

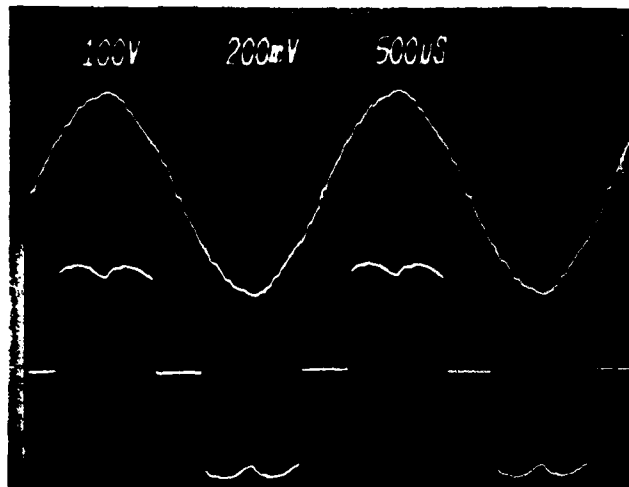
(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) <u>I_{OC} THD</u>	<u>HP 390A</u>	<u>27.5</u>		<u>27.5070</u>				

3 ϕ
FULL WAVE
BRIDGE





SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION _____

V1 V ϕ A 100V/DIV

V2 I ϕ A 20A/DIV

V3 _____

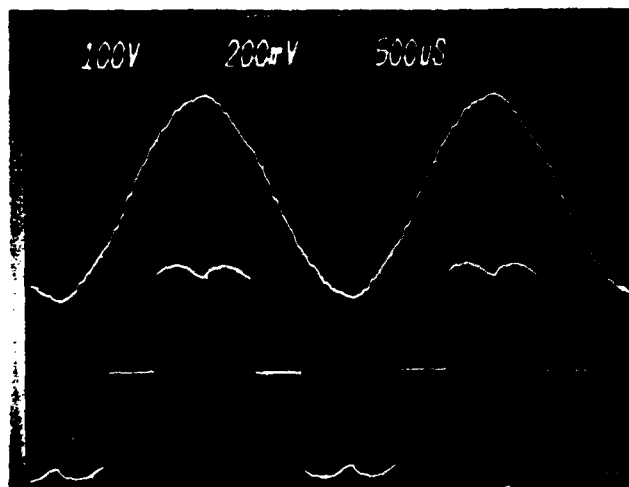
V4 _____

H1 500US/DIV

H2 _____

TEST NO. 16-06-01

PIX NO. 1



V1 V ϕ B 100V/DIV

V2 I ϕ B 20A/DIV

V3 _____

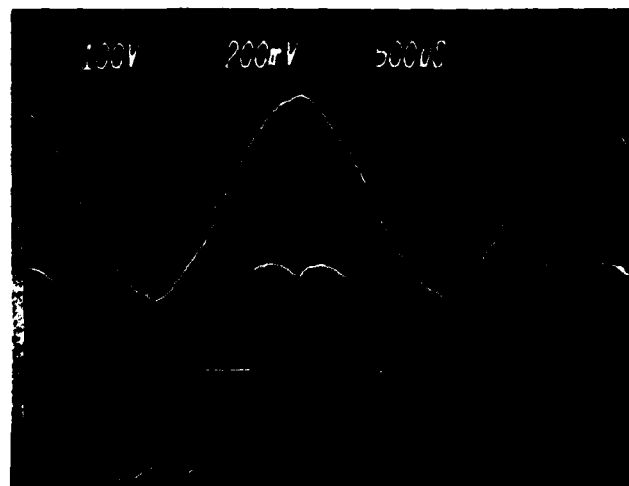
V4 _____

H1 500US/DIV

H2 _____

TEST NO. 16-06-01

PIX NO. 2



V1 V ϕ C 100V/DIV

V2 I ϕ C 20A/DIV

V3 _____

V4 _____

H1 500US/DIV

H2 _____

TEST NO. 16-06-01

PIX NO. 3

R82-127

I-9



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION _____

V1 SPECTRUM V ϕ A

V2 1090/DIV

V3 _____

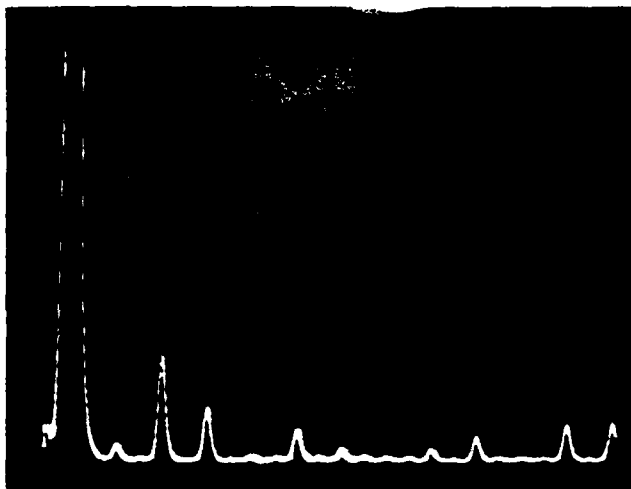
V4 _____

H1 1 KHZ/DIV

H2 _____

TEST NO. 16-06-01

PIX NO. 4



T

V1 SPECTRUM I ϕ A

V2 1090/DIV

V3 _____

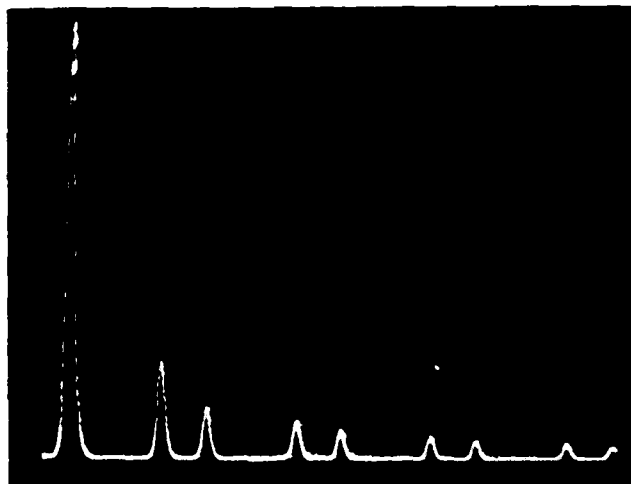
V4 _____

H1 1 KHZ/DIV

H2 _____

TEST NO. 16-06-01

PIX NO. 5



T

V1 _____

V2 _____

V3 _____

V4 _____

H1 _____

H2 _____

TEST NO. _____

PIX NO. _____

R62-127

SP1

EQUIP DESCRIPTION 13.5KVA,400H2, 120/208VH-G SetMFR Electric Machinery Mfg. Co.

MODEL NO. _____

SERIAL NO. 1Q144072/3

SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION H-G SETOUTPUT WAVEFORM WITHNON-LINEAR LOADINGREF: 1040TEST NO. 17-06-04SHEET 1 OF 4DATE 17-JUN-82PROJ ENGR A.H. BARRETT

TEST BY _____

OBSERVER _____

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) <u>V_{ΦA} (grv rms)</u>	<u>15051</u>	<u>120.4</u>		<u>120.4 VRMS</u>		<u>1, 4, 5</u>		
(b) <u>V_{ΦB}</u>	<u>25447</u>	<u>123.6</u>		<u>123.6 VRMS</u>		<u>2</u>		
(c) <u>V_{ΦC}</u>		<u>122.4</u>		<u>122.4 VRMS</u>		<u>3</u>		
(d) <u>I_{ΦA}</u>		<u>26.73</u>		<u>26.73 ARMS</u>		<u>1, 6</u>		
(e) <u>I_{ΦB}</u>		<u>27.75</u>		<u>27.75 ARMS</u>		<u>2</u>		
(f) <u>I_{ΦC}</u>		<u>30.20</u>		<u>30.20 ARMS</u>		<u>3</u>		
(g) <u>P_{ΦA}</u>		<u>2932</u>		<u>2932 W</u>	<u>PF = 0.911</u>			
(h) <u>P_{ΦB}</u>		<u>3210</u>		<u>3210 W</u>	<u>PF = 0.936</u>			
(i) <u>P_{ΦC}</u>		<u>3424</u>		<u>3424 W</u>	<u>PF = 0.926</u>			
(j) <u>P_{TOT}</u>		<u>9560</u>		<u>9560 W</u>				
(k) <u>V_{ΦA} THD</u>	<u>489A</u>	<u>12.5</u>		<u>12.5%</u>		<u>4, 5</u>		
(l) <u>V_{ΦB} THD</u>		<u>10.4</u>		<u>10.4%</u>				
(m) <u>V_{ΦC} THD</u>		<u>10.7</u>		<u>10.7%</u>				
(n) <u>I_{ΦA} THD</u>		<u>27.5</u>		<u>27.5%</u>		<u>6</u>		
(o) <u>I_{ΦB} THD</u>		<u>27.8</u>		<u>27.8%</u>				

NOTES: LOAD CONFIGURATION: SEE SHEET 2L = 30μH C = 6600μF

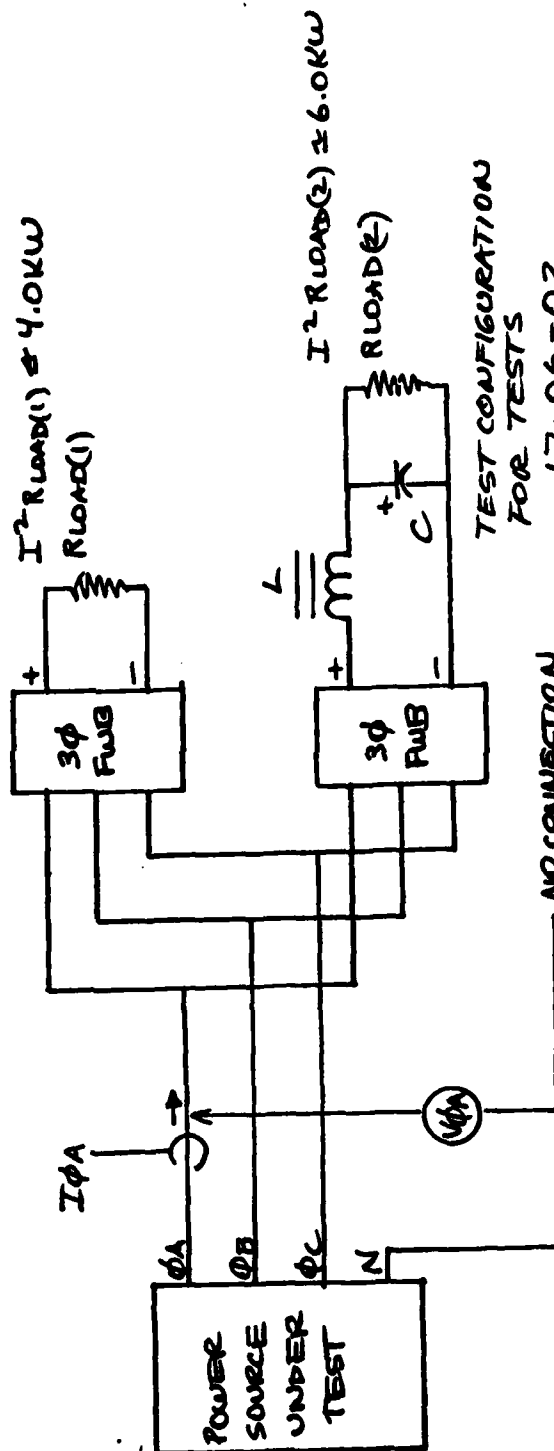
EQUIP DESCRIPTION 12.5 KVA,
400 Hz, 120/208V
M-G SET
 MFR Electric Machinery Mfg. Co.
 MODEL NO. _____
 SERIAL NO. 1444072/3



TEST DESCRIPTION M-G SET
OUTPUT WAVEFORM WITH
NON-LINEAR LOADS

TEST NO. 17-06-04
 SHEET 2 OF 4
 DATE 17-JUN-82
 PROJ ENGR A.H. BARRETT
 TEST BY _____
 OBSERVER _____

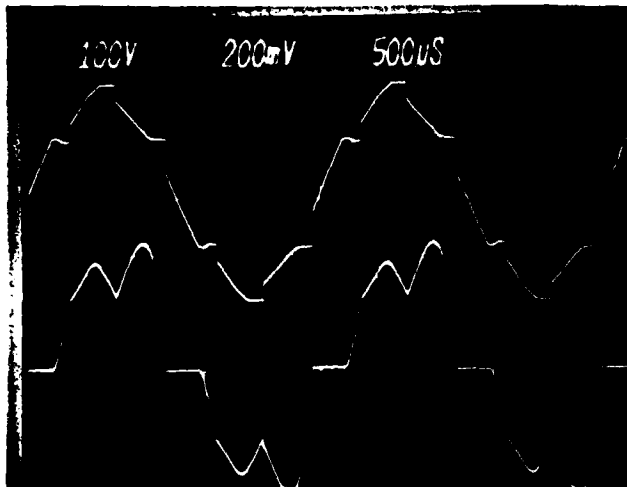
(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) <u>I_{φC} THD</u>	<u>HP 339A</u>	<u>25.1</u>		<u>25.1%</u>				



TEST CONFIGURATION
 FOR TESTS
 17-06-02
 THRU 17-06-05



SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION _____

V1 V_{φA} 100V/DIV

V2 I_{φA} 20A/DIV

V3 _____

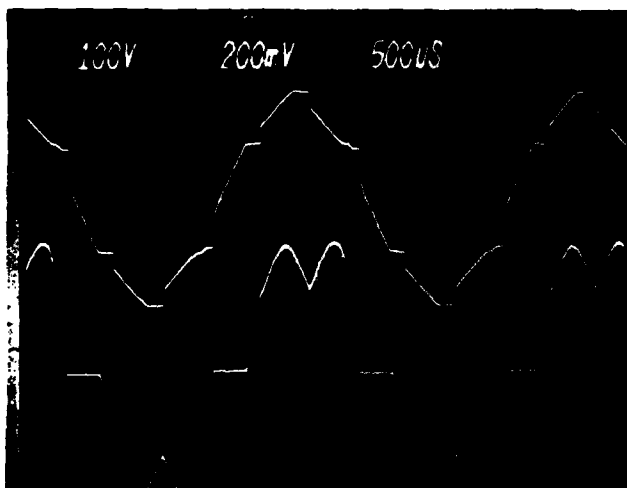
V4 _____

H1 500μs/DIV

H2 _____

TEST NO. 17-06-04

PIX NO. 1



V1 V_{φB} 100V/DIV

V2 I_{φB} 20A/DIV

V3 _____

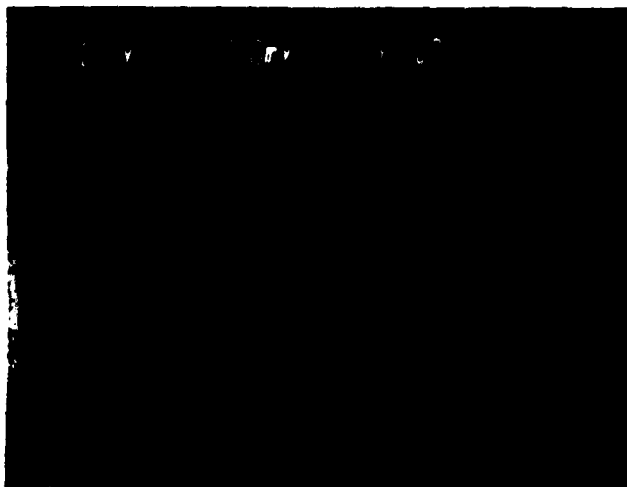
V4 _____

H1 500μs/DIV

H2 _____

TEST NO. 17-06-04

PIX NO. 2



V1 V_{φC} 100V/DIV

V2 I_{φC} 20A/DIV

V3 _____

V4 _____

H1 500μs/DIV

H2 _____

TEST NO. 17-06-04

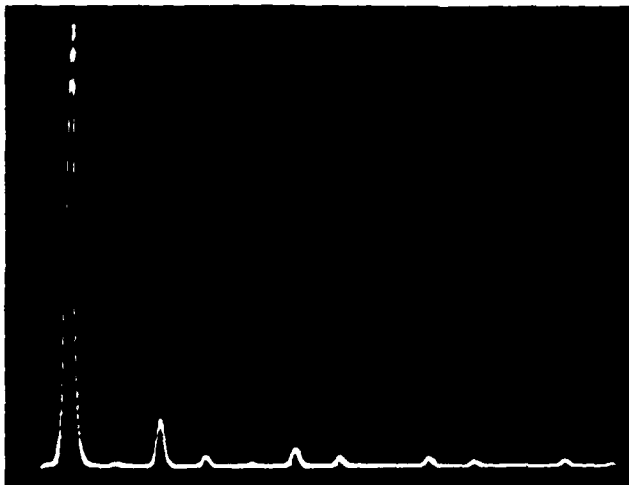
PIX NO. 3

883-127

I-13



SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION _____

V1 SPECTRUM V ϕ A

V2 10 ϕ 0/DIV

V3 _____

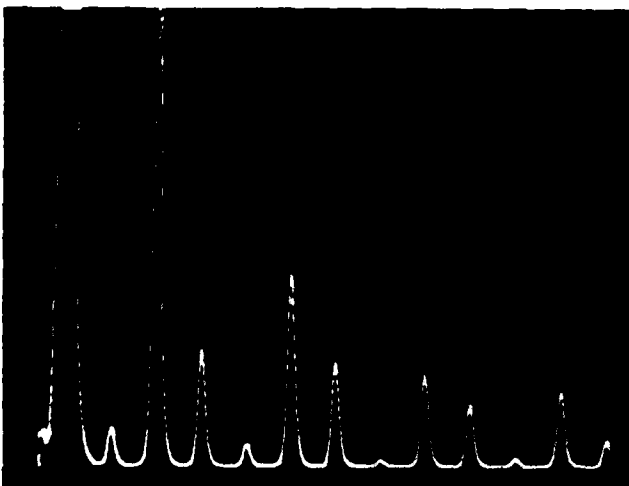
V4 _____

H1 1 KHz/DIV

H2 _____

TEST NO. 17-06-04

PIX NO. 4



V1 SPECTRUM V ϕ A

V2 10 ϕ 0/DIV

V3 _____

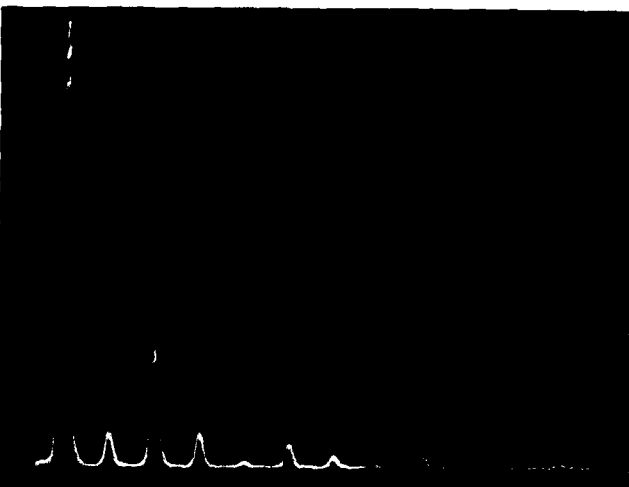
V4 _____

H1 1 KHz/DIV

H2 _____

TEST NO. 17-06-04

PIX NO. 5



V1 SPECTRUM I ϕ A

V2 10 ϕ 0/DIV

V3 _____

V4 _____

H1 1 KHz/DIV

H2 _____

TEST NO. 17-06-04

PIX NO. 6

R62-127

EQUIP DESCRIPTION 10KWFIREFINDER PCU /TURBINE / RTMFGR DELCOMODEL NO. TBU D423ASERIAL NO. TEST BED UNIT 1

SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION INVERTER
OUTPUT WAVEFORM WITH
NON-LINEAR LOADSREF: OKUTEST NO. 17-06-02SHEET 1 OF 4DATE 17-JUN-82PROJ ENGR A.H. BARNETT

TEST BY _____

OBSERVER _____

(1) MEASUREMENT	(2) INST NO.(S)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) $V_{\phi A}$ TRG RMS	NEW 1505A	122.0		122.0 VRMS		1, 4		
(b) $V_{\phi B}$	254-17	121.9		121.9 VRMS		2		
(c) $V_{\phi C}$		121.9		121.9 VRMS		3		
(d) $I_{\phi A}$		32.00		32.00 ARMS		1, 5		
(e) $I_{\phi B}$		31.90		31.90 ARMS		2		
(f) $I_{\phi C}$		31.94		31.94 ARMS		3		
(g) $P_{\phi A}$		3373		3373 W	PF = 0.864			
(h) $P_{\phi B}$		3365		3365 W	PF = 0.865			
(i) $P_{\phi C}$		3365		3365 W	PF = 0.864			
(j) P_{TOT}		10100		10100 W				
(k) $V_{\phi A}$ THD	HP 430A	5.32		5.32%		4		
(l) $V_{\phi B}$ THD		5.25		5.25%				
(m) $V_{\phi C}$ THD		5.29		5.29%				
(n) $I_{\phi A}$ THD		51.0		51.0%		5		
(o) $I_{\phi B}$ THD		51.2		51.2%				

NOTES: LOAD CONFIGURATIONS SEE SHEET 2
L = 30 μ H C = 6600 μ F

EQUIP DESCRIPTION 10 KW

TEST NO. 17-06-02

SANTA BARBARA, CALIFORNIA

SHEET 2 OF 4

TEST DESCRIPTION INVERTER
OUTPUT WAVEFORM WITH

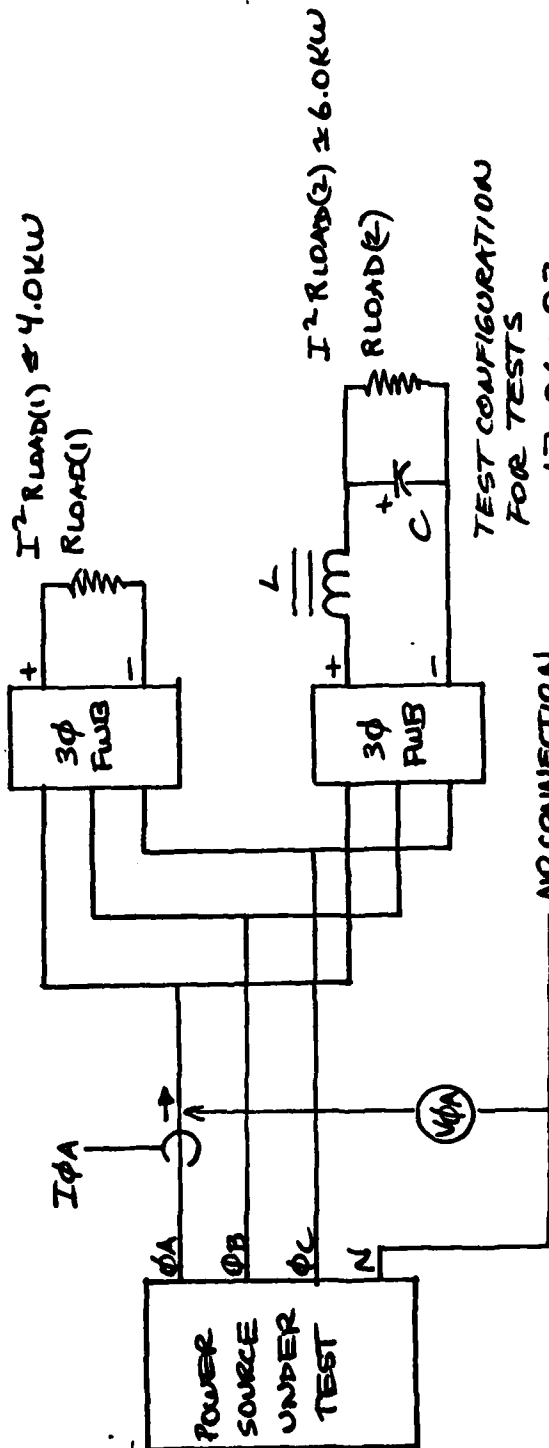
PROJ ENGR A.H. BARETT

TEST BY _____

OBSERVER

REF: _____

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
TOC T&D	HP 889A	51.3		51.3%				



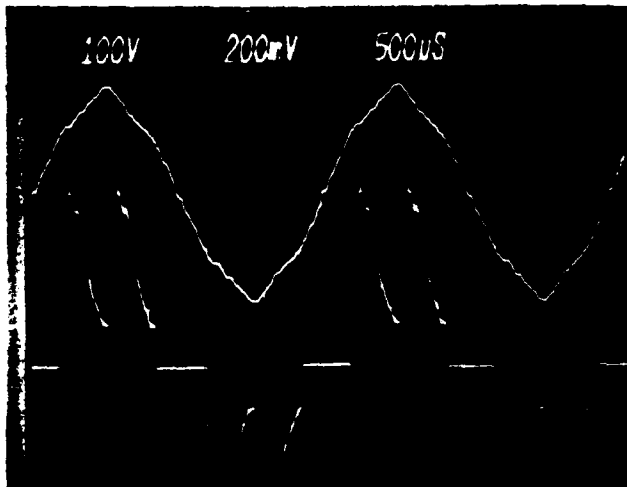
TEST CONFIGURATION FOR TESTS

17-06-02
THRU 17-06-05

NO CONNECTION



SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION _____

V1 V_{φA} 100V/DIV

V2 I_{φA} 20A/DIV

V3 _____

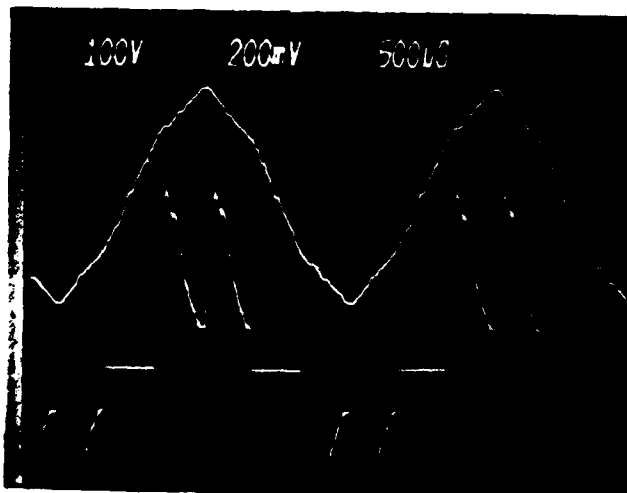
V4 _____

H1 500μs/DIV

H2 _____

TEST NO. 17-06-02

PIX NO. 1



V1 V_{φB} 100V/DIV

V2 I_{φB} 20A/DIV

V3 _____

V4 _____

H1 500μs/DIV

H2 _____

TEST NO. 17-06-02

PIX NO. 2



V1 V_{φC} 100V/DIV

V2 I_{φC} 20A/DIV

V3 _____

V4 _____

H1 500μs/DIV

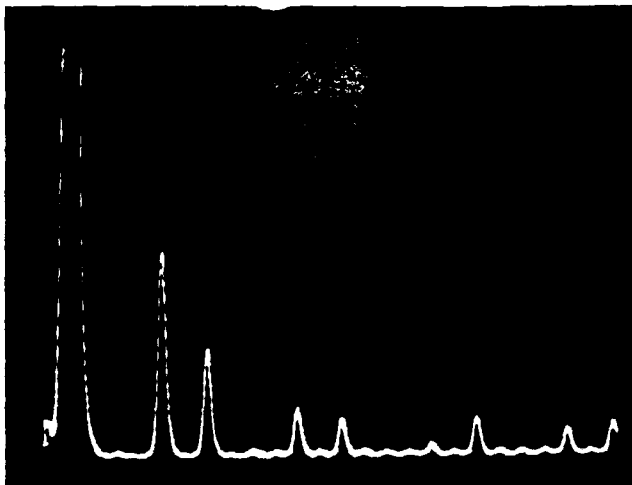
H2 _____

TEST NO. 17-06-02

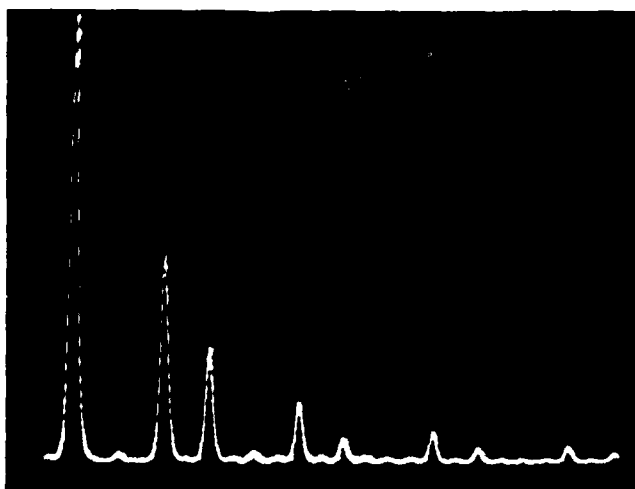
PIX NO. 3

R62-127

I-17



T



T



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION

V1 SPECTROM VφA

V2 10% DIV

V3

V4

H1 1 KHz DIV

H2

TEST NO. 17-06-02

PIX NO. 4

V1 SPECTROM IφA

V2 10% DIV

V3

V4

H1 1 KHz

H2

TEST NO. 17-06-02

PIX NO. 5

V1

V2

V3

V4

H1

H2

TEST NO.

PIX NO.

R62-127

EQUIP DESCRIPTION 12.5KVA,400Hz, 120/208VH-C SetMFR Electric Machinery Mfg. Co.

MODEL NO. _____

SERIAL NO. 19144072/3TEST NO. 17-06-05SHEET 1 OF 4DATE 17-JUN-82PROJ ENGR A.H. BARRETT

TEST BY _____

OBSERVER _____



SANTA BARBARA, CALIFORNIA

 TEST DESCRIPTION N-G SET
OUTPUT WAVEFORM WITH
NON-LINEAR LOADING
REF: 10KW

(1) MEASUREMENT	(2) INST NO. (s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) <u>V_{DA} (true rms)</u>	<u>NEW 15051</u>	<u>121.5</u>		<u>121.5 VRMS</u>		<u>1, 4</u>		
(b) <u>V_{DB}</u>	<u>2514-11</u>	<u>124.0</u>		<u>124.0 VRMS</u>		<u>2</u>		
(c) <u>V_{DC}</u>		<u>123.2</u>		<u>123.2 VRMS</u>		<u>3</u>		
(d) <u>I_{QA}</u>		<u>27.05</u>		<u>27.05 ARMS</u>		<u>1, 5, 6</u>		
(e) <u>I_{QB}</u>		<u>28.00</u>		<u>28.00 ARMS</u>		<u>2</u>		
(f) <u>I_{QC}</u>		<u>29.42</u>		<u>29.42 ARMS</u>		<u>3</u>		
(g) <u>P_{QA}</u>		<u>3057</u>		<u>3057 W</u>	<u>PF = 0.930</u>			
(h) <u>P_{QB}</u>		<u>3286</u>		<u>3286 W</u>	<u>PF = 0.946</u>			
(i) <u>P_{QC}</u>		<u>3400</u>		<u>3400 W</u>	<u>PF = 0.938</u>			
(j) <u>P_{TOT}</u>		<u>9740</u>		<u>9740 W</u>				
(k) <u>V_{QA} THD</u>	<u>350A</u>	<u>13.1</u>		<u>12.1%</u>		<u>4</u>		
(l) <u>V_{QB} THD</u>		<u>9.8</u>		<u>9.8%</u>				
(m) <u>V_{QC} THD</u>		<u>9.8</u>		<u>9.8%</u>				
(n) <u>I_{QA} THD</u>		<u>24.3</u>		<u>24.3%</u>				
(o) <u>I_{QB} THD</u>		<u>24.4</u>		<u>24.6%</u>		<u>5, 6</u>		

 NOTES: LOAD CONFIGURATION: SEE SHEET 2
L = 750μH C = 6600μF

EQUIP DESCRIPTION 12.5 KVA,
400 Hz, 120/208V
M-G SET
 MFR Electric Machinery Mfg. Co.
 MODEL NO. _____
 SERIAL NO. 10444022/3



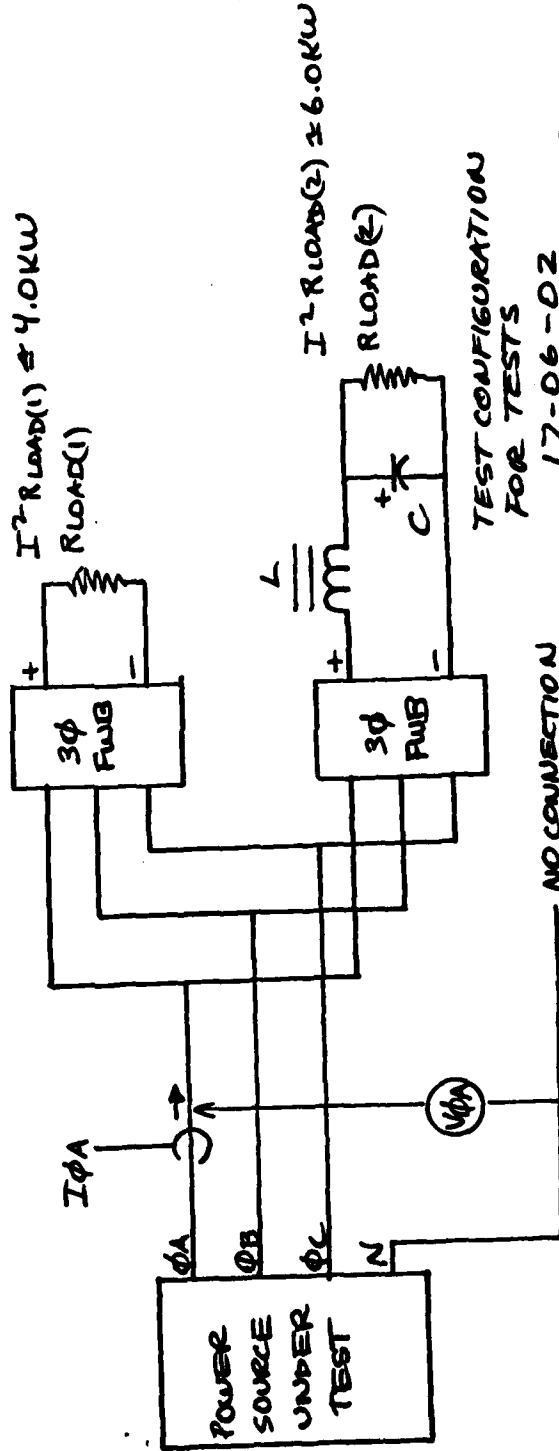
SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION M-G SET
OUTPUT WAVEFORM WITH
NON-LINEAR LOADINGS

TEST NO. 17-06-05
 SHEET 2 OF 4
 DATE 17-JUN-82
 PROJ ENGR A.H. BARRETT
 TEST BY _____
 OBSERVER _____

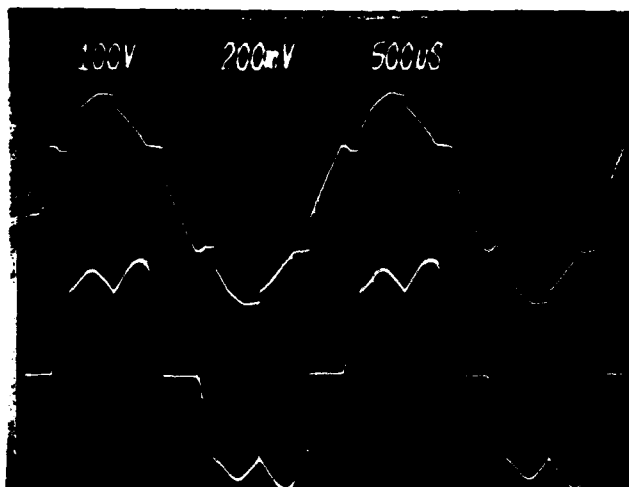
REF: _____

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) <u>I_{φC} THP</u>	<u>HP 339A</u>	<u>22.6</u>		<u>22.6%</u>				



TEST CONFIGURATION
 FOR TESTS

17-06-02
 THRU 17-06-05



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION

V1 VφA 100V/DIV

V2 IφA 20A/DIV

V3

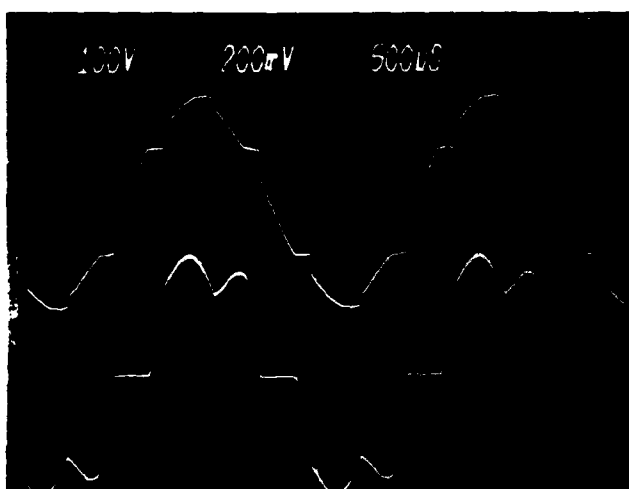
V4

H1 500μs/DIV

H2

TEST NO. 17-06-05

PIX NO. 1



V1 VφB 100V/DIV

V2 IφB 20A/DIV

V3

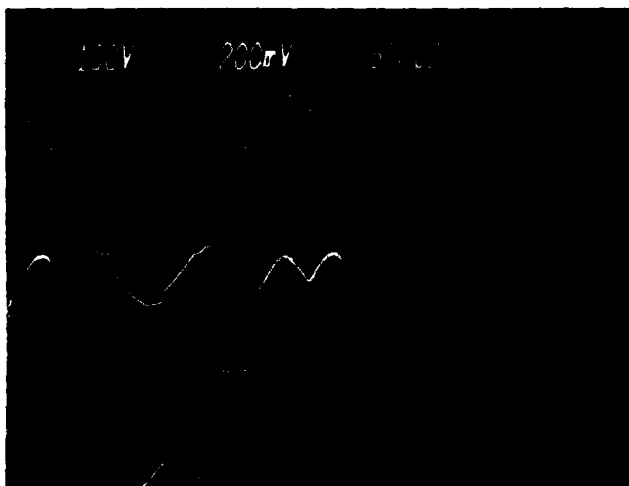
V4

H1 500μs/DIV

H2

TEST NO. 17-06-05

PIX NO. 2



V1 VφC 100V/DIV

V2 IφC 20A/DIV

V3

V4

H1 500μs/DIV

H2

TEST NO. 17-06-05

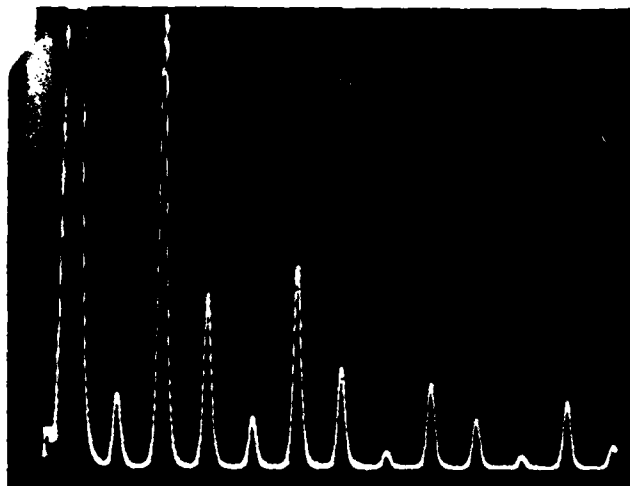
PIX NO. 3

I-21



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION _____



V1 SPECTRUM 10A

V2 10% / DIV

V3 _____

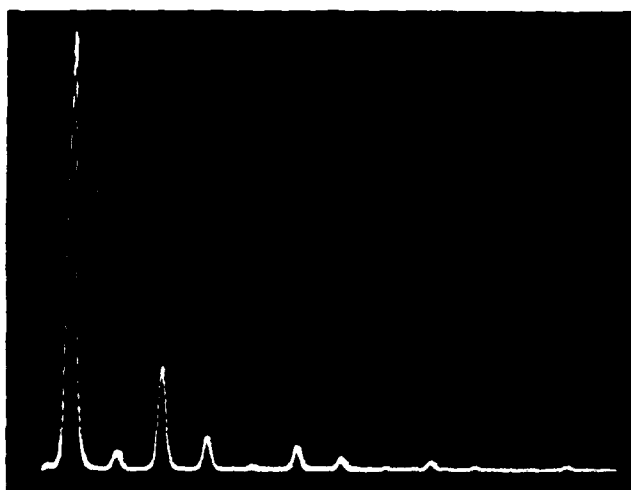
V4 _____

H1 1 KHz / DIV

H2 _____

TEST NO. 17-06-05

PIX NO. 4



V1 SPECTRUM 10A

V2 10% / DIV

V3 _____

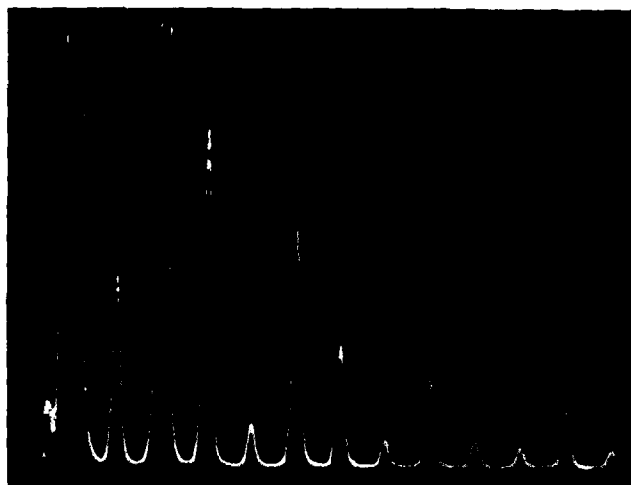
V4 _____

H1 1 KHz / DIV

H2 _____

TEST NO. 17-06-05

PIX NO. 5



V1 SPECTRUM 10A

V2 10% / DIV

V3 _____

V4 _____

H1 1 KHz / DIV

H2 _____

TEST NO. 17-06-05

PIX NO. 6

R82-127



SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 10KW
FIREFINDER PCU /
TURBINE/ALT
 MFR DELCO
 MODEL NO. TBU D423A
 SERIAL NO. TEST BED UNIT 1

TEST DESCRIPTION INVERTER
OUTPUT WAVEFORM WITH
NON-LINEAR LOADS

REF: 10KW

OBSERVER

TEST NO. 17-06-03
 SHEET 1 OF 4
 DATE 17-JUN-82
 PROJ ENGR A.H. BARRETT
 TEST BY

(1) MEASUREMENT	(2) INST NO. (s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
V _{ΦA} TRMS	NEW 2505A	122.0		122.0 VRMS		1, 4		
V _{ΦB}	2504A	121.9		121.9 VRMS		2		
V _{ΦC}		121.8		121.8 VRMS		3		
I _{ΦA}		29.29		29.29 ARMS		1, 5		
I _{ΦB}		29.26		29.26 ARMS		2		
I _{ΦC}		29.33		29.33 ARMS		3		
P _{ΦA}		3363		3363 W	PF = 0.941			
P _{ΦB}		3357		3357 W	PF = 0.941			
P _{ΦC}		3365		3365 W	PF = 0.942			
P _{TOT}		10080		10080 W		4		
V _{ΦA} THD	55A	3.60		3.60%				
V _{ΦB} THD		3.60		3.60%				
V _{ΦC} THD		3.58		3.58%				
I _{ΦA} THD		30.4		30.4%		5		
I _{ΦB} THD		30.6		30.6%				

NOTES: LOAD CONFIGURATION SEE SHEET 2
L = 750 μH C = 6600 μF

EQUIP DESCRIPTION DELCO
ENGINE/ALT
TURBINE/ALT
 MFR DELCO
 MODEL NO. D423A
 SERIAL NO. TEST BED UNIT 1



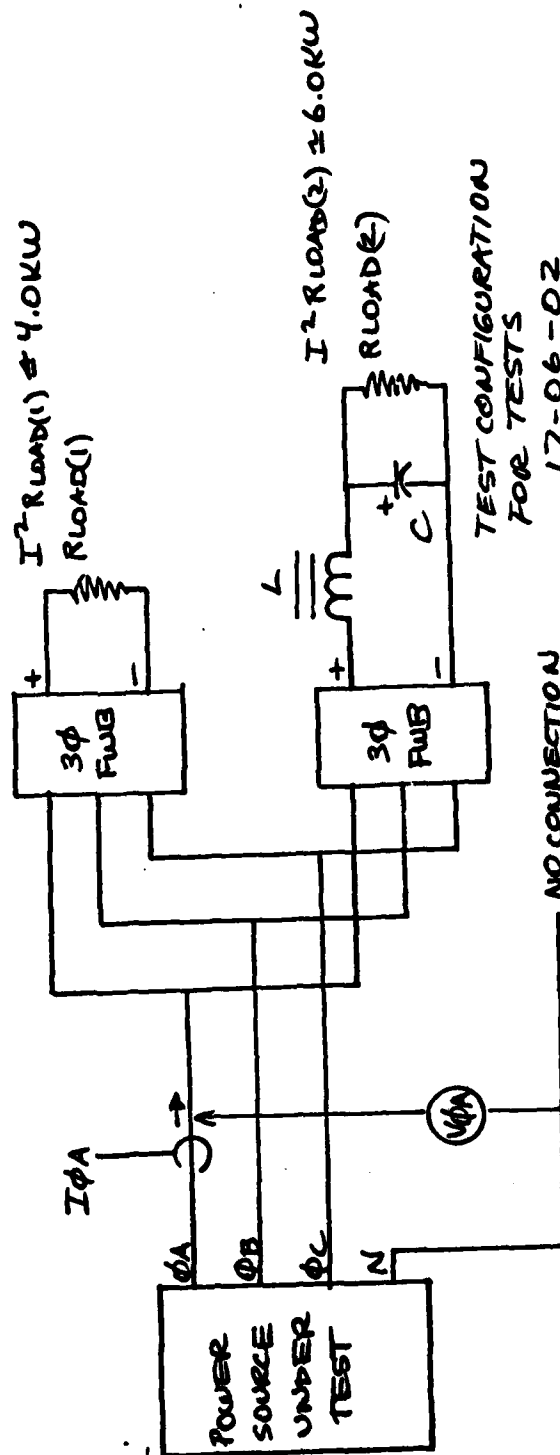
SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION INVERTER
OUTPUT WAVEFORM WITH
NON-LINEAR LOADS

TEST NO. 17-06-03
 SHEET 2 OF 4
 DATE 17-JUN-82
 PROJ ENGR A.H. BARRETT
 TEST BY _____
 OBSERVER _____

REF:

(1) MEASUREMENT	(2) INST NO. (s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
<u>TPC THD</u>	<u>HP 399A</u>	<u>30.4</u>		<u>30.4070</u>				





SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION _____

V1 V ϕ A 100V/DIV

V2 I ϕ A 20A/DIV

V3 _____

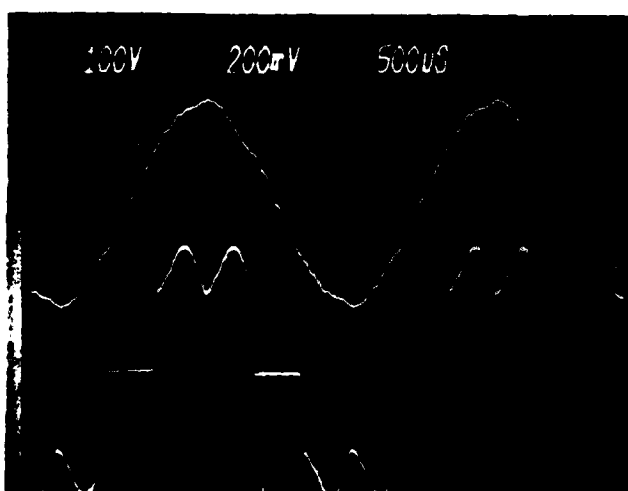
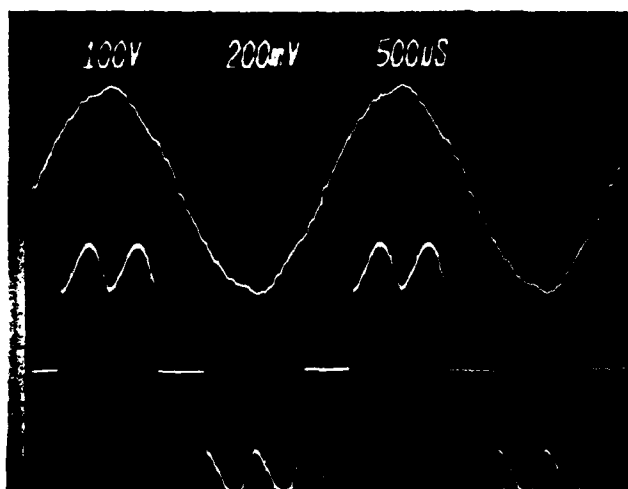
V4 _____

H1 1 KHz/DIV

H2 _____

TEST NO. 17-06-03

PIX NO. 1



V1 V ϕ B 100V/DIV

V2 I ϕ B 20A/DIV

V3 _____

V4 _____

H1 1 KHz/DIV

H2 _____

TEST NO. 17-06-03

PIX NO. 2



V1 V ϕ C 100V/DIV

V2 I ϕ C 20A/DIV

V3 _____

V4 _____

H1 1 KHz/DIV

H2 _____

TEST NO. 17-06-03

PIX NO. 3



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION _____

V1 SPECTRUM V ϕ A

V2 100/DIV

V3 _____

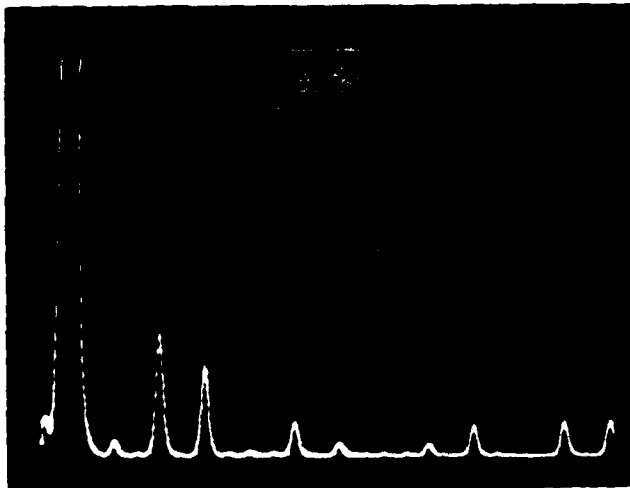
V4 _____

H1 _____

H2 _____

TEST NO. 17-06-03

PIX NO. 4



V1 SPECTRUM I ϕ A

V2 100/DIV

V3 _____

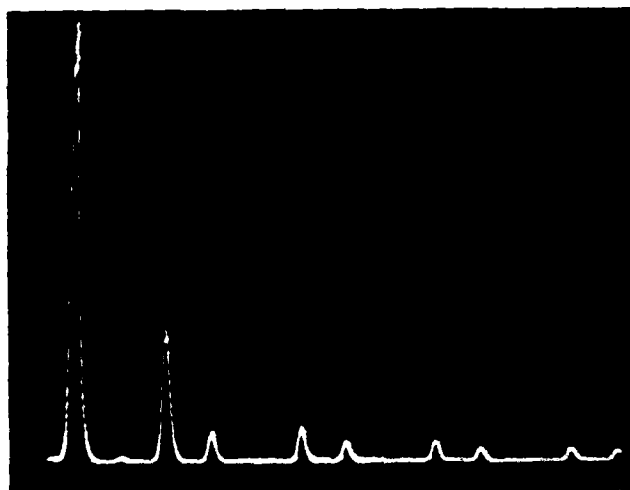
V4 _____

H1 _____

H2 _____

TEST NO. 17-06-03

PIX NO. 5



V1 _____

V2 _____

V3 _____

V4 _____

H1 _____

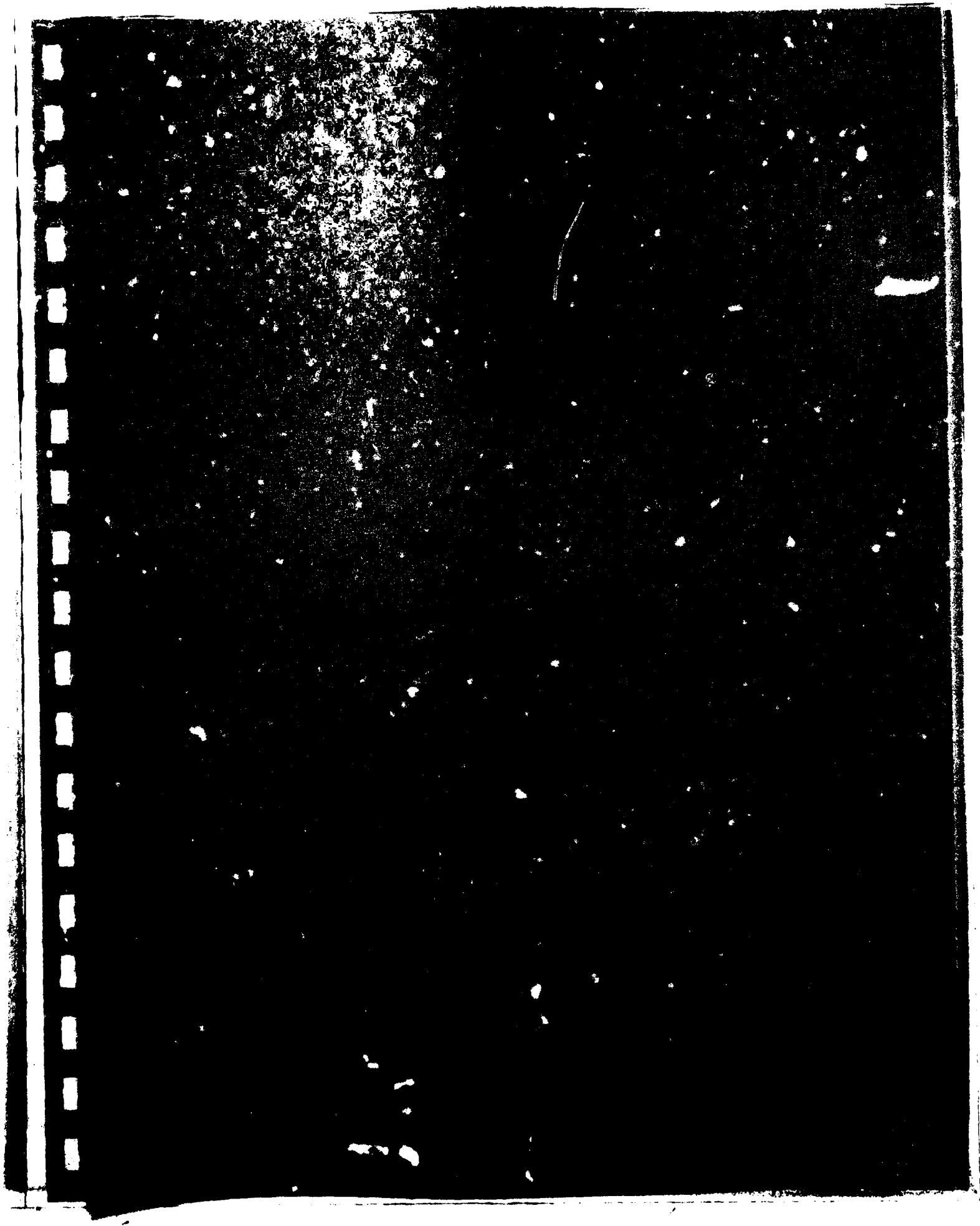
H2 _____

TEST NO. _____

PIX NO. _____

R82-127

SSP1



TESTING WITH SINGLE PHASE NONLINEAR LOADING

Both the 15 kW Frequency Changer and the 10 kW Firefinder Generator Set (MEP D423A) were tested with balanced single phase nonlinear loads. These loads, consisting of single phase full wave bridge rectifiers with L-C filters and resistive loads, were connected in three- and four-wire wye configurations.

Figure J-1 shows a schematic diagram of the three-wire wye connected nonlinear load. Figure J-2 shows a schematic diagram of the four-wire wye connected load. This latter configuration rather closely simulates the type of loading caused by dc power supplies.

For test 24-05-03, the load circuit of Figure J-1 was used to load the 60 Hz utility power line of the Solid State Power Laboratory at the Delco plant. This load caused a line current total harmonic distortion (THD) of approximately 23 percent. For test 24-05-04, the load circuit of Figure J-2 was used to load the 60 Hz utility power line. The load caused a line current THD of approximately 44 percent. Due to source regulation, the voltage THD increased to approximately 2.6 percent with this nominally 9 kW load.

For test 24-05-05, the load circuit of Figure J-2 was used to load the 10 kW Firefinder Generator Set. The inductance value in this load is largely relative to the 400 Hz output of the Firefinder Set. With a line current THD, at 6 kW output, of approximately 37 percent, the output voltage THD was slightly less than 3 percent.

For test 24-05-06, the load circuit of Figure J-2 was used to load the 15 kW Frequency Changer. The output frequency tested was 400 Hz. (The 15 kW Frequency Changer does not start this load at 60 Hz.) With a line current THD of approximately 44 percent, the output voltage THD was approximately 5.5 percent. That the Frequency Changer has higher output distortion for this particular nonlinear load than the Firefinder Set is explained by the fact that the output circuit of the former has 60 Hz magnetics with higher impedance at 400 Hz than the latter which has 400 Hz magnetics.

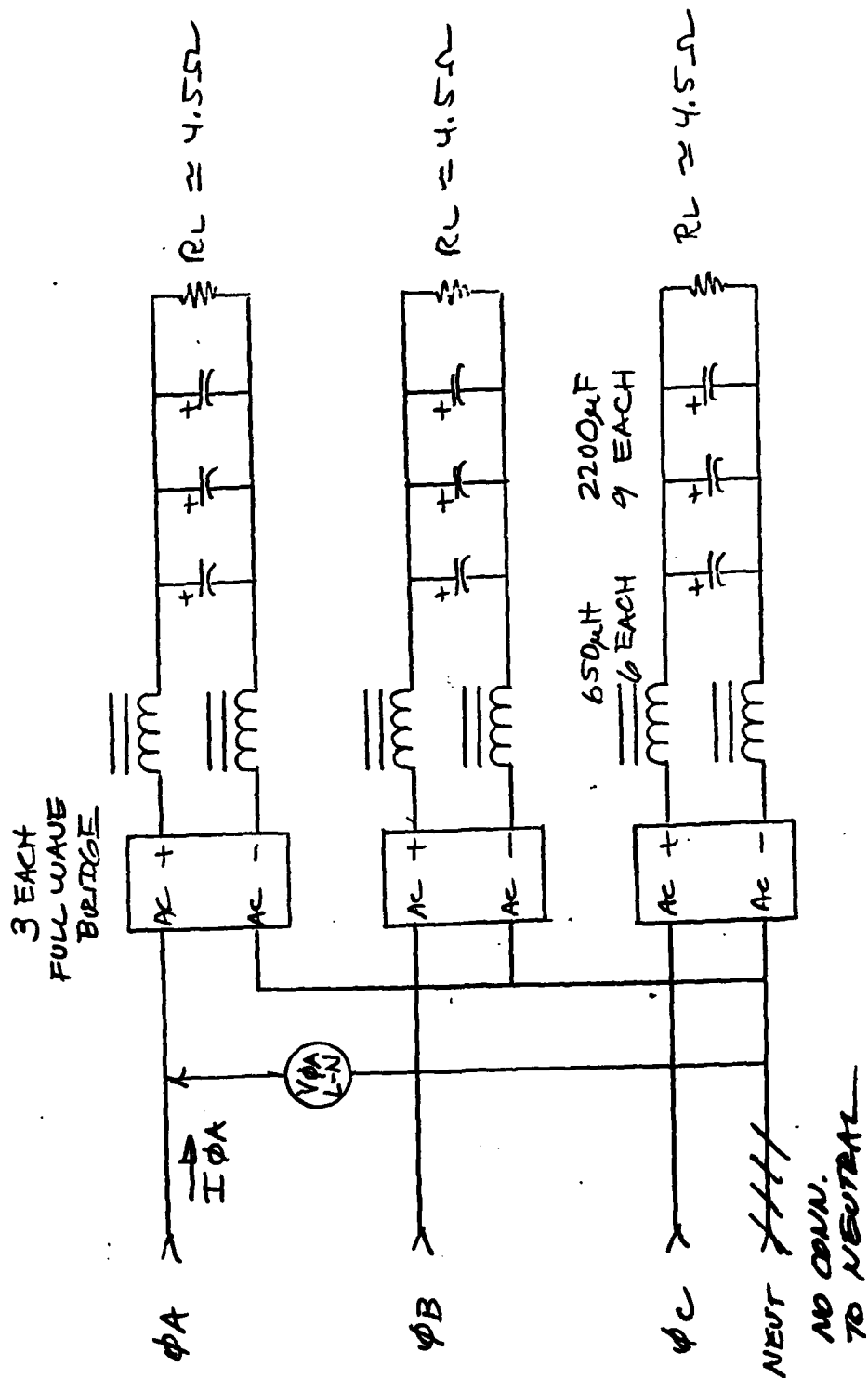


Figure J-1. Three-Wire Wye Connection, Test Configuration 1, Test 24-05-03

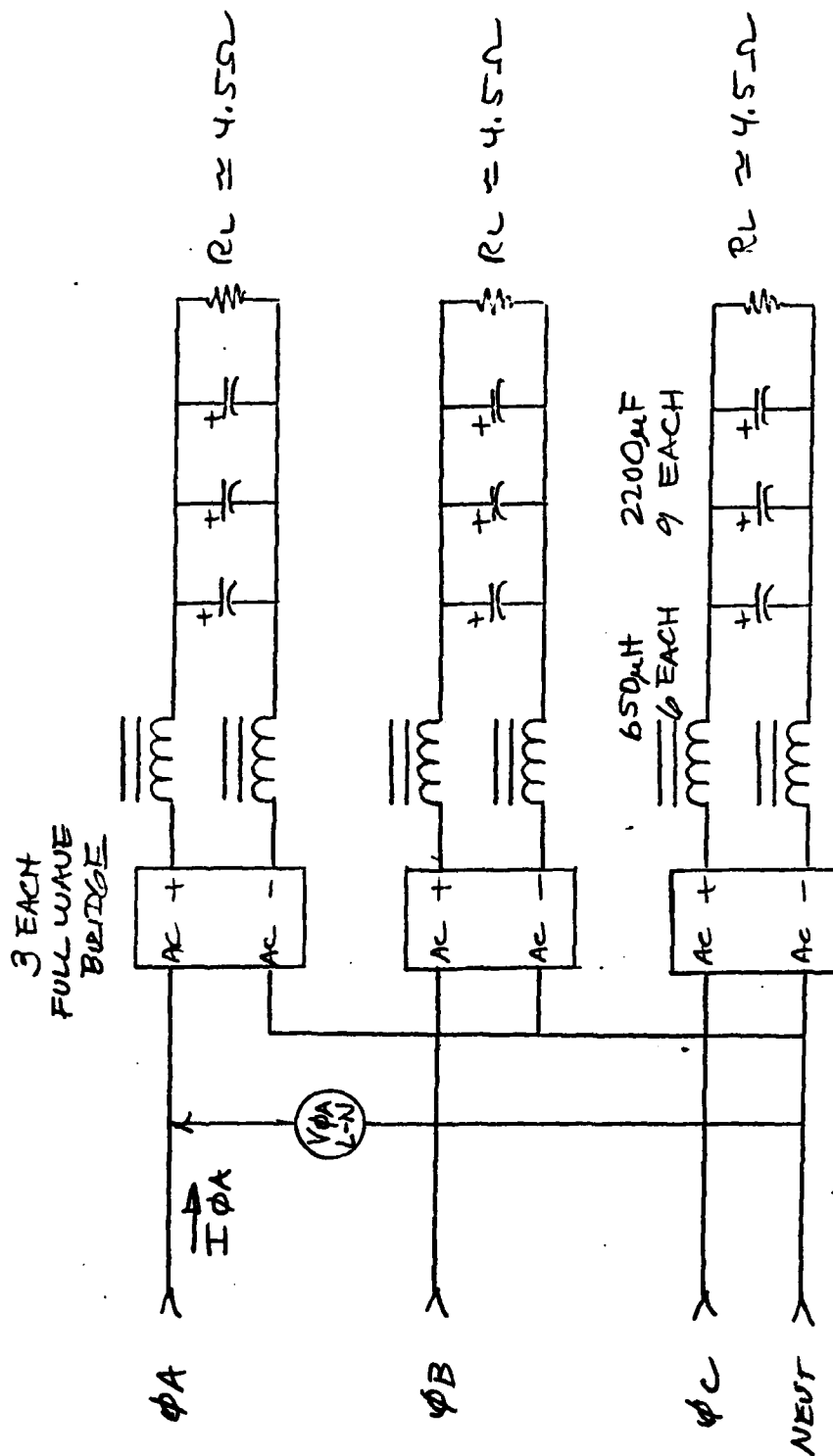


Figure J-2. Four-Wire Wye Connection, Test Configuration 1, Test 24-05-04

EQUIP DESCRIPTION	300 PEST	TEST CONFIGURATION 1	BUT FLOATING NEUTRAL	FOR

TEST NO. 24-5-C-3
SHEET _____ OF _____
DATE 24-MAY-1982
PROJECT
TEST BY
OBSERVER

TEST DESCRIPTION	INPUT	V-I-PWR
1.0		
2.0		
3.0		
4.0		
5.0		
6.0		
7.0		
8.0		
9.0		
10.0		
11.0		
12.0		
13.0		
14.0		
15.0		
16.0		
17.0		
18.0		
19.0		
20.0		
21.0		
22.0		
23.0		
24.0		
25.0		
26.0		
27.0		
28.0		
29.0		
30.0		
31.0		
32.0		
33.0		
34.0		
35.0		
36.0		
37.0		
38.0		
39.0		
40.0		
41.0		
42.0		
43.0		
44.0		
45.0		
46.0		
47.0		
48.0		
49.0		
50.0		
51.0		
52.0		
53.0		
54.0		
55.0		
56.0		
57.0		
58.0		
59.0		
60.0		
61.0		
62.0		
63.0		
64.0		
65.0		
66.0		
67.0		
68.0		
69.0		
70.0		
71.0		
72.0		
73.0		
74.0		
75.0		
76.0		
77.0		
78.0		
79.0		
80.0		
81.0		
82.0		
83.0		
84.0		
85.0		
86.0		
87.0		
88.0		
89.0		
90.0		
91.0		
92.0		
93.0		
94.0		
95.0		
96.0		
97.0		
98.0		
99.0		
100.0		

MODEL NO. _____
SERIAL NO. _____
REF: B.6 KW

[illegible]

NOTES

TEST CONFIGURATION 1 WITH FLOATING NEUTRAL



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION VOL-L-N &

I_B WAVEFORMS

V1 VOL-L-N THD 1.88%

V2 I_{ΦA} THD 23.4%

V3 _____

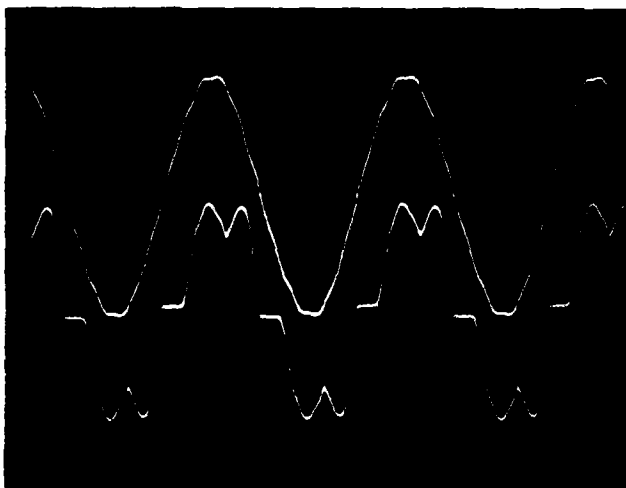
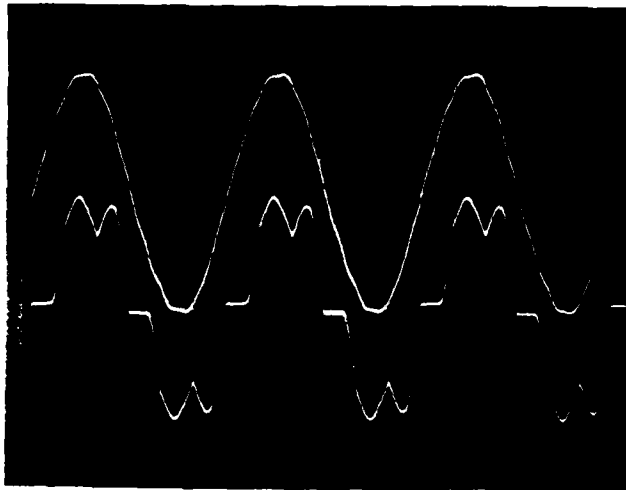
V4 _____

H1 5MS/DIV

H2 _____

TEST NO. 24-5-03

PIX NO. _____



V1 VOL-L-N THD =2.24%

V2 I_{ΦB} THD =23.0%

V3 _____

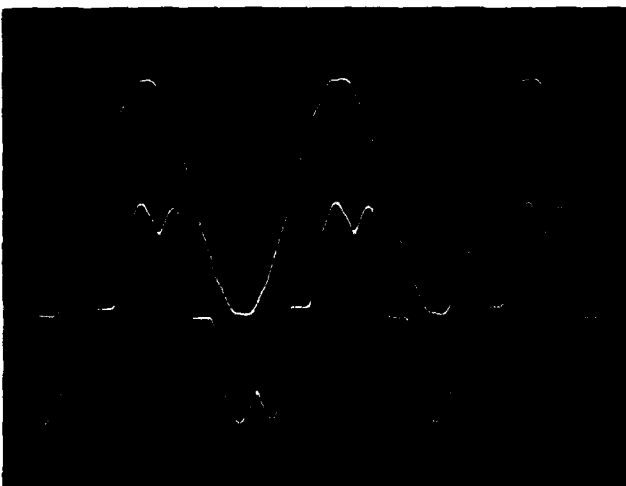
V4 _____

H1 5MS/DIV

H2 _____

TEST NO. _____

PIX NO. _____



V1 VOL-L-N THD =1.82%

V2 I_{ΦC} THD =22.4%

V3 _____

V4 _____

H1 5MS/DIV

H2 _____

TEST NO. _____

PIX NO. _____

R82-127

J-5



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION $I\phi_x$
NAVEFORNS CALIB

V1 $I\phi_A$

V2 20A/DIV

V3

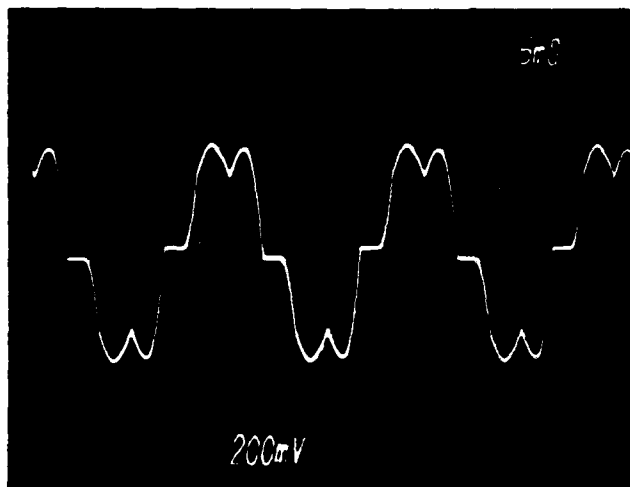
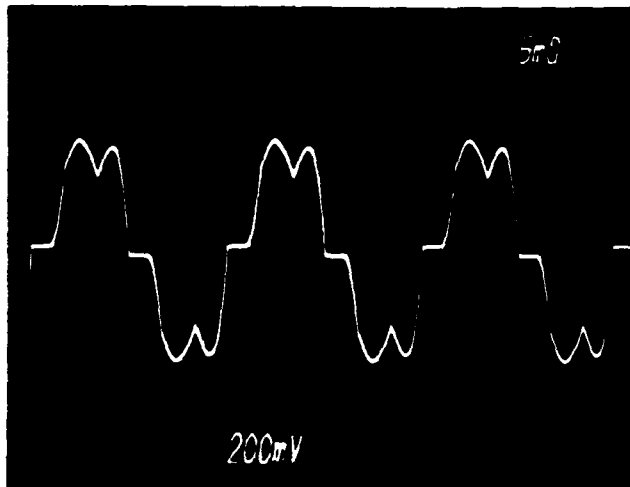
V4

H1 5MS/DIV

H2

TEST NO. 24-05-03

PIX NO.



V1 $I\phi_B$

V2 20A/DIV

V3

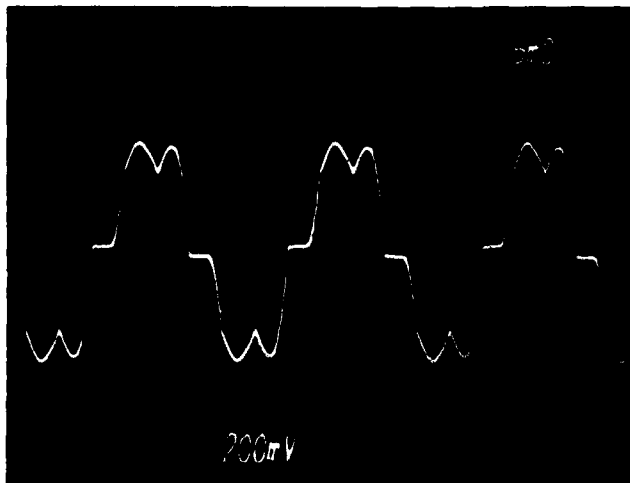
V4

H1 5MS/DIV

H2

TEST NO.

PIX NO.



V1 $I\phi_C$

V2 20A/DIV

V3

V4

H1 5MS/DIV

H2

TEST NO.

PIX NO.

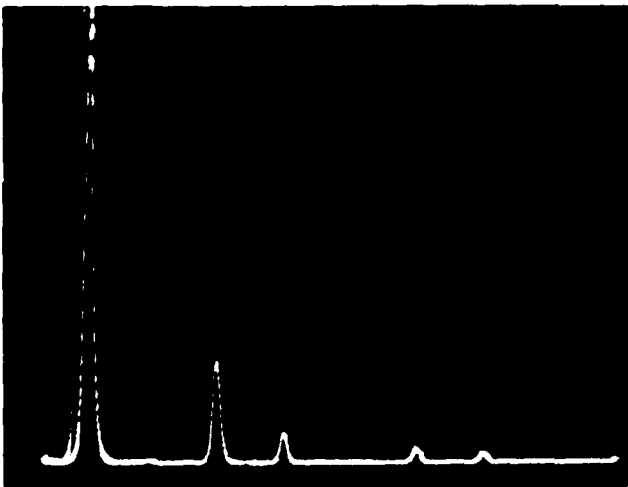
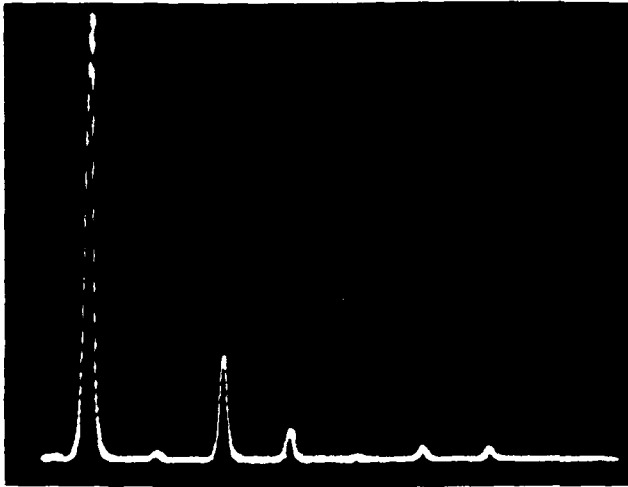


SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION $I\phi x$
~~DISTORTION COMPONENTS~~

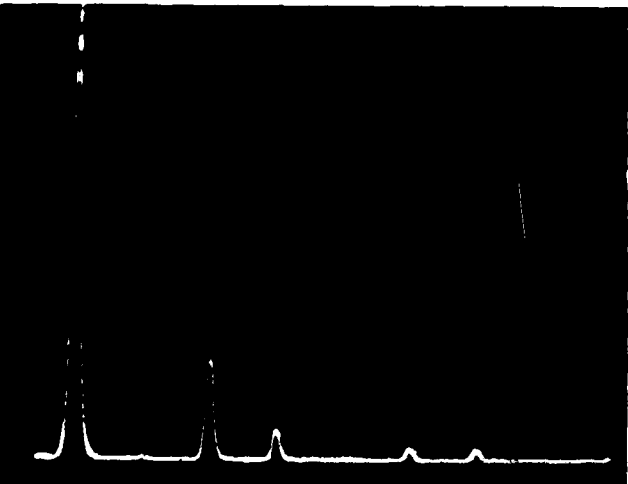
V1 $I\phi A$
V2 10% / DIV
V3 _____
V4 _____
H1 100 Hz / DIV
H2 _____

TEST NO. 24-5-03
PIX NO. _____



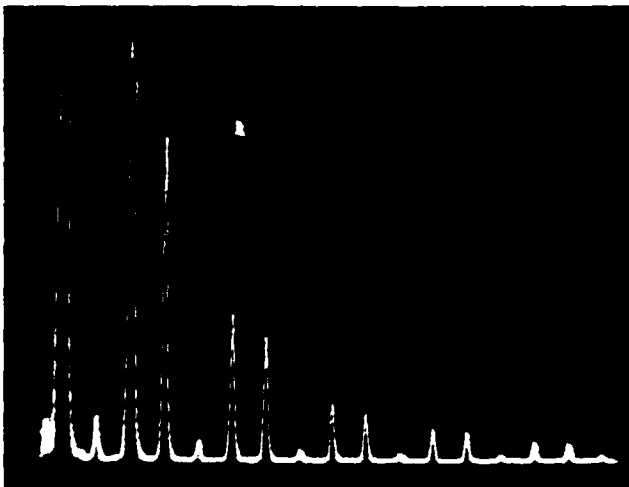
V1 $I\phi B$
V2 _____
V3 _____
V4 _____
H1 _____
H2 _____

TEST NO. _____
PIX NO. _____



V1 $I\phi C$
V2 _____
V3 _____
V4 _____
H1 _____
H2 _____

TEST NO. _____
PIX NO. _____

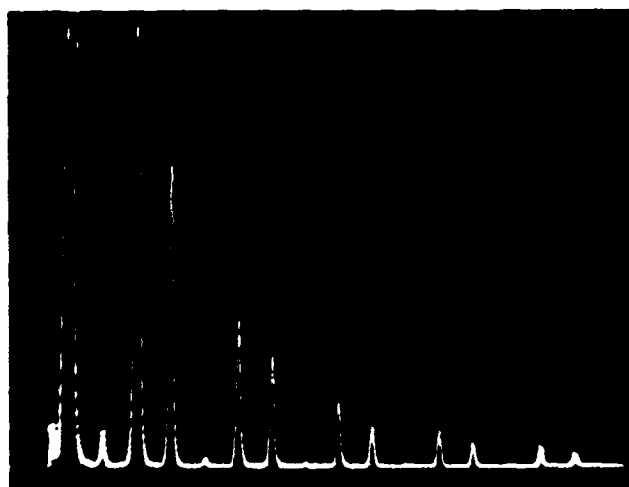


SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION $I\phi x$
DISTORTION COMPONENTS

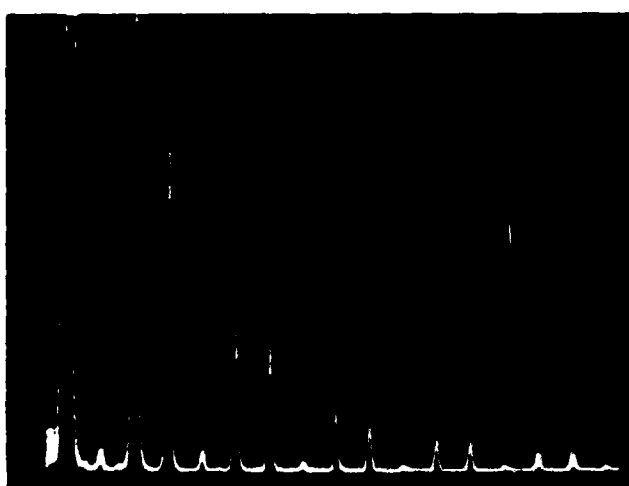
V1 $I\phi A$
V2 1% / DIV
V3 _____
V4 _____
H1 200 Hz / DIV
H2 _____

TEST NO. 24-5-03
PIX NO. _____



V1 $I\phi B$
V2 _____
V3 _____
V4 _____
H1 _____
H2 _____

TEST NO. _____
PIX NO. _____



V1 $I\phi C$
V2 _____
V3 _____
V4 _____
H1 _____
H2 _____

TEST NO. _____
PIX NO. _____

EQUIP DESCRIPTION 3 ϕ RECT
TEST CONFIGURATION 1
4 WIRE INPUT



SANTA BARBARA, CALIFORNIA

TEST NO. 24-5-04
 SHEET OF
 DATE 24-MAY-1982
 PROJ ENGR
 TEST BY
 OBSERVER

TEST DESCRIPTION INPUT V-I-PWR
 MANFR
 MODEL NO.
 SERIAL NO. REF:

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) INPUT ϕ A VOLTAGE		119.7		119.7 V				
(b) ϕ A CURRENT		31.99		31.99 A		1		
(c) ϕ A PHASE ANGLE		—		— deg	PF = 0.792			
(d) ϕ A POWER		3032		3032 W				
(e) ϕ B VOLTAGE		119.8		119.8 V				
(f) ϕ B CURRENT		31.49		31.49 A		2		
(g) ϕ B PHASE ANGLE		—		— deg	PF = 0.792			
(h) ϕ B POWER		2989		2989 W				
(i) ϕ C VOLTAGE		119.2		119.2 V				
(j) ϕ C CURRENT		31.93		31.93 A		3		
(k) ϕ C PHASE ANGLE		—		— deg	PF = 0.796			
(l) ϕ C POWER		3020		3028 W				
(m) CONV FREQUENCY		—		— Hz				
(n) TOTAL POWER IN		9049W		9049 W				

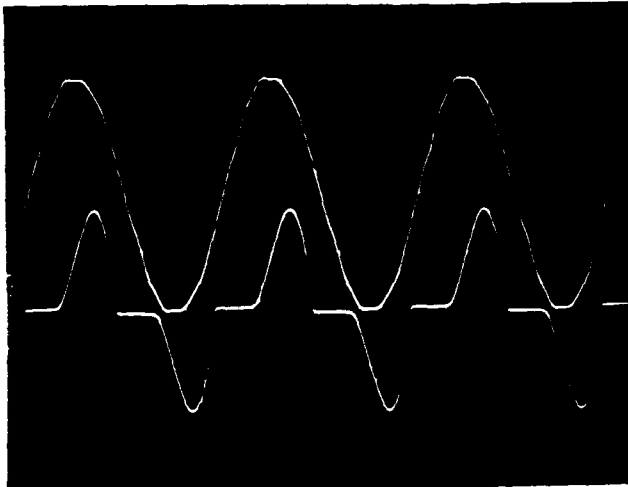
NOTE:

SIMULATES TYPICAL POWER SUPPLY LOAD

TEST CONFIGURATION 1



SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION VOL L-N &

IPR WAVEFORMS

V1 VOL L-N THD=2.46%

V2 IPR THD=45.5%

V3 _____

V4 _____

H1 5MS/DIV

H2 _____

TEST NO. 24-5-04

PIX NO. 1



V1 VOL L-N THD=2.53%

V2 IPR THD=43.5%

V3 _____

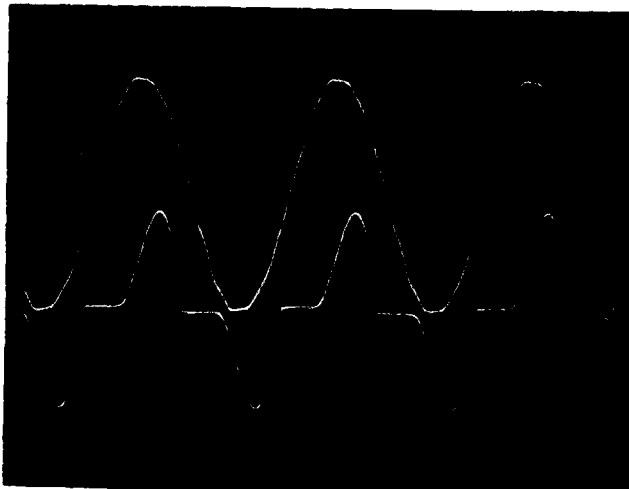
V4 _____

H1 5MS/DIV

H2 _____

TEST NO. _____

PIX NO. 2



V1 VOL L-N THD=2.65%

V2 IPR THD=42.5%

V3 _____

V4 _____

H1 5MS/DIV

H2 _____

TEST NO. _____

PIX NO. 3

R82-127

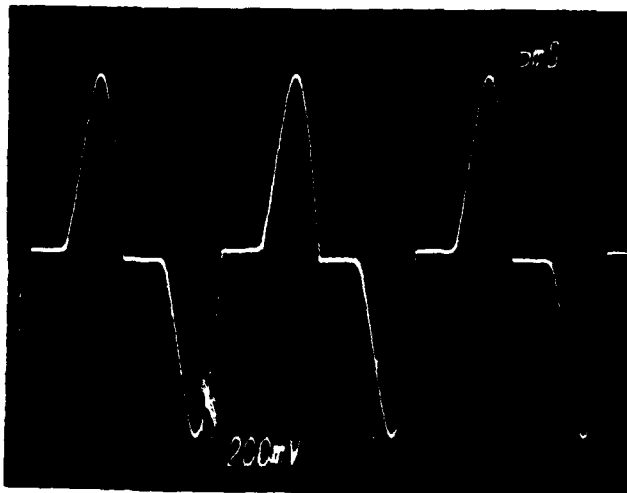


SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION I_{DR}
WAVEFORM, CALIB

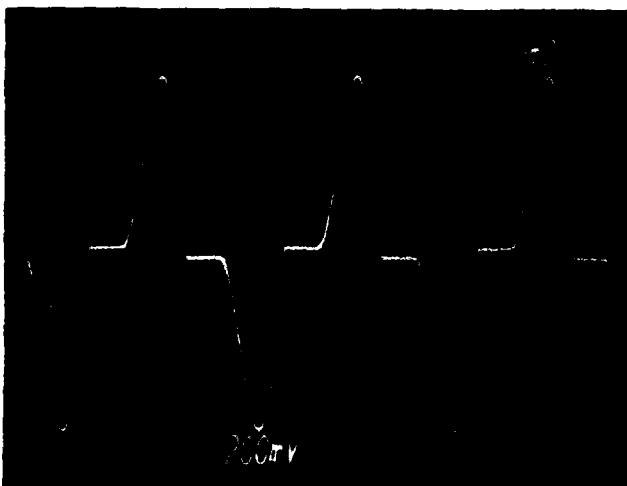
V1 I_{DR}
V2 20A/DIV
V3 _____
V4 _____
H1 _____
H2 _____

TEST NO. 24-5-04
PIX NO. _____



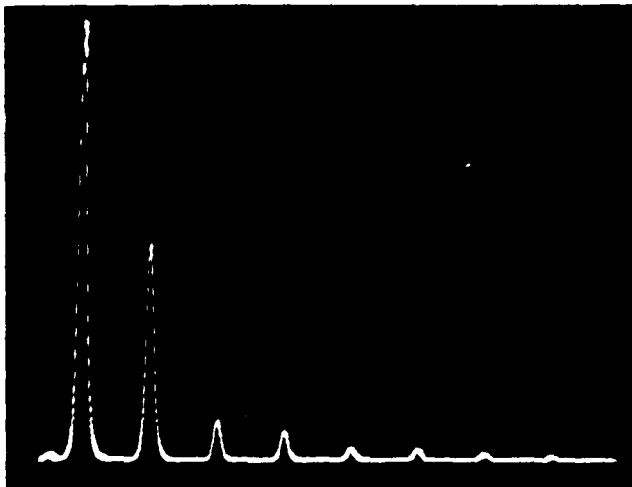
V1 I_{DB}
V2 20A/DIV
V3 _____
V4 _____
H1 _____
H2 _____

TEST NO. _____
PIX NO. _____



V1 I_{DC}
V2 20A/DIV
V3 _____
V4 _____
H1 _____
H2 _____

TEST NO. _____
PIX NO. _____

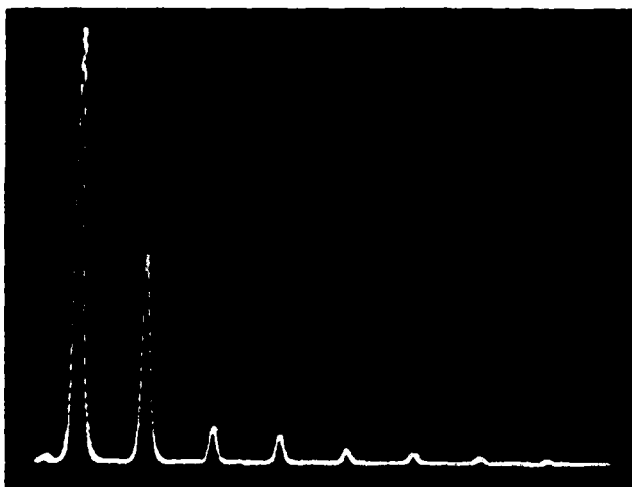


SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION $I_{\phi x}$
DISTORTION COMPONENTS

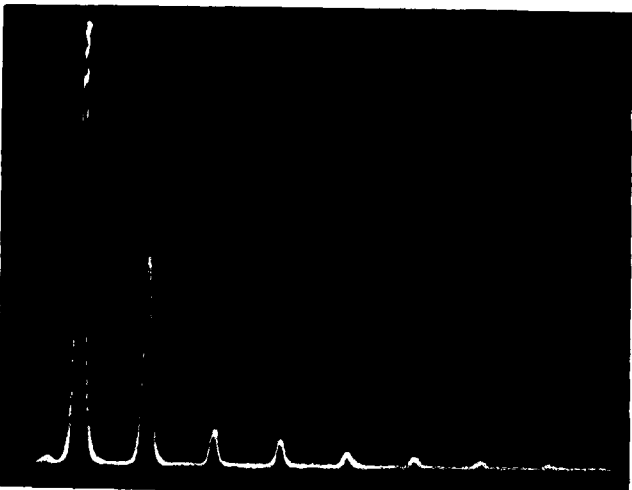
V1 $I_{\phi A}$
 V2 100% DIV
 V3 _____
 V4 _____
 H1 100Hz/DIV
 H2 _____

TEST NO. 24-5-04
 PIX NO. _____



V1 $I_{\phi B}$
 V2 100% DIV
 V3 _____
 V4 _____
 H1 100Hz/DIV
 H2 _____

TEST NO. _____
 PIX NO. _____

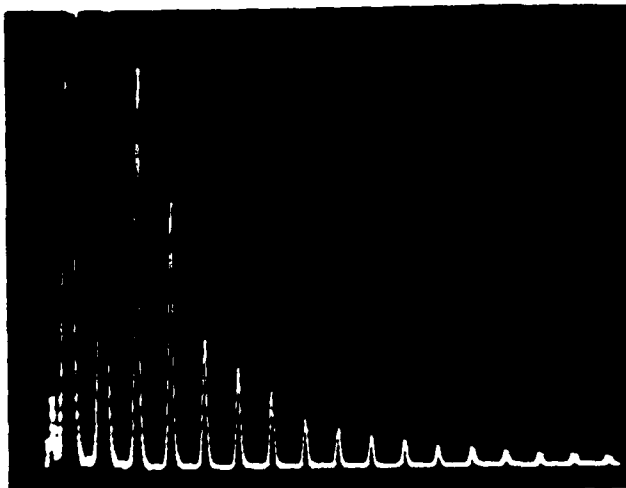


V1 $I_{\phi C}$
 V2 100% DIV
 V3 _____
 V4 _____
 H1 100Hz/DIV
 H2 _____

TEST NO. _____
 PIX NO. _____



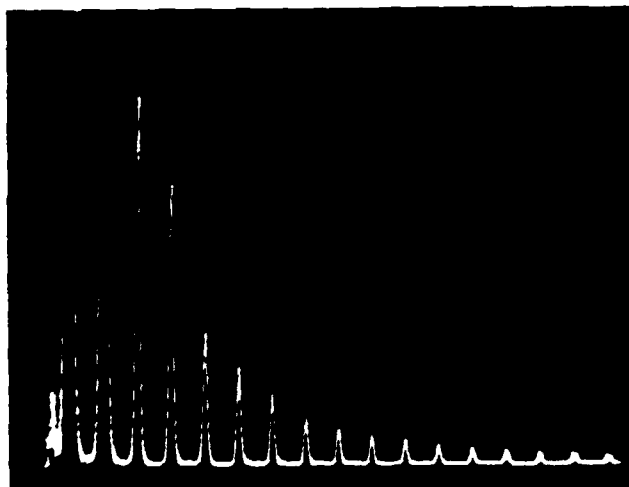
SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION $I\phi x$
DISTORTION COMPONENTS

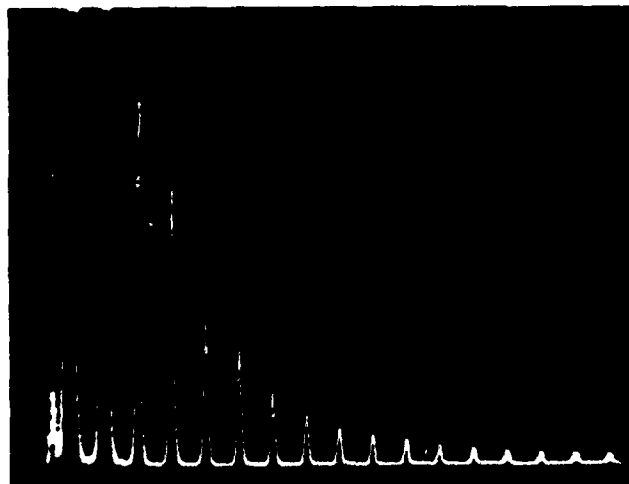
V1 $I\phi A$
V2 100/DIV
V3 _____
V4 _____
H1 200 Hz/DIV
H2 _____

TEST NO. 24-5-04
PIX NO. _____



V1 $I\phi B$
V2 100/DIV
V3 _____
V4 _____
H1 200 Hz/DIV
H2 _____

TEST NO. _____
PIX NO. _____



V1 $I\phi C$
V2 100/DIV
V3 _____
V4 _____
H1 200 Hz/DIV
H2 _____

TEST NO. _____
PIX NO. _____

EQUIP DESCRIPTION _____

SANTA BARBARA, CALIFORNIA

TEST NO. 24-5-05

SHEET _____ OF _____

TEST DESCRIPTION INPUT V-I-PWRDATE 24-MAY-1982MFR DELCO

PROJ ENGR _____

MODEL NO. F1500000

TEST BY _____

SERIAL NO. TEST BED UNIT

OBSERVER _____

REF: _____

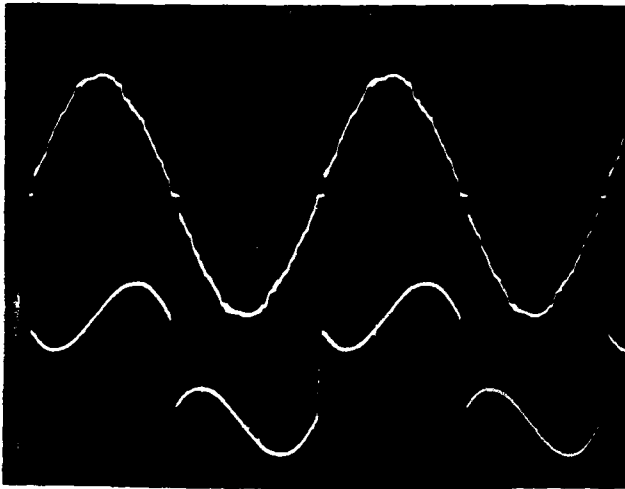
(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
INPUT ϕ A VOLTAGE		120.5		120.5 V				
ϕ A CURRENT		20.01		20.01 A				
ϕ A PHASE ANGLE		—		— deg	PF = 0.839			
ϕ A POWER		2024		2024 W				
ϕ B VOLTAGE		120.5		120.5 V				
ϕ B CURRENT		19.67		19.67 A				
ϕ B PHASE ANGLE		—		— deg	PF = 0.854			
ϕ B POWER		2024		2024 W				
ϕ C VOLTAGE		120.4		120.4 V				
ϕ C CURRENT		19.93		19.93 A				
ϕ C PHASE ANGLE		—		— deg	PF = 0.854			
ϕ C POWER		2049		2049 W				
CONV FREQUENCY				Hz				
TOTAL POWER		6097W		6097W				

NOTES:

TEST CONFIGURATION 1



SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION V ϕ L-N

I ϕ WAVEFORMS

V1 V ϕ A L-N THD = 2.98%

V2 I ϕ A THD = 36.9%

V3 _____

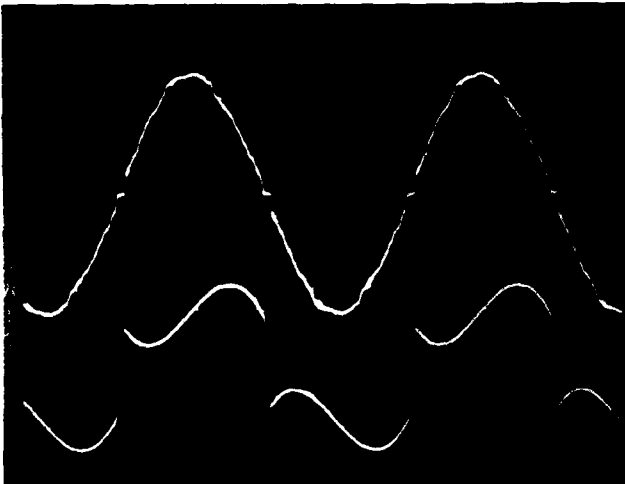
V4 _____

H1 500 μ s/DIV

H2 _____

TEST NO. 24-505

PIX NO. _____



V1 V ϕ B L-N THD = 2.92%

V2 I ϕ B THD = 37.2%

V3 _____

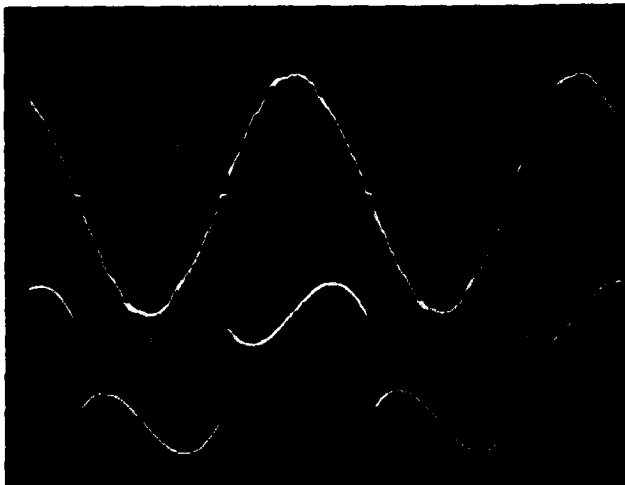
V4 _____

H1 _____

H2 _____

TEST NO. _____

PIX NO. _____



V1 V ϕ C L-N THD = 2.85%

V2 I ϕ C THD = 37.1%

V3 _____

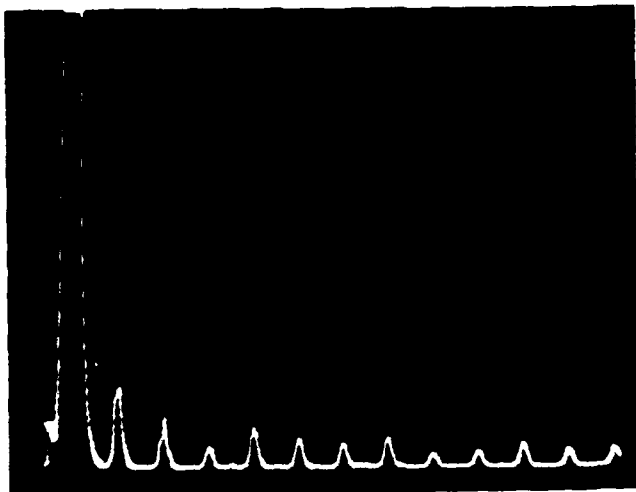
V4 _____

H1 _____

H2 _____

TEST NO. _____

PIX NO. _____

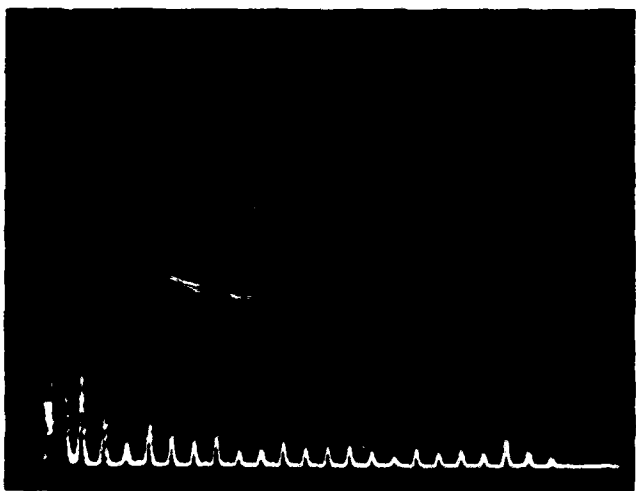


SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION V_{PA} L-N
DISTORTION COMPONENTS

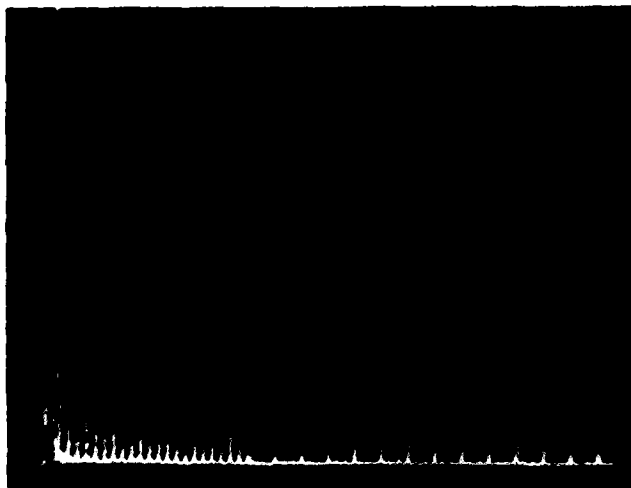
V1 V_{PA} L-N
 V2 100/DIV
 V3 _____
 V4 _____
 H1 1 KHz/DIV
 H2 _____

TEST NO. 24-5-05
 PIX NO. _____



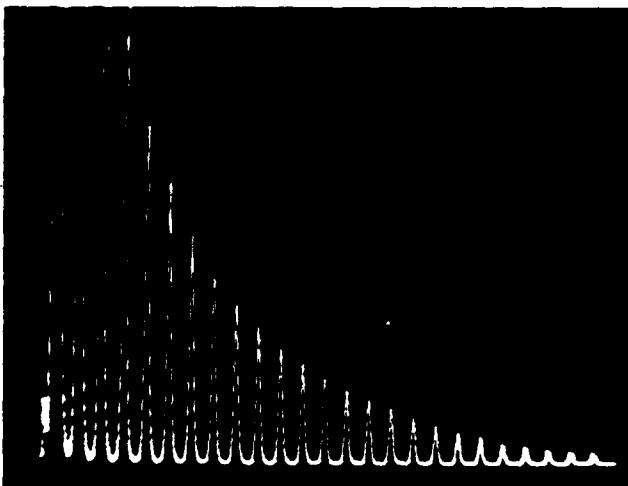
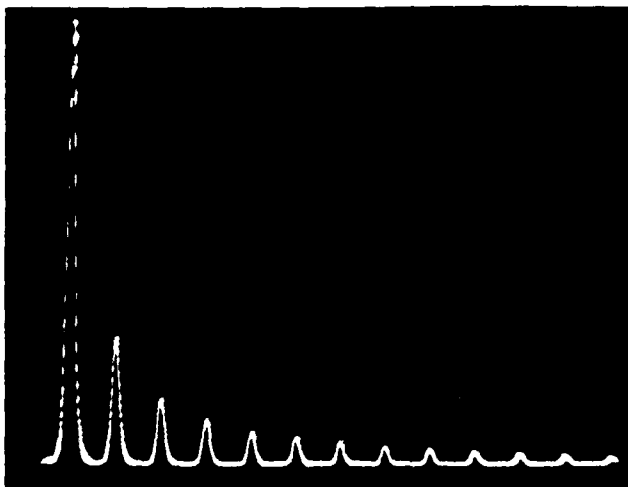
V1 V_{PA} L-N
 V2 100/DIV
 V3 _____
 V4 _____
 H1 2 KHz/DIV
 H2 _____

TEST NO. _____
 PIX NO. _____



V1 V_{PA} L-N
 V2 100/DIV
 V3 _____
 V4 _____
 H1 5 KHz/DIV
 H2 _____

TEST NO. _____
 PIX NO. _____



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION IΦx

DISTORTION COMPONENTS

V1 IΦA

V2 1090/DIV

V3 _____

V4 _____

H1 1 KHz/DIV

H2 _____

TEST NO. 24-05-05

PIX NO. _____

V1 IΦA

V2 1090/DIV

V3 _____

V4 _____

H1 2 KHz/DIV

H2 _____

TEST NO. _____

PIX NO. _____

V1 _____

V2 _____

V3 _____

V4 _____

H1 _____

H2 _____

TEST NO. _____

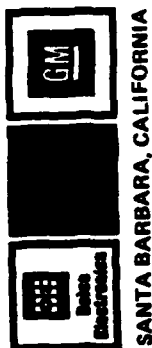
PIX NO. _____

R82-127

J-17

EQUIP DESCRIPTION (SKW) FREQ
CHARGER 400Hz
OUTPUT TO NON LINEAR LOAD
 MFR DELCO

MODEL NO. _____
 SERIAL NO. _____



SANTA BARBARA, CALIFORNIA

TEST NO. 24-5-06
 SHEET _____ OF _____
 DATE 24-MAY-1982
 PROJ ENGR _____
 TEST BY _____
 OBSERVER _____

TEST DESCRIPTION INPUT V-I-PWR

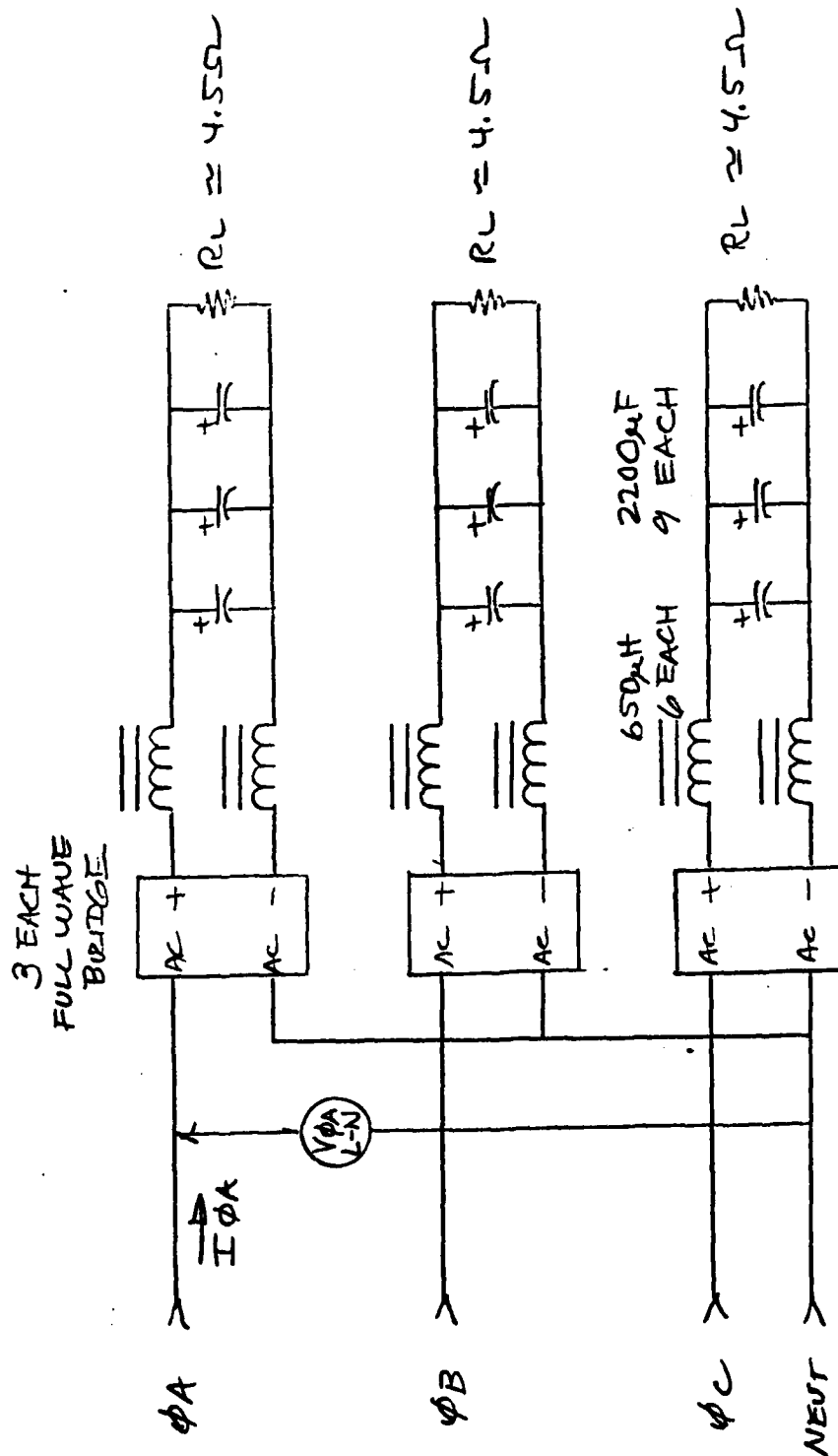
REF: _____

(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
INPUT ϕ A VOLTAGE		120.6		120.6 V				
ϕ A CURRENT		19.98		19.98 A				
ϕ A PHASE ANGLE				— deg	PF = 0.822			
ϕ A POWER		1981		1981 W				
ϕ B VOLTAGE		120.8		120.8 V				
ϕ B CURRENT		19.68		19.68 A				
ϕ B PHASE ANGLE				— deg	PF = 0.840			
ϕ B POWER		1996		1996 W				
ϕ C VOLTAGE		121.0		121.0 V				
ϕ C CURRENT		19.98		19.98 A				
ϕ C PHASE ANGLE		—		— deg	PF = 0.840			
ϕ C POWER		2030		2030 W				
CONV FREQUENCY		—		— Hz				

NOTES:

TEST CONFIRMATION 1

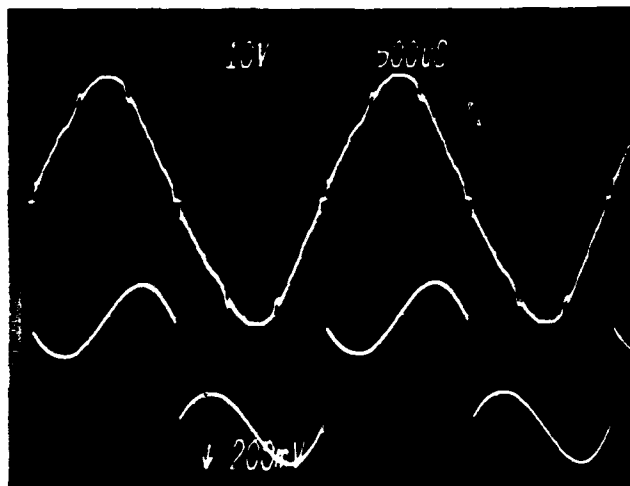
22-141 50 SHEETS
22-142 140 SHEETS
22-143 90 SHEETS



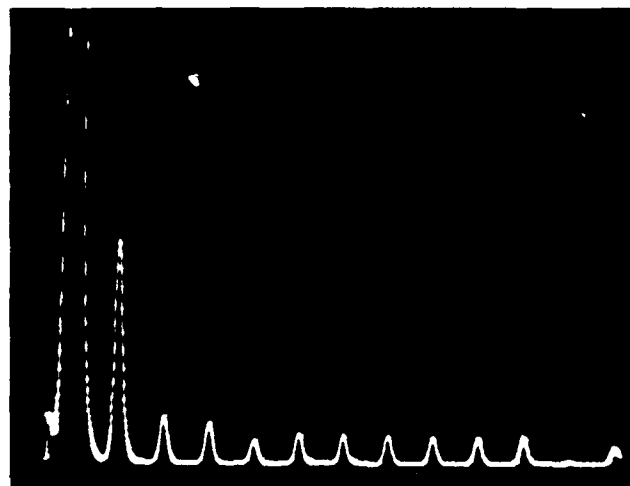
TEST CONFIGURATION 1
TEST NO. 24-5-06



SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION 15KW
FREQ CHGR NON-LINEAR
LOAD
V1 V_{ΦA} L-N THD = 5.5%
V2 I_{ΦA} THD = 44.0%
V3 _____
V4 _____
H1 500μs/DIV
H2 _____
TEST NO. 24-5-06
PIX NO. _____



V1 V_{ΦA} L-N
V2 10V/DIV
V3 _____
V4 _____
H1 1 KHz/DIV
H2 _____
TEST NO. _____
PIX NO. _____

J-20

V1 _____
V2 _____
V3 _____
V4 _____
H1 _____
H2 _____
TEST NO. _____
PIX NO. _____

R82-127

SSP1

AD A145 531

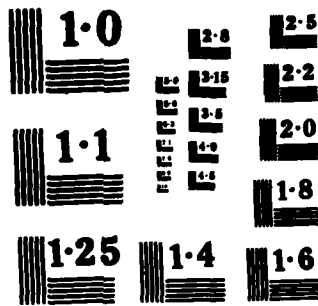
PROGRESS IN POWER DISTRIBUTION IN FISCAL YEAR 1982(U)
GENERAL MOTORS CORP GOLETA CA DELCO ELECTRONICS DIV
OCT 82 R82-127

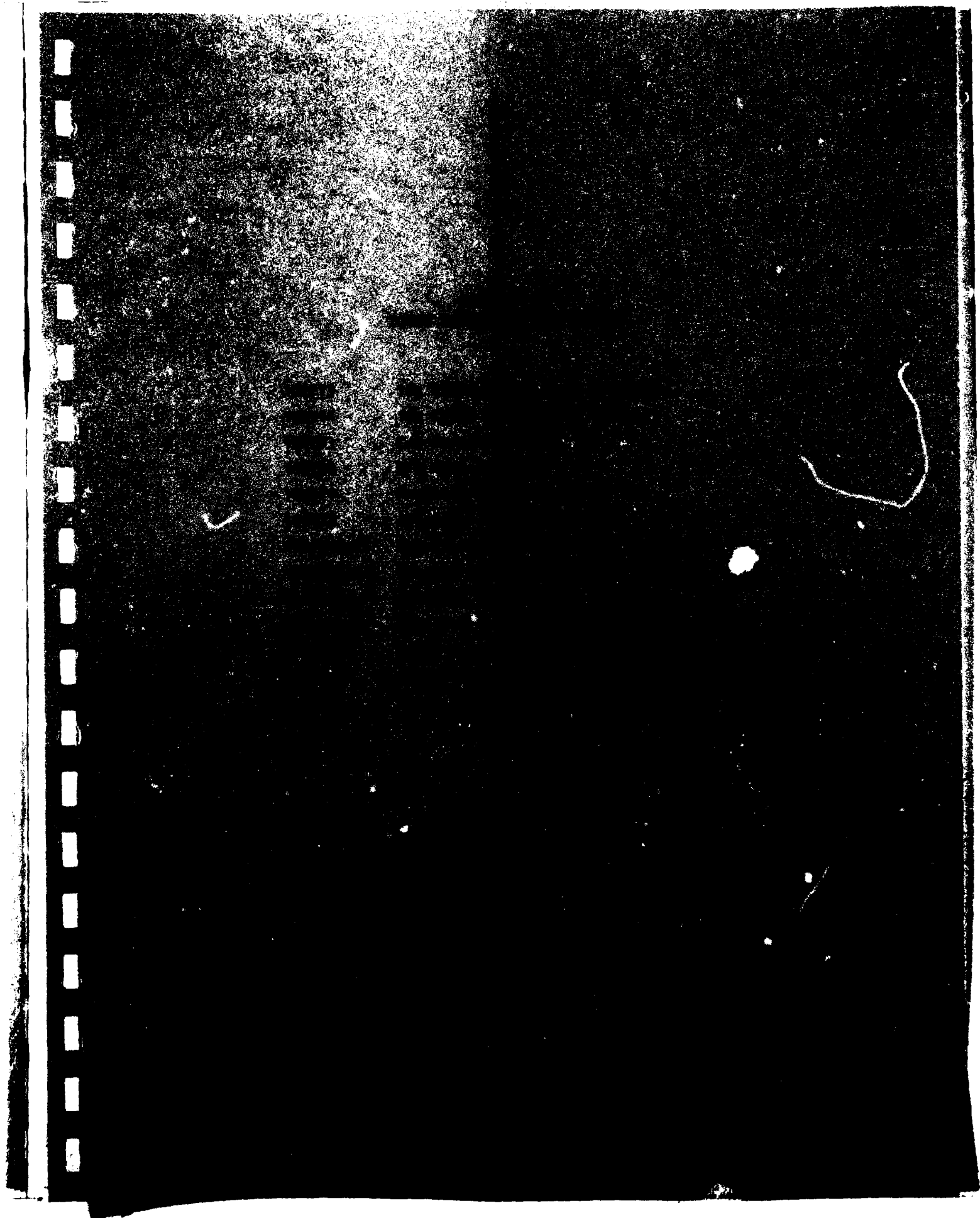
3/64

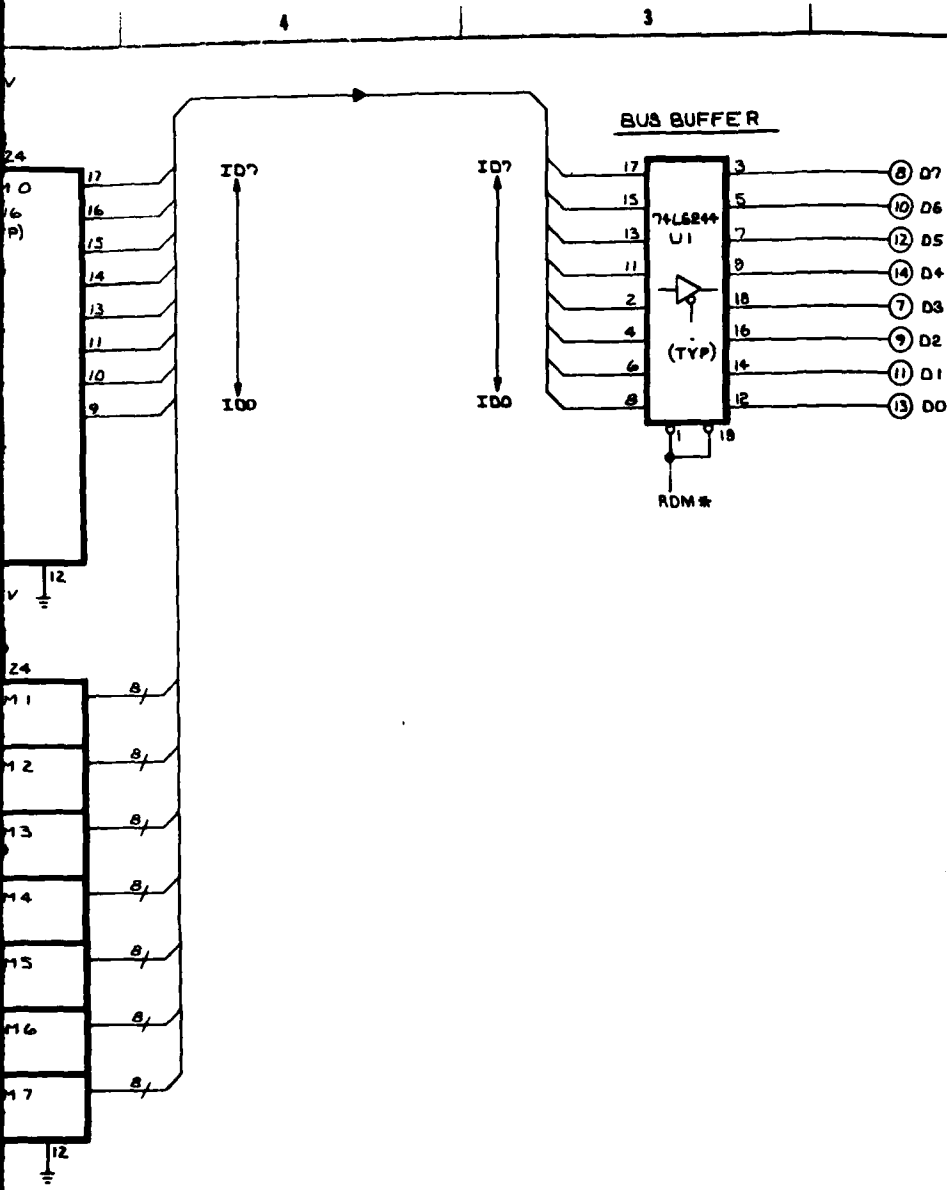
UNCLASSIFIED

F/G 10/2

NI







REVISIONS				
REV	DOC REV	DESCRIPTION	DATE	APPV
A		ADDED PINS 51 & 52. PCR.0261; PCN.0129.	11-1-77	g.m.
B		ADDED JUMPER TO 2 & DELETED JUMPER FROM OF U2. CHANGED NOTE 1. PCR.0326.	1-9-77	g.m.
C		REVISED PER PCN 0743	2-6-77	g.m.
D		REVISED PER PCN 0831	4-1-78	g.m.

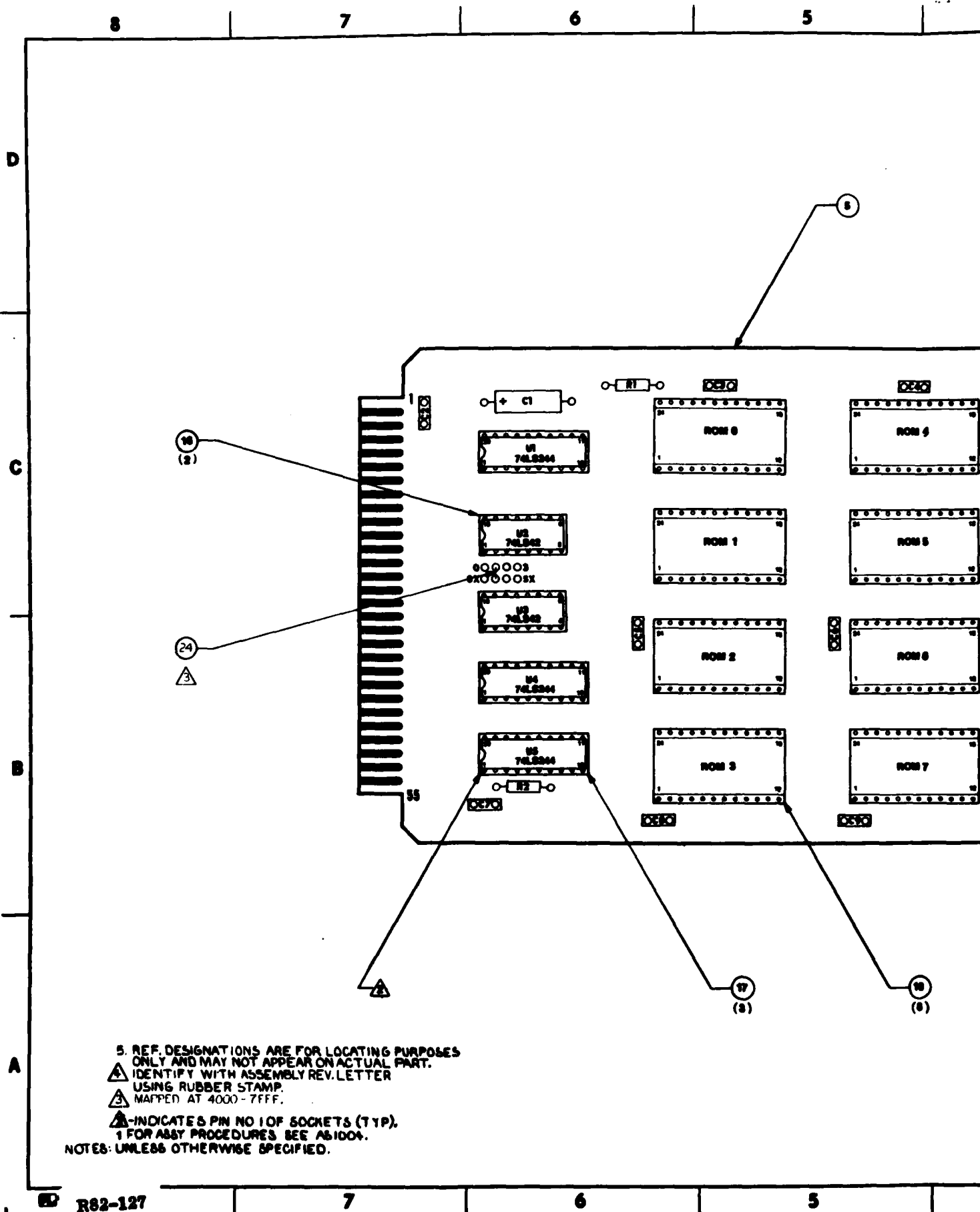
⚠ JUMPER MOVES MEMORY IN 16K BLOCKS

ASSEMBLY 102714
PARTS LIST 102715

PRO-LOG CORPORATION	
	SCHEMATIC-7702
H. REEVES 9-20-77	16K EPROM MEMORY CARD
102714	102715

2

K-1



4

3

2

1

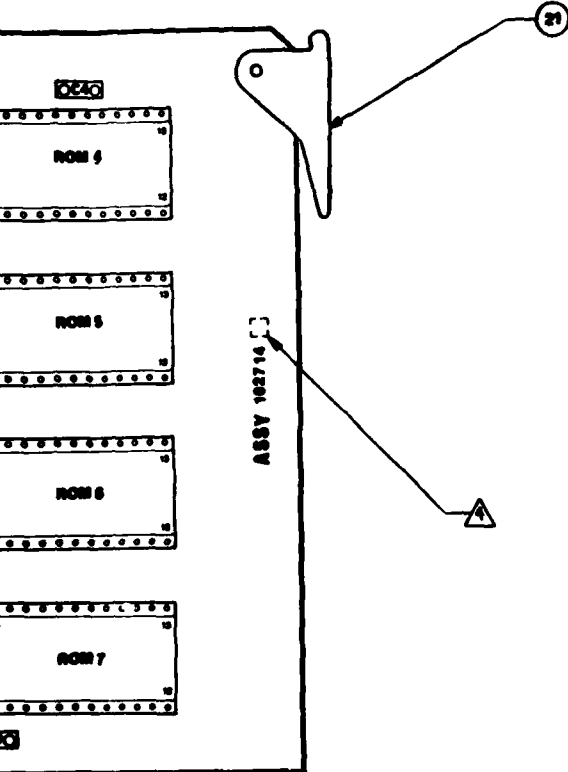
REVISIONS				
REV	DATE	DESCRIPTION	BY	APP
A	1-7	ADDED ITEM 24. ADDED NOTE 3. PCR 0326.		
B	1-6	REVISED PER PCN#0851		

D

C

B

A



21
(8)

SCHEMATIC NO. 102713
PARTS LIST NO. 102715

10	1K 1/4W 5%	R1-R2
9		
8	0.1μF 50V	CE-CA
7	1.0μF 55V	C1
ITEM	DESCRIPTION	REF. DESIGNATION
PRO-LOG CORPORATION		
ASSEMBLY, 7702		
16K EPROM MEMORY CARD.		
CA CLARK	7-8-78	
D	102714	BY B

K-2

2

4

3

2

1



PCRT-3

ASSEMBLY NO. 102784
PARTS LIST NO. 102785

PRO-LOG CORPORATION

SCHEMATIC, 7601
I/O CARD

Q JANSSENS	4-6-77

D	102783

人

K-3

2

4

3

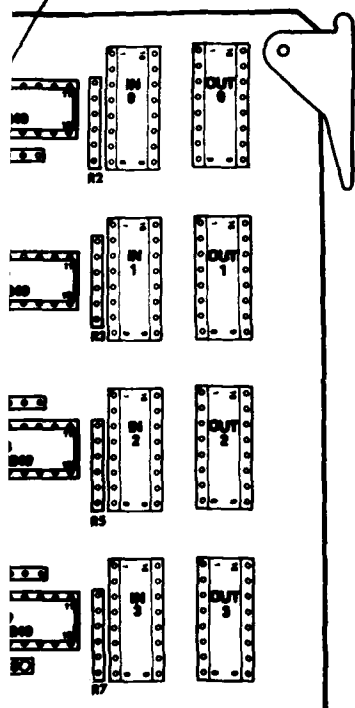
2

1

REVISIONS				
REV	DATE	DESCRIPTION	BY	APP
A	11/17/78	ADDED ITEM 25. ADDED NOTE 4. PCR 329		

20
(8)

22

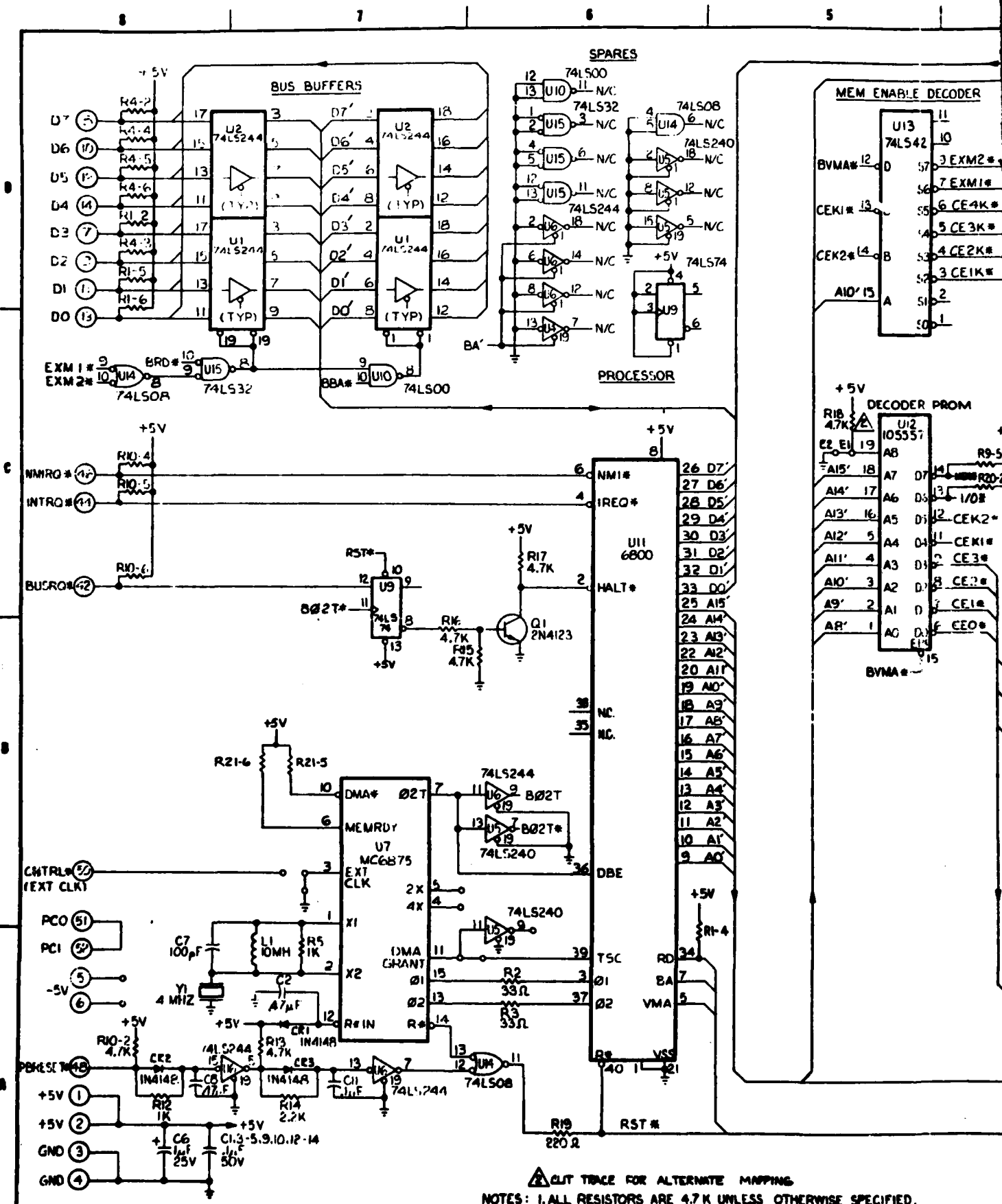


SCHEMATIC NO. 102783
PARTS LIST NO. 102785

10	KHZ NETWORK	R1 - R7
9		
8	0.1 μ 50V	CE - C8
7	1.0 μ 25V	C9
ITEM	DESCRIPTION	REF. DESIGNATION
PRO-LOG CORPORATION		
~~XXXXXXXXXX~~		ASSEMBLY, 7601
~~XXXXXXXXXX~~		I/O CARD
C A CLARK	8-18-78	
Q Higgins	8-18-78	
D	102784	REV A

K-4

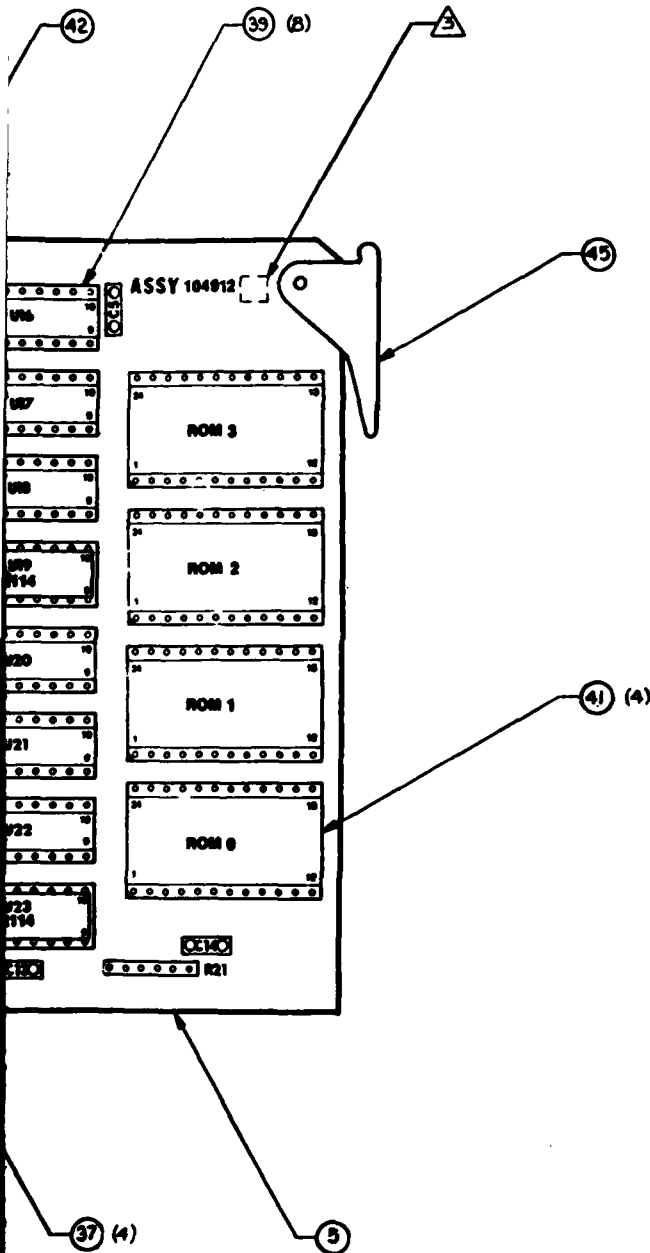
2



CLIT TRACE FOR ALTERNATE MAPPING
 NOTES: 1. ALL RESISTORS ARE 4.7K UNLESS OTHERWISE SPECIFIED.

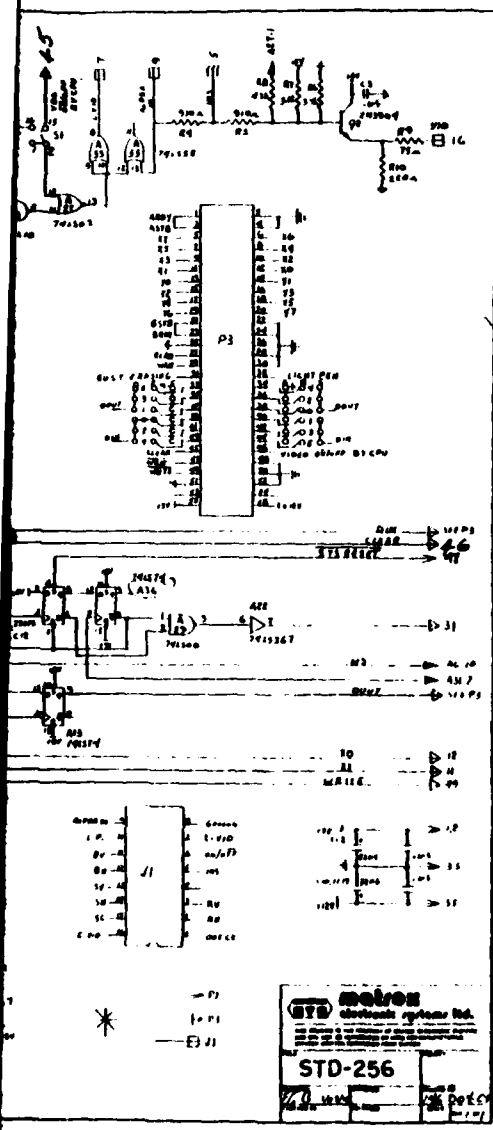


REVISIONS				
REV	DOC REV	DESCRIPTION	DATE	APPR
A		REVISED PER PLN 0516	7-26-74	P. G.
B		REVISED PER PCN 0477	10-2-74	P. H.
C		REVISED PER PCN 0478	10-2-74	P. H.
D		REVISED PER PCN 0508	11-1-74	P. K.

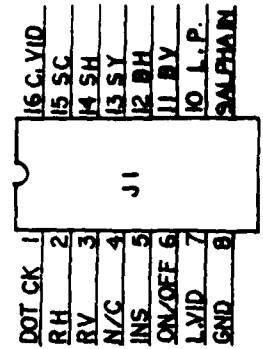


36	2.2K 1/4W, CF, 5%	R14
35	1K 1/4W, CF, 5%	R5, 12
34	33Ω 1/4W, CF, 5%	R2, 3
33	4.7K 1/4W, CF, 5%	R13, 15-18
32	220Ω 1/4W, CF, 5%	R19
31	4.7K, NETWORK	R1, 4, 6-11, 20, 21
14	10μH 10%	L1
13	2N4123	Q1
12	1N4148	CR1-3
11	4MHZ	Y1
10	1.0μF, 50V	C6
9	.47μF, 50V	C2, 8
8	1μF, 50V	C1, 3, 5, 9-14
7	100pF, 50V	C7
ITEM	DESCRIPTION	REF. DESIGNATION
PRO-LOG CORPORATION		
ASSEMBLY, 7802		
PROCESSOR CARD		
6800 CPU		
D 104912		

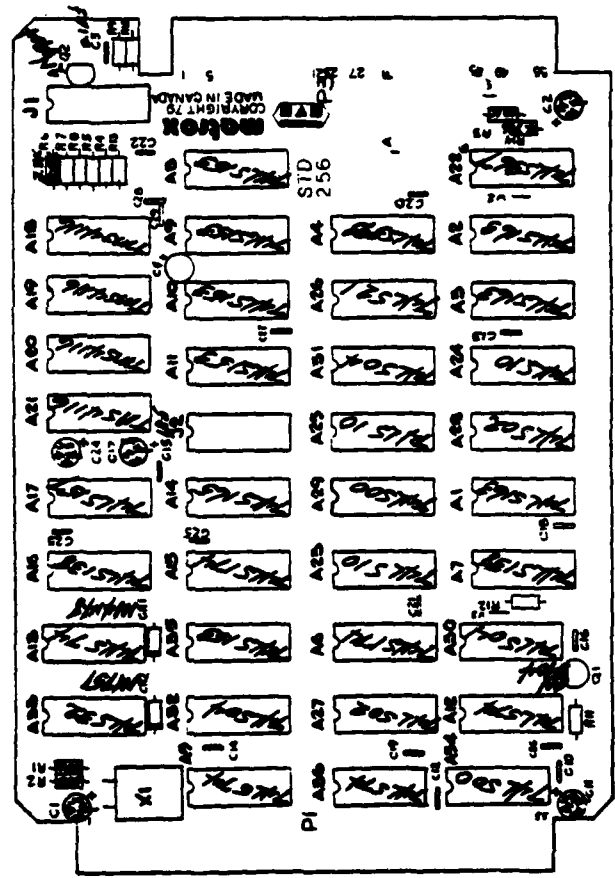
SCHEMATIC 104911
PART LIST 104913



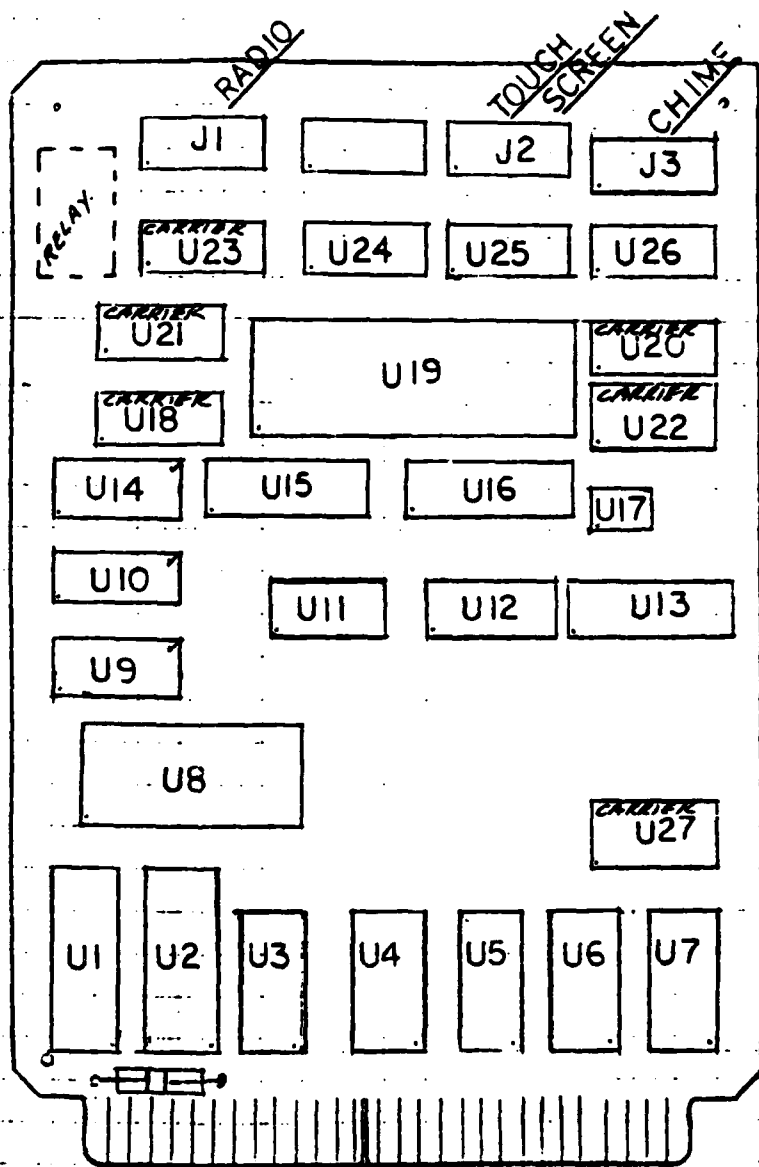
REDUCE TO 6.500



GTD ELECTRONIC SYSTEMS	
STD-256	16-000-01
ASSEMBLY	16-000-01

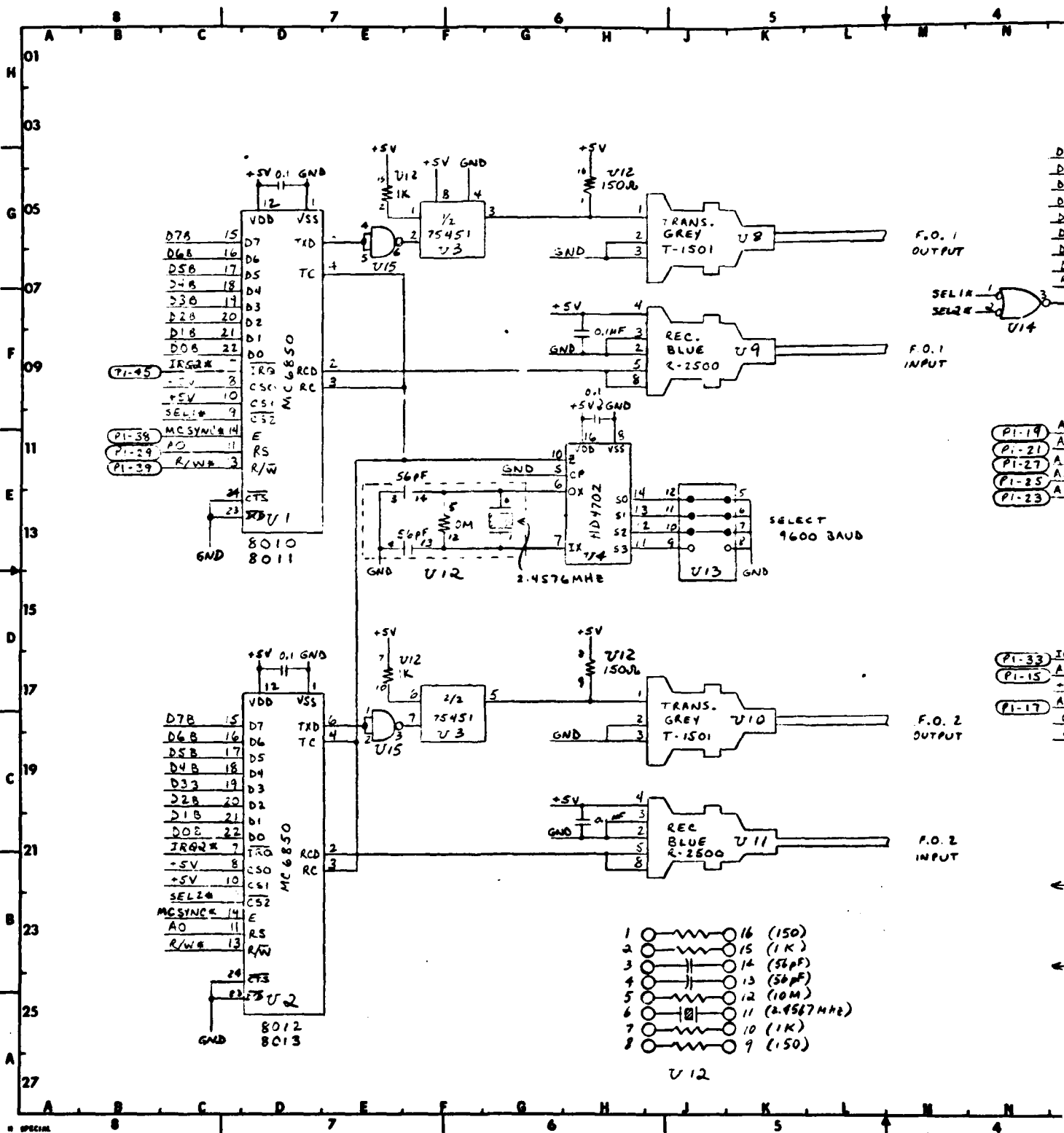


K-7/8



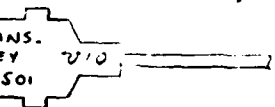
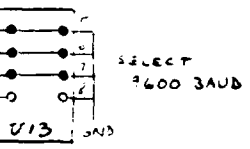
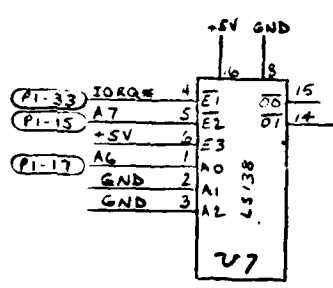
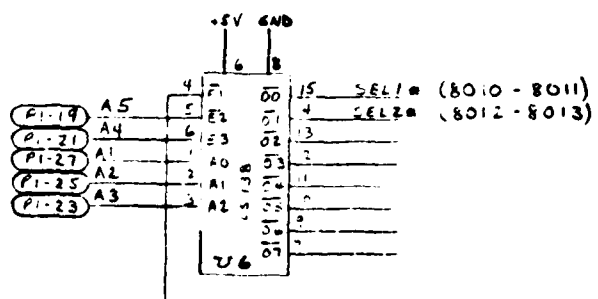
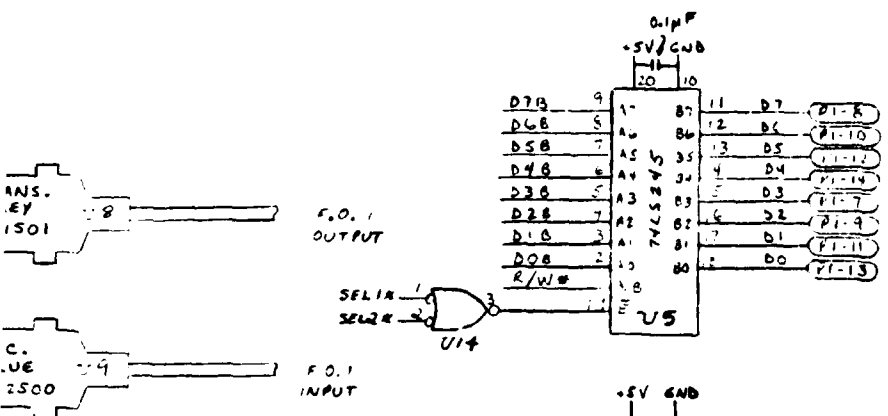
K-9/10

2

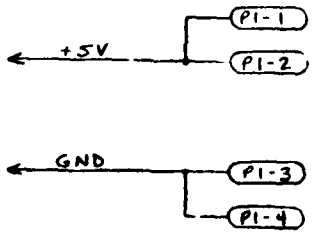


J K L M N P Q R S T U

REV	DESCRIPTION	AUTH	DATE	APPROVED
1	V I W I X			
A	ADDED U14, U15	SEC	11/6/81	Cy



- 16 (150)
- 15 (1K)
- 14 (56pF)
- 13 (56pF)
- 12 (10M)
- 11 (0.9567MHz)
- 10 (1K)
- 7 (150)



FIBER OPTIC SERIAL INTERFACE
(CIRCUIT IS BUILT ON PROLOG 7903 UTILITY CARD)
T. LA ROVERE P-7-81

REV B 8-18-82 JRC

Delco Electronics			
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA			
TITLE TOUCH SCREEN CRT CONTROLLER			
FIBER OPTIC SERIAL INTERFACE			
SIZE	CODE IDENT NO	DWG NO	REV
13160	SK003914		B
SCALE	WEIGHT	SHEET 1 OF 1	

REV	CODE IDENT NO	DWG NO	REV
H	13160	430811-4	A

K-11

2

J K L M N P Q R S T U

APRIL 10, 1981

PRELIMINARY
MODEL SPECIFICATIONS FOR
VEHICULAR CRT MONITOR

MODEL VM34H

ZENITH RADIO CORPORATION
VEHICULAR & INDUSTRIAL ELECTRONIC PRODUCTS

CATHODE RAY TUBE

3" x 4" aspect ratio, 12KV nominal high voltage at 50 μ A average beam current.

DISPLAY AREA

12 square inches, defined by 3" x 4" rectangle centered on the CRT faceplate.

OPTICAL CHARACTERISTICS

Brightness (Note 1).....	2000 Foot Lamberts
Color.....	Yellow-Green
Faceplate Transmission.....	65%
Faceplate Reflectivity.....	36% Typical
Contrast Ratio (Zero Ambient Illumination).....	35:1 Min.
Viewing Angle.....	To limit of character recognition (without reticules or decals).
Center Spot Size..... (Beam Current 1.5ma)	.037 $\pm$.005 inches
Resolution.....	Pulse rise time 70 n.s. for 50 volt rise at CRT cathode.
Ageing Characteristic (Note 2).....	10,000 hours to 50% of original brightness

MONITOR CHASSIS ELECTRICAL DATA

POWER SUPPLY

Input Voltage Range.....	9 to 24 Volts
Input Current.....	1.8 Amps $\pm 15\%$ Input Voltage = 12 Volts
Regulator System.....	Switch-mode
System Protection:	
Undamaged When Subjected To:	
Jumper Starts.....	+24V for 30 minutes
Reverse Polarity.....	-24V
Load Dump.....	120V, 188ms Time Constant
Inductive Load Switching.....	-286V, 1ms Time Constant
Alternator Field Decay.....	-90V, 38ms Time Constant
Mutual Coupling.....	214V, 1 μ s Time Constant

INPUTS (Refer to Figure 1)

Video:

Input Level.....	1 to 5 Volts peak-to-peak
Input Impedance.....	100 ohm
Coupling.....	DC
Polarity.....	Increasing voltage at input increases CRT brightness: black is at zero volts.

Horizontal Drive (Refer to Figure 1):

Input Level.....	4-12V p-p Positive Edge Triggered
Frequency.....	15,750 $\pm$ 300 Hz
Waveshape.....	Rectangular
Minimum Pulse Width.....	1 μ s
Input Impedance.....	1K ohm

K-12a

MONITOR CHASSIS ELECTRICAL DATA (cont'd.)

Vertical Sync (Refer to Figure 1):

Input Level.....	2 to 5 Volts peak-to-peak
Frequency Range.....	85 to 115 Hz.
Waveshape.....	Positive-going Rectangular Pulse
Pulse Width.....	50 to 2500 μ sec.
Input Impedance.....	6.8K ohm

CONTROLS

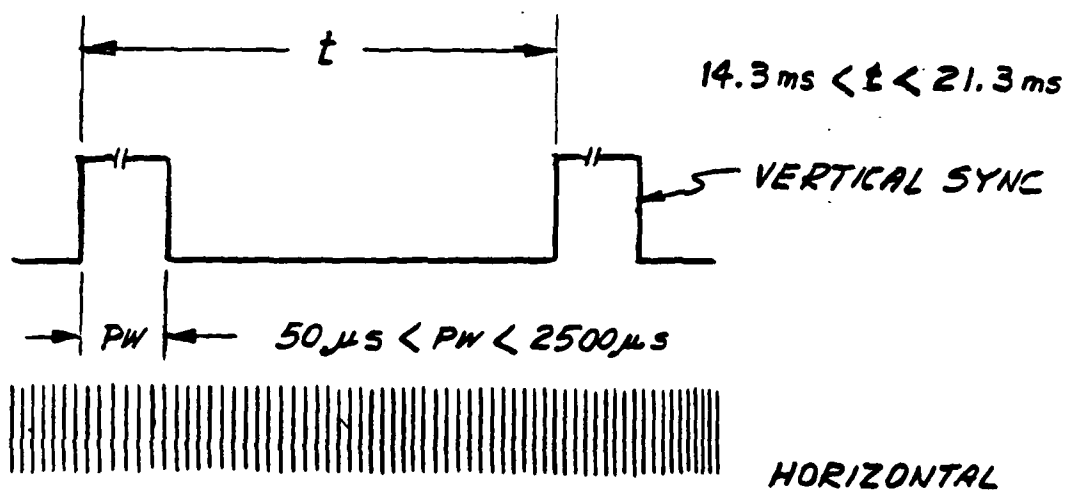
Automatic Brightness Set
Brightness Range
Background
Focus
Vertical Size
Horizontal Size
Raster Centering (adjustment rings on yoke)

MONITOR CHASSIS ELECTRICAL DATA

ENVIRONMENTAL CHARACTERISTICS:

Temperature: Operational.....	-40°C to +85°C
Storage.....	-40°C to +85°C
Humidity: Operational.....	0 - 98% at 38°C

VERTICAL TIMING DETAIL



HORIZONTAL & VIDEO TIMING DETAIL

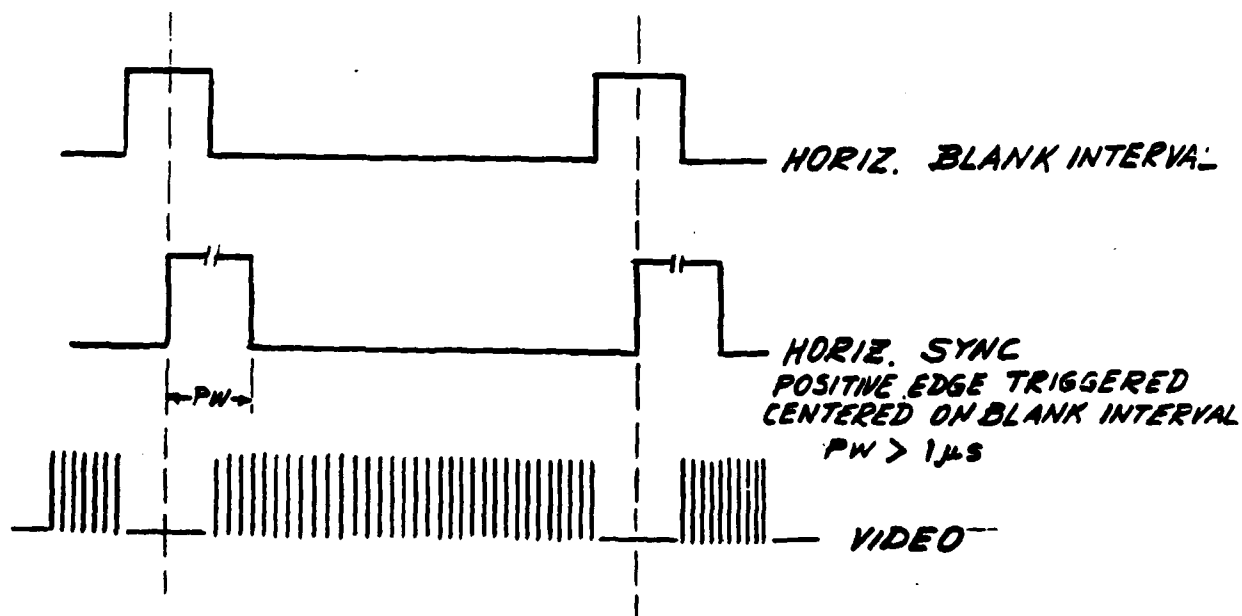


FIG. 1

K-12b.

NOT

MONITOR CHASSIS ELECTRICAL DATA (cont'd.)

NOT

VIBRATION

Operational 1.3 g maximum
Storage 1.0 to 5.0 Hertz

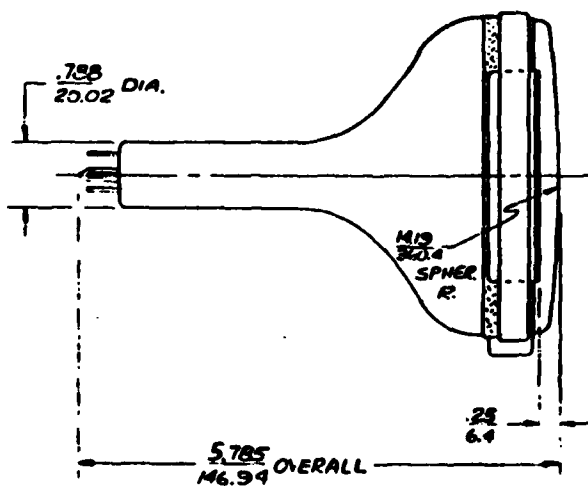
6 g maximum
5 - 1000 Hertz
Sinusoidal

SHOCK

Operational 50 g; 1/2 sine
Storage 9-13 millisc. duration

ALTITUDE

Operational 15,000 ft. Maximum
Storage

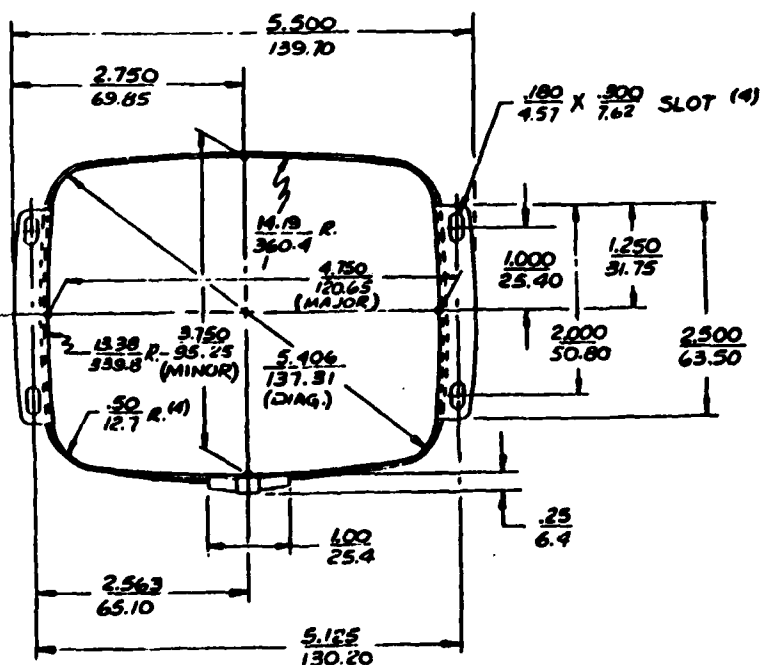


NOTE: MILLIMETER VALUE SHOWN
BELOW INCH DIMENSION; I.E., .100 IN.
2.54 MM

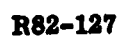
NOTE 1: Brightness is measured by producing an unmodulated (DC) raster in the central 3"x4" area of the faceplate. The brightness is adjusted to produce 1mA average beam current. The brightness is then measured such that the measurement area fills the field of view of the measuring instrument. Ambient illumination is zero. The standard eye response curve (4000Å - 7800Å) should be used.

NOTE 2: The ageing characteristic defines the time interval over which the light output of the tube is reduced to 50% of its original value. The usage schedule used to derive the ageing characteristic is shown below. This schedule defines the time that the VCRT spends at a given output level.

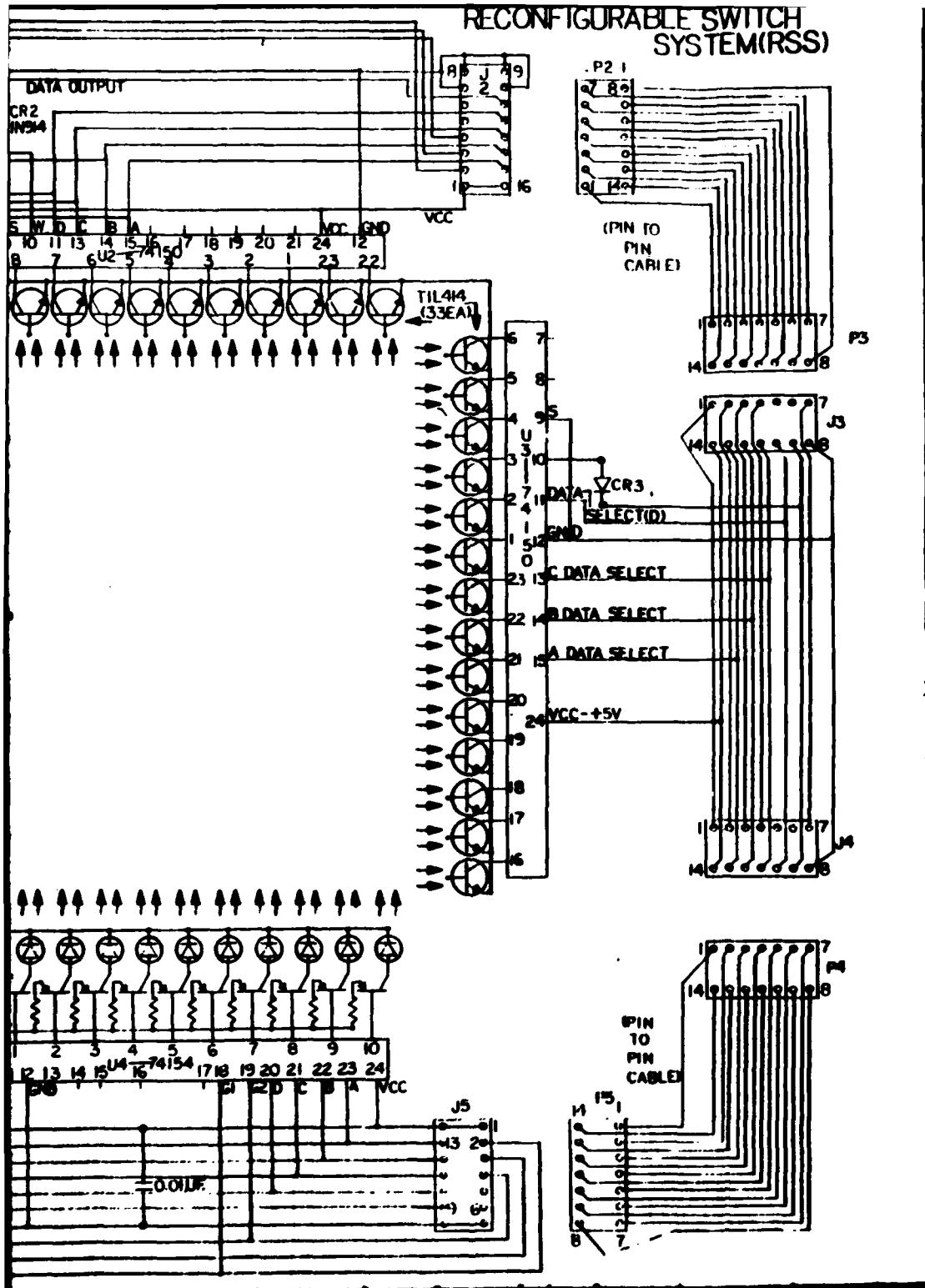
<u>USE TIME</u> <u>(Percent)</u>	<u>RELATIVE BRIGHTNESS</u> <u>(Percent)</u>	<u>ABSOLUTE BRIGHTNESS</u> <u>(Foot Lamberts)</u>
10	100	2000
20	75	1500
25	50	1000
20	30	600
15	20	400
10	10	200

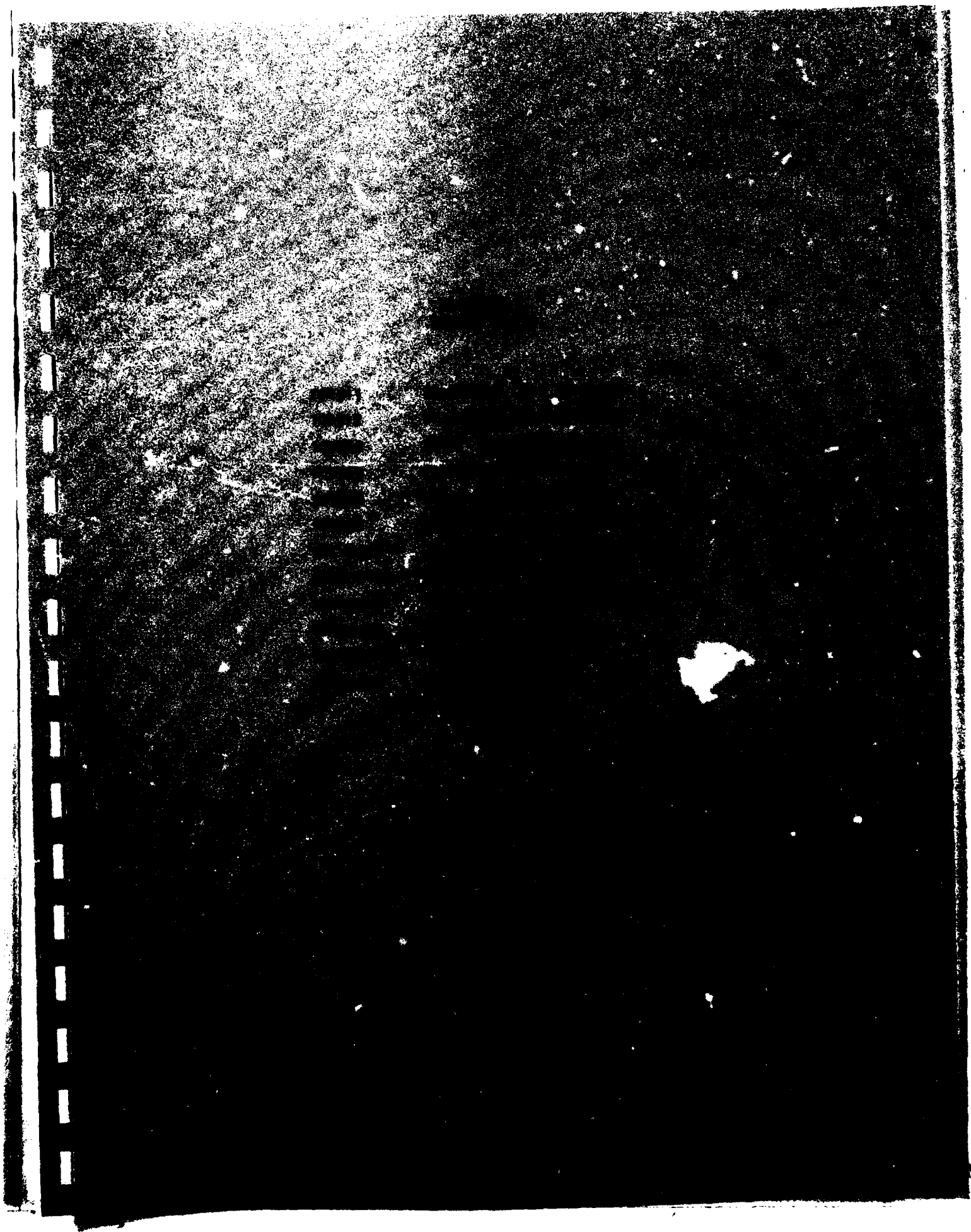


K-12c

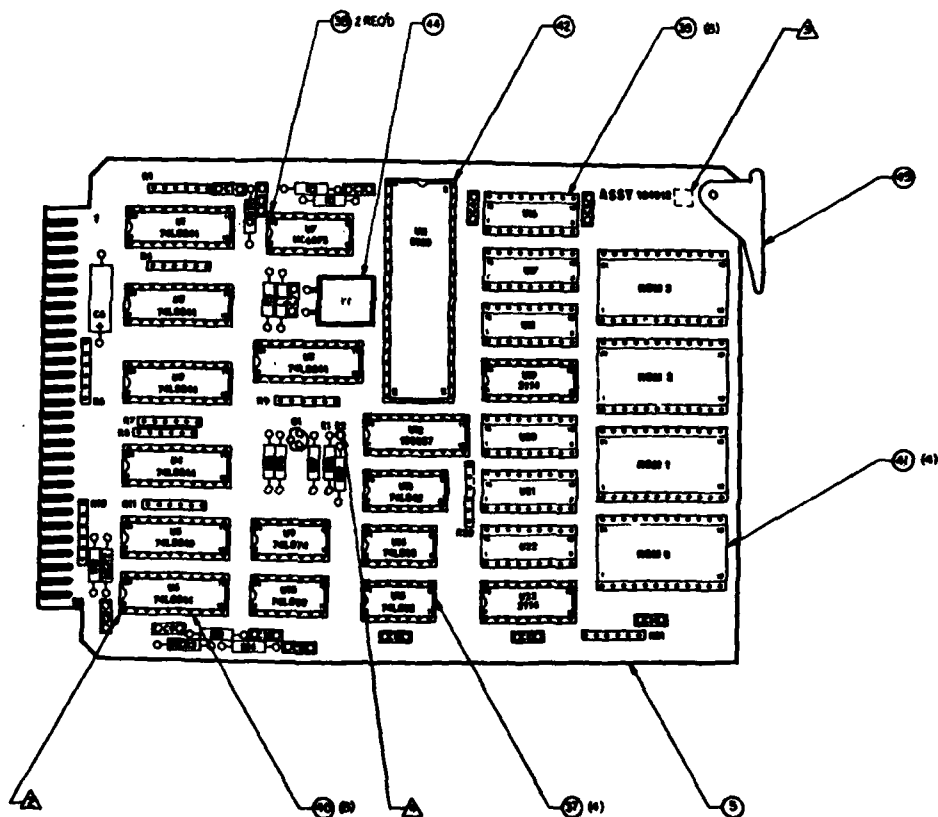
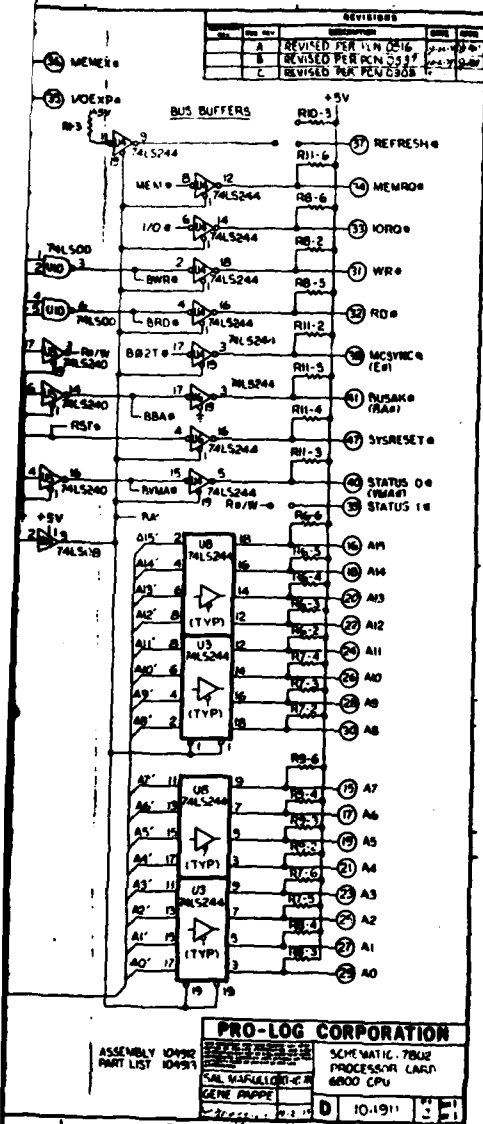


RECONFIGURABLE SWITCH SYSTEM(RSS)





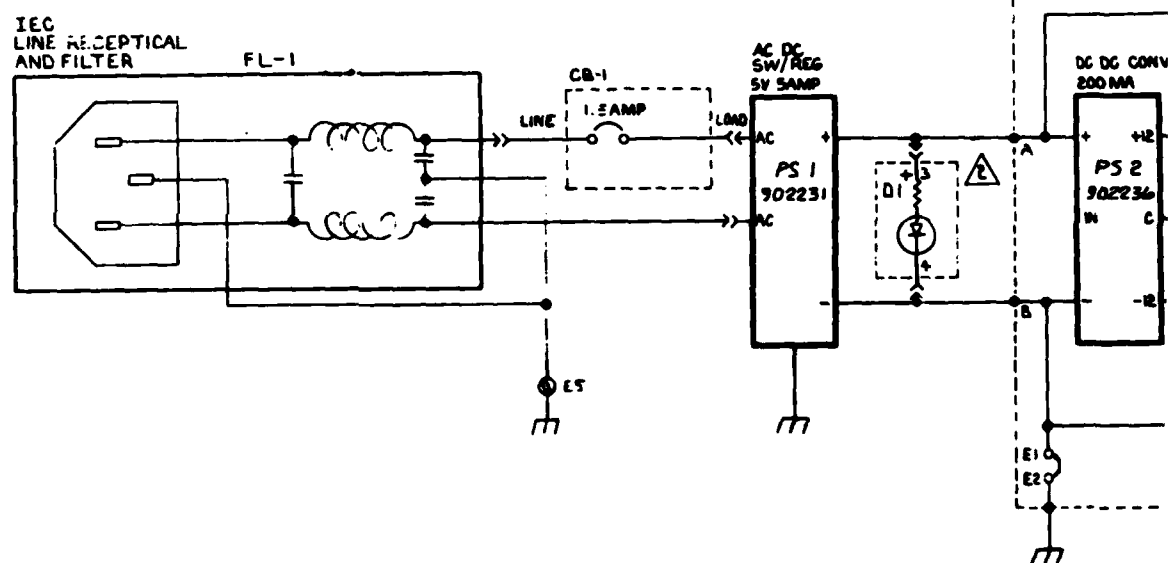




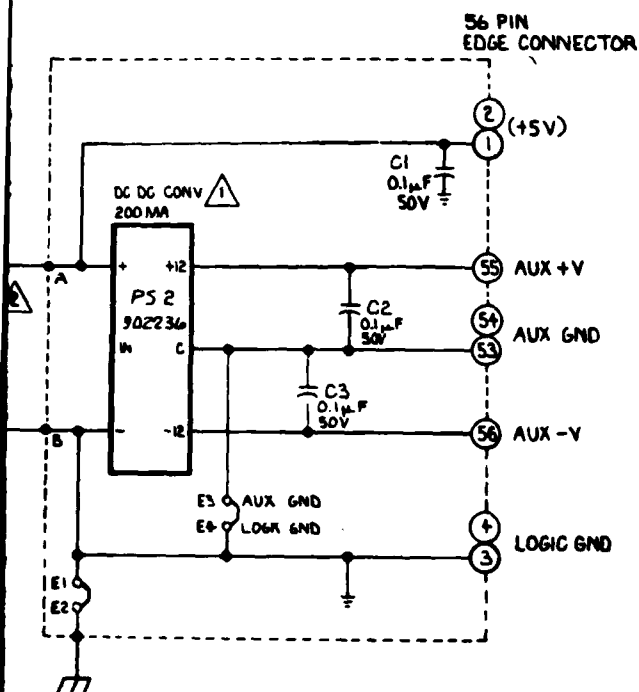
△ CUT TRACE FOR ALTERNATE MAPPING
△ IDENTIFY WITH ASSY REF LETTER USING RUBBER STAMP
△ INDICATES PIN NO. 1 OF SOCKETS (TYP).
1. FOR ASSY PROCEDURES SEE AS4004.
NOTES: UNLESS OTHERWISE SPECIFIED.

SCHEMATIC 10491
PART LIST 10493

ITEM	DESCRIPTION	REF. DESIGNATION
30	2.2K OHM 1/4W	R1
31	1K OHM 1/4W	R2
32	10K OHM 1/4W	R3
33	100K OHM 1/4W	R4
34	1M OHM 1/4W	R5
35	10M OHM 1/4W	R6
36	100M OHM 1/4W	R7
37	1K OHM 1/4W	R8
38	10K OHM 1/4W	R9
39	100K OHM 1/4W	R10
40	1M OHM 1/4W	R11
41	10M OHM 1/4W	R12
42	100M OHM 1/4W	R13
43	1K OHM 1/4W	R14
44	10K OHM 1/4W	R15
45	100K OHM 1/4W	R16
46	1M OHM 1/4W	R17
47	10M OHM 1/4W	R18
48	100M OHM 1/4W	R19
49	1K OHM 1/4W	R20
50	10K OHM 1/4W	R21
51	100K OHM 1/4W	R22
52	1M OHM 1/4W	R23
53	10M OHM 1/4W	R24
54	100M OHM 1/4W	R25
55	1K OHM 1/4W	R26
56	10K OHM 1/4W	R27
57	100K OHM 1/4W	R28
58	1M OHM 1/4W	R29
59	10M OHM 1/4W	R30
60	100M OHM 1/4W	R31
61	1K OHM 1/4W	R32
62	10K OHM 1/4W	R33
63	100K OHM 1/4W	R34
64	1M OHM 1/4W	R35
65	10M OHM 1/4W	R36
66	100M OHM 1/4W	R37
67	1K OHM 1/4W	R38
68	10K OHM 1/4W	R39
69	100K OHM 1/4W	R40
70	1M OHM 1/4W	R41
71	10M OHM 1/4W	R42
72	100M OHM 1/4W	R43
73	1K OHM 1/4W	R44
74	10K OHM 1/4W	R45
75	100K OHM 1/4W	R46
76	1M OHM 1/4W	R47
77	10M OHM 1/4W	R48
78	100M OHM 1/4W	R49
79	1K OHM 1/4W	R50
80	10K OHM 1/4W	R51
81	100K OHM 1/4W	R52
82	1M OHM 1/4W	R53
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91	1K OHM 1/4W	R62
92	10K OHM 1/4W	R63
93	100K OHM 1/4W	R64
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95	10M OHM 1/4W	R66
96	100M OHM 1/4W	R67
97	1K OHM 1/4W	R68
98	10K OHM 1/4W	R69
99	100K OHM 1/4W	R70
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110	10K OHM 1/4W	R81
111	100K OHM 1/4W	R82
112	1M OHM 1/4W	R83
113	10M OHM 1/4W	R84
114	100M OHM 1/4W	R85
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REVISIONS				
REV	DOC REV	DESCRIPTION	DATE	APP
	A	INITIAL RELEASE PER PCN # 05-04	12-8-72	5-02
	B	REVISED PER PCN # 10-32	7-10-73	6-7



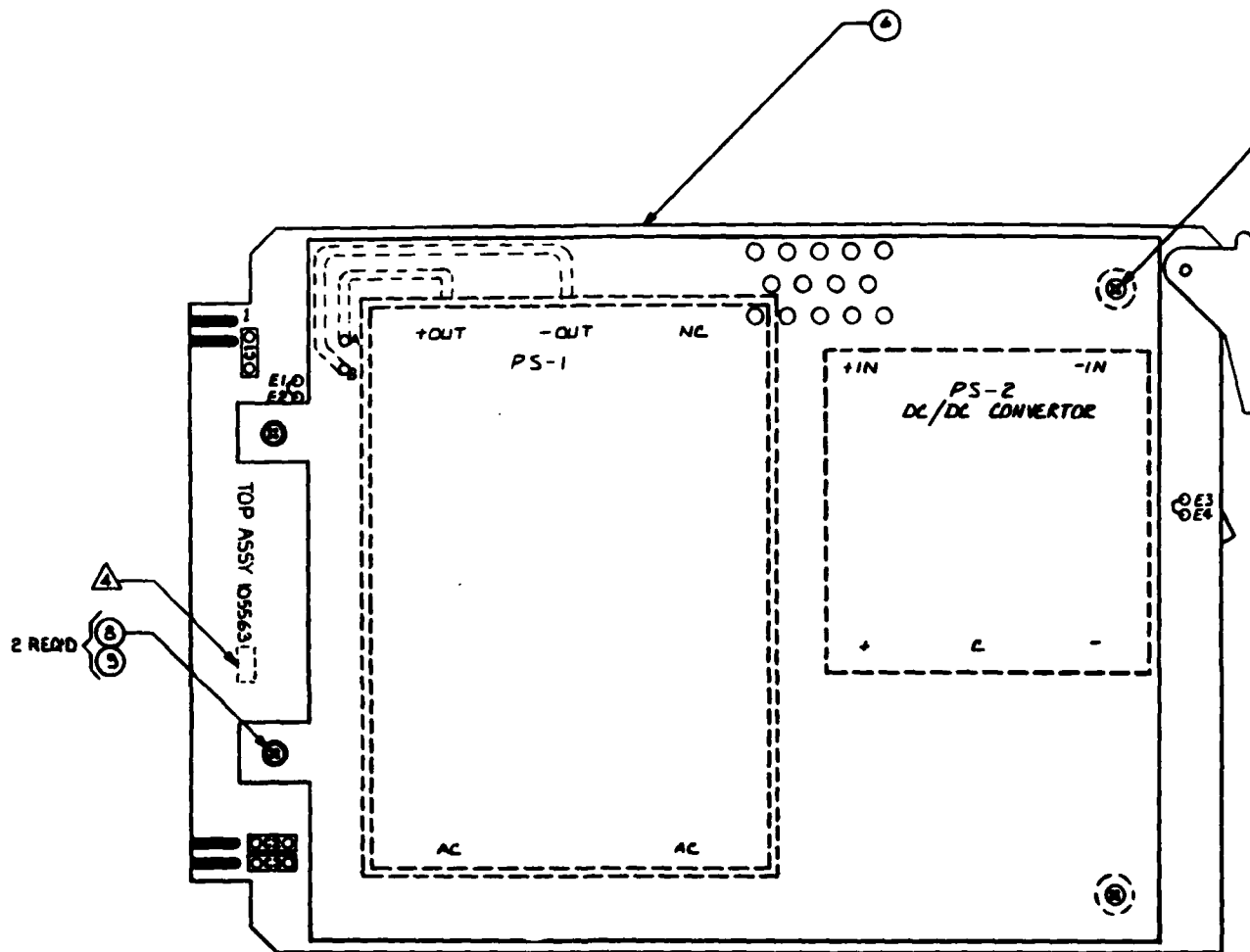
2 DI=LED INDICATOR (PART OF CE-1)
 1 ITEM DELETED ON 7920
 NOTES: UNLESS OTHERWISE SPECIFIED

PRO-LOG CORPORATION

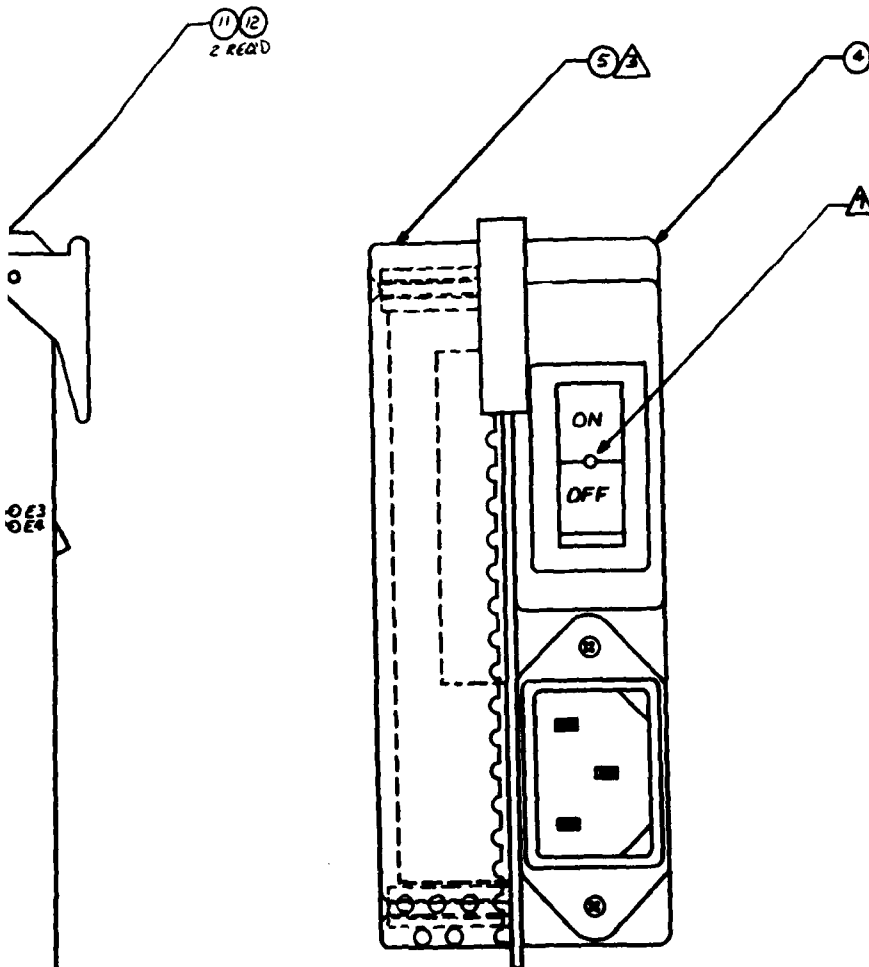
105588	105589			SCHEMATIC, 7920/21	
105586	105587	C.A. CLARK	7-25-73	IN-RACK POWER SUPPLY	
105563	105564	9-1-73	12-8-72		
ASSEMBLY	PARTS LIST			D	105562 3-1

2

L-3



REVISIONS				
REV	DATE	DESCRIPTION	DATE	APP
A		INITIAL RELEASE PER PCN# 0564		
B		REVISED PER PCN#1092		

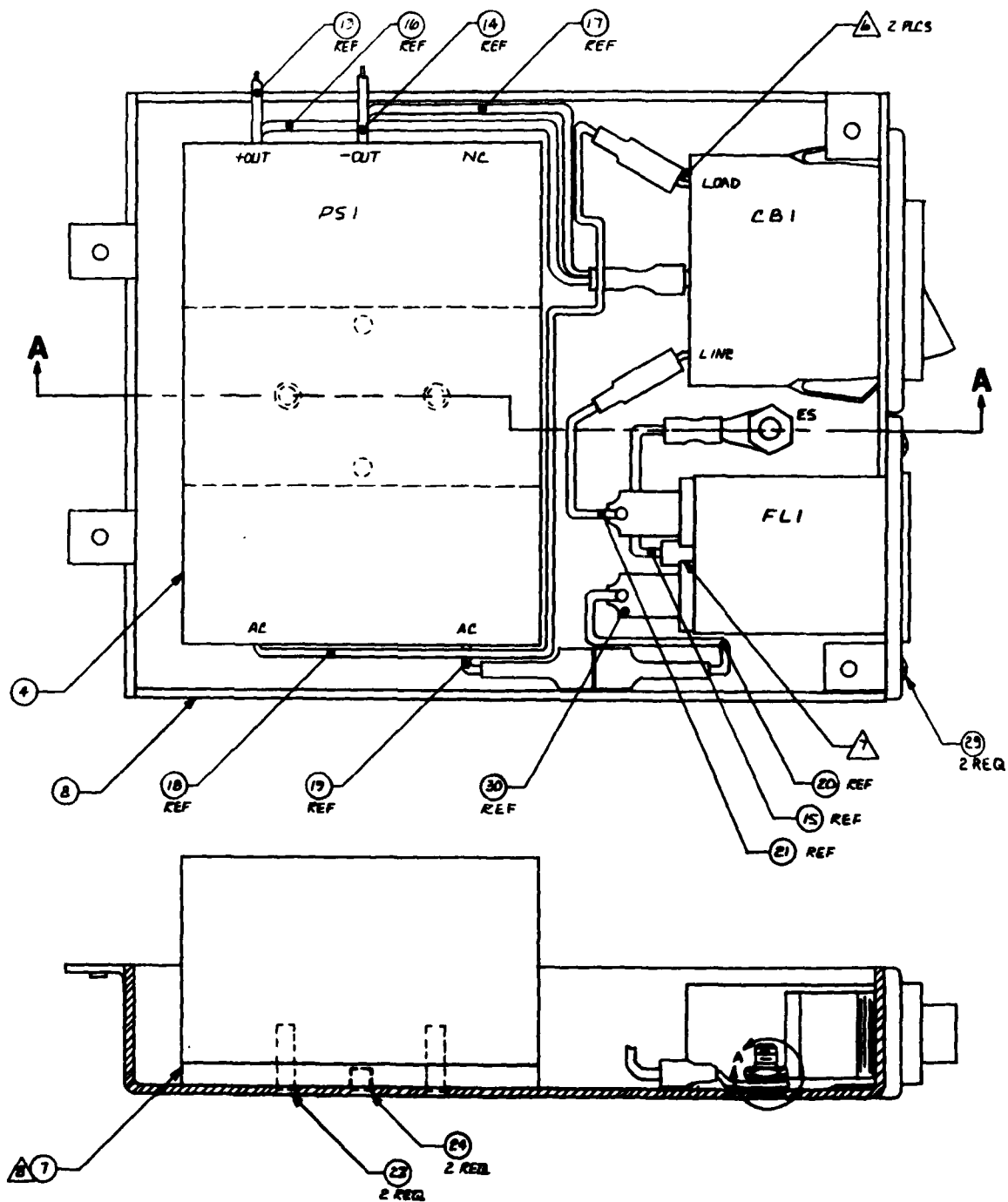


- NOTES:** UNLESS OTHERWISE SPECIFIED
- 1- ALL WIRES ARE TO BE SOLDERED ON CIRCUIT SIDE OF PWB
 - 2- E1-E4 ARE FOR REF ONLY AND DO NOT APPEAR ON PWB
 - 3- PERFORATED COVER, ALL LINES SHOWN AS HIDDEN LINES FOR CLARITY
 - 4- IDENTIFY WITH ASSY REV LETTER USING RUBBER STAMP
 - 5- BOARD TO CONFORM WITH ASSEMBLY PROCEDURES AS 1004.
 - 6- REFERENCE DESIGNATIONS ARE FOR LOCATING PURPOSES ONLY AND MAY NOT APPEAR ON ACTUAL PART.
- WHEN POWER SWITCH IS PLACED TO THE ON POSITION THE RED LED, CENTER OF SWITCH WILL ILLUMINATE.

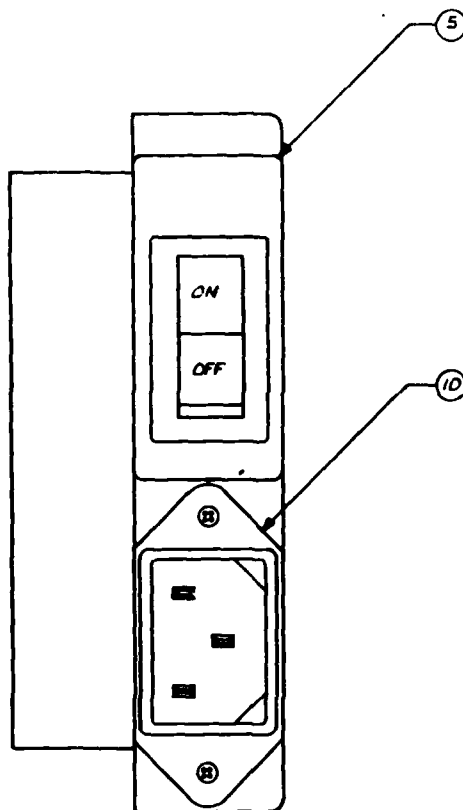
SCHEMATIC NO. 105562
PARTS LIST NO. 105564

ITEM	DESCRIPTION	REF. DESIGNATION
PRO-LOG CORPORATION		
ASSEMBLY, 7721 IN RACK POWER SUPPLY		
APPROVED	DATE	
27-1-77	10-27-76	
		D 105563 8 1

L-4



REVISIONS				
REV	DOC REV	DESCRIPTION	DATE	APPR
A		INITIAL RELEASE PER PCN 0564	12-5-79	
B		REVISED PER PCN 0855	1-2-80	



NOTES: UNLESS OTHERWISE SPECIFIED

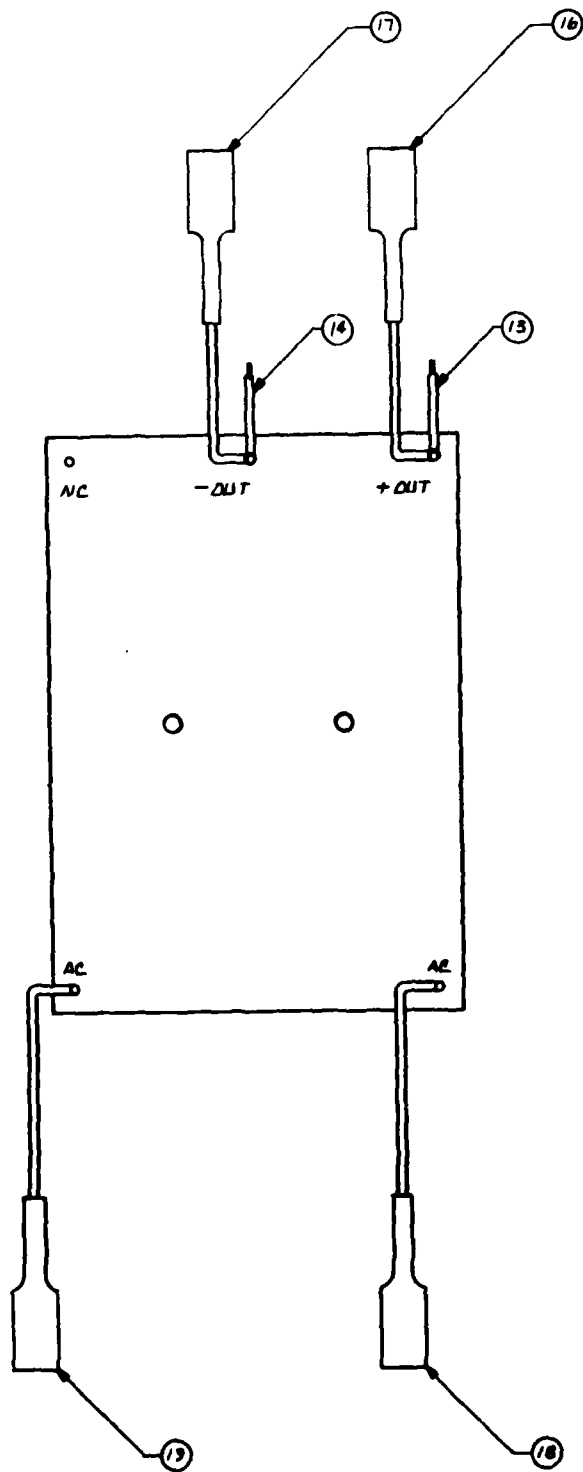
1. SCALE: 2/1
2. SOME ITEMS OR LINES ARE OMITTED FOR CLARITY
3. IDENTIFY ASST USING TAG WITH PART NO. & REVISION
4. COVER CLUTTER IN SIDE VIEW FOR CLARITY
5. SEE WIRE TABLE FOR POINT TO POINT WIRE-HOPS
6. BEND 30° LINE & LOAD TERMINALS, PRIOR TO INSTALLATION OF C.B.
7. BEND UP 45° (GND TERMINAL)
8. APPLY THERMAL GREASE TOP & BOTTOM
9. REF DESIGNATIONS ARE FOR REF ONLY AND MAY NOT APPEAR ON ACTUAL PART
10. SEE SHEET 2 FOR WIRE WOOD-UP OF PS1 & FL1

WIRE TABLE					
FROM:	WIRE NO.	WIRE CODE	TO:	WIRE NO.	WIRE CODE
FL1 (GEN)	15	GRN	ES, PEM STUD	—	—
FL1 (WHT)	20	WHT	PS1 (AC)	19	WHT
FL1 (BLK)	21	BLK	CB1 (LINE TERM)	—	—
PS1 (+OUT)	13	RED	N/C	—	—
PS1 (-OUT)	14	BLK	N/C	—	—
PS1 (+OUT)	16	RED	CB1 (PIN 3)	—	—
PS1 (-OUT)	17	BLK	CB1 (PIN 4)	—	—
PS1 (AC)	18	BLK	CB1 (LOAD TERM)	—	—
PS1 (AC)	19	WHT	FL1 (WHT)	20	WHT

SCHEMATIC NO. 105562
PARTS LIST NO. 105587

PRO-LOG CORPORATION			
ASSEMBLY, (COVER) 7921		1N-RACK POWER SUPPLY	
DATE	10-25-79	REV	1
BY	12-5-79	REV	2
D	105586	REV	2

L-5a

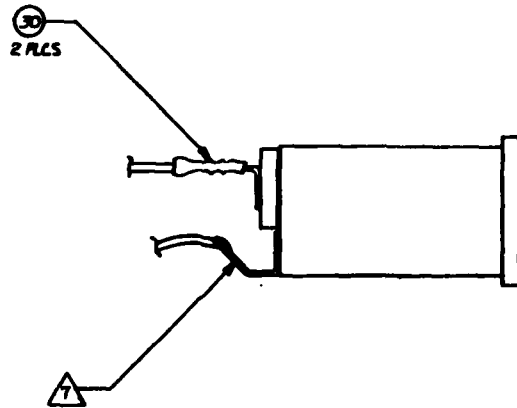
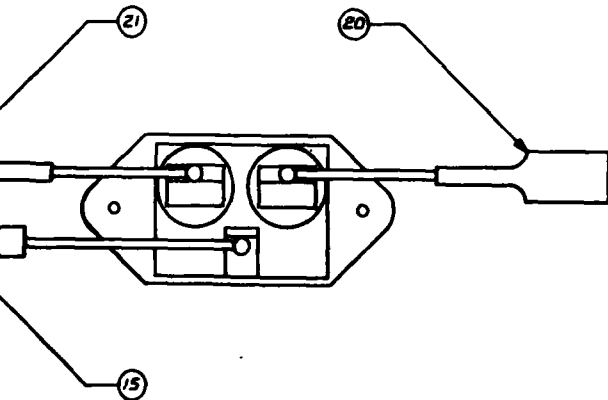
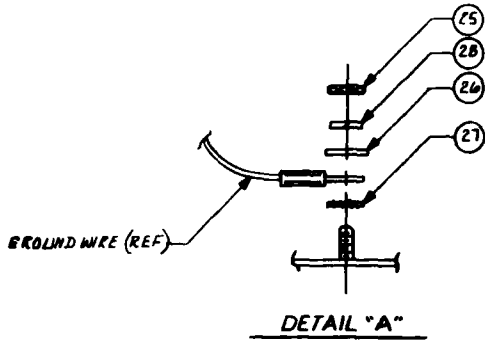


GROUND WIRE (REF)

FLI FA

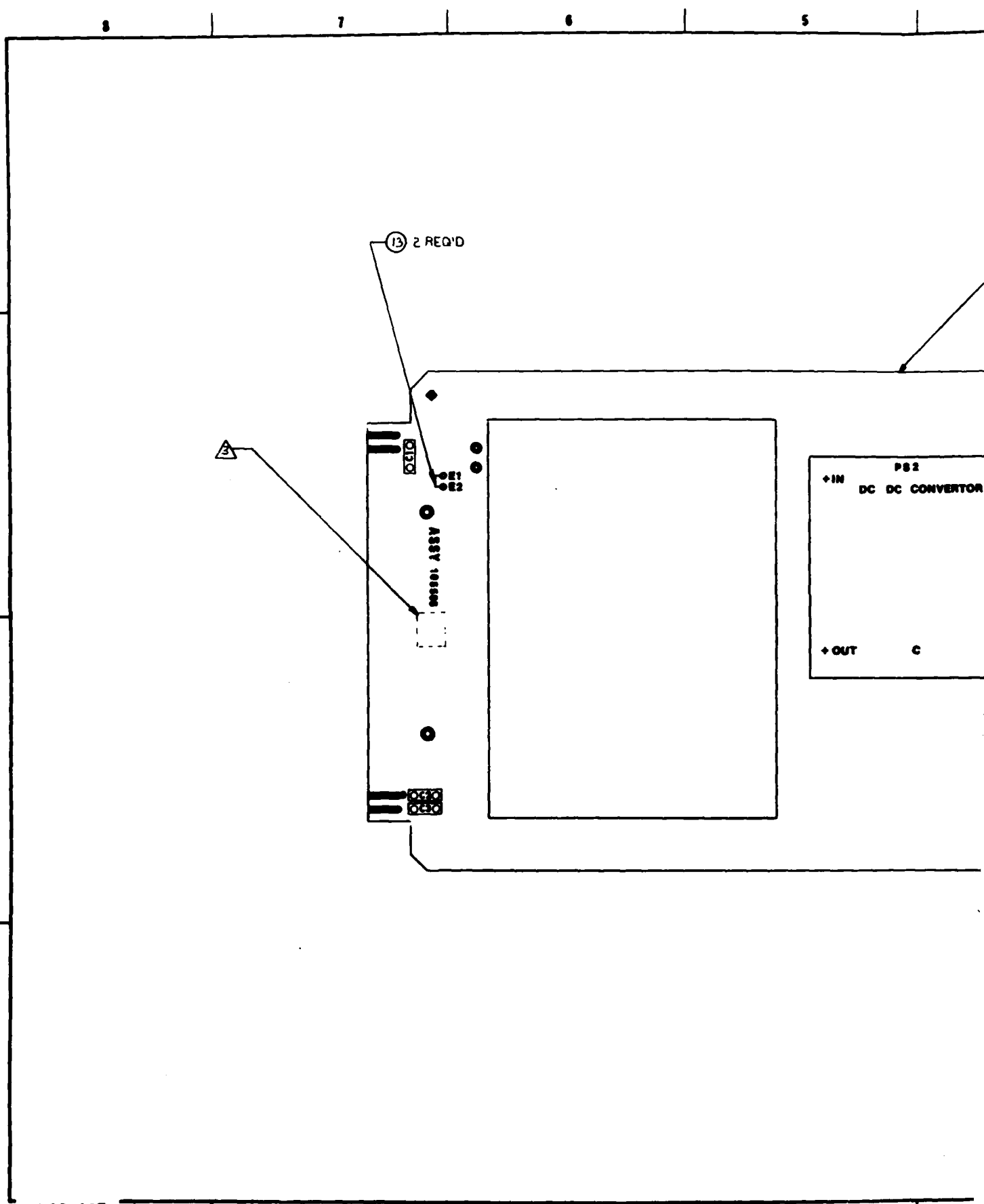
PSI BOTTOM VIEW

REVISIONS				
REV	DATE	DESCRIPTION	BY	APP

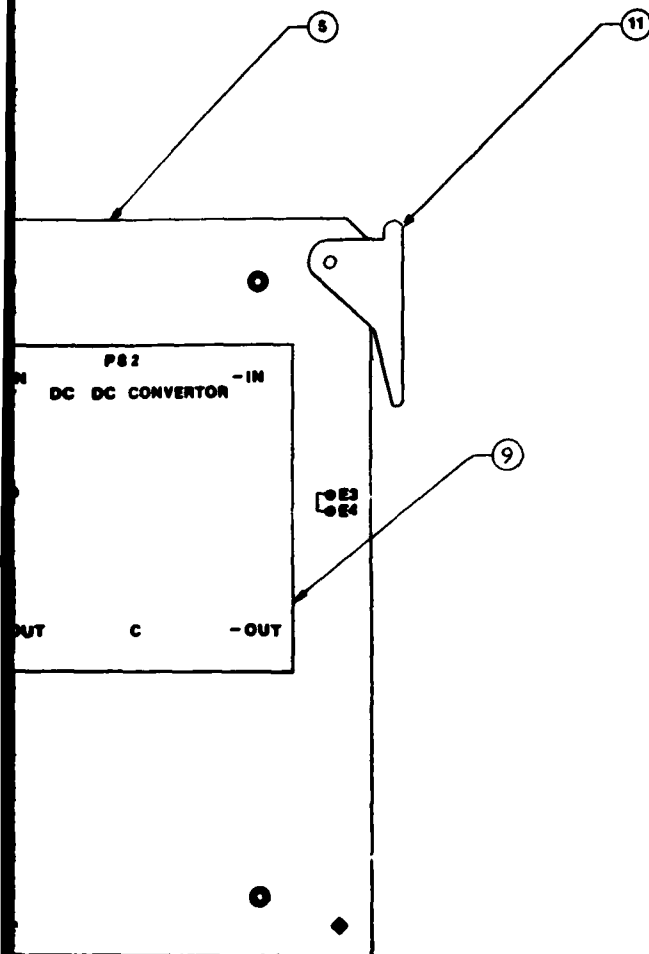


PRO-LOG CORPORATION			
MARULLO		11-5-73	12-5-73
7911-1		12-5-73	12-5-73
D	105584	8	12-5-73

L-5b



REVISIONS			
REV	DATE	DESCRIPTION	APPV
1	12-5-77	INITIAL RELEASE PER PCN=0564	



NOTES: UNLESS OTHERWISE SPECIFIED

1-FOR ASSEMBLY PROCEDURES SEE AS100A

2-REF DESIGNATION FILE FOR LOCATING PUMPLES

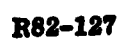
OR 1 & MM NOT APPEAR ON PARTIAL PART

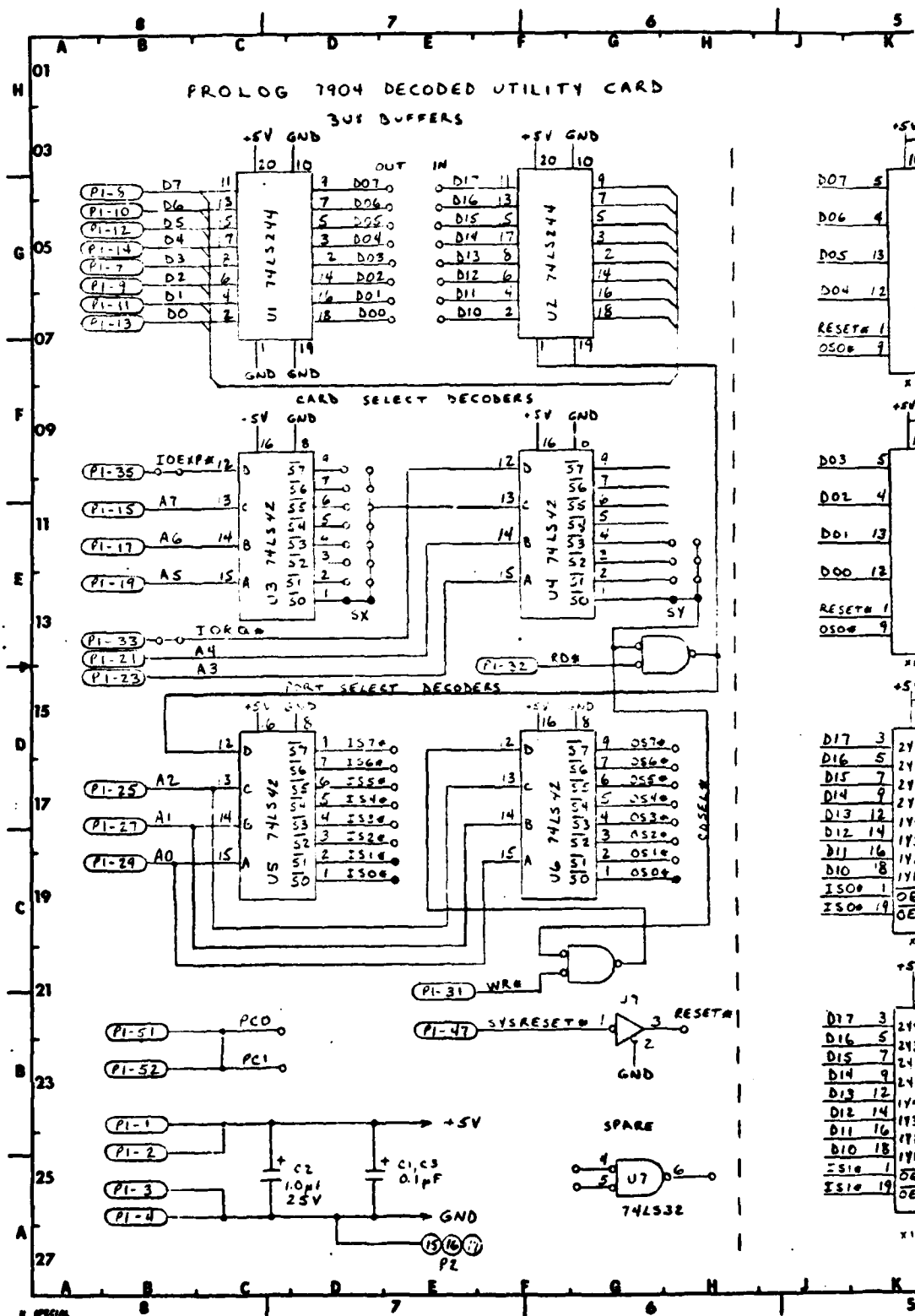
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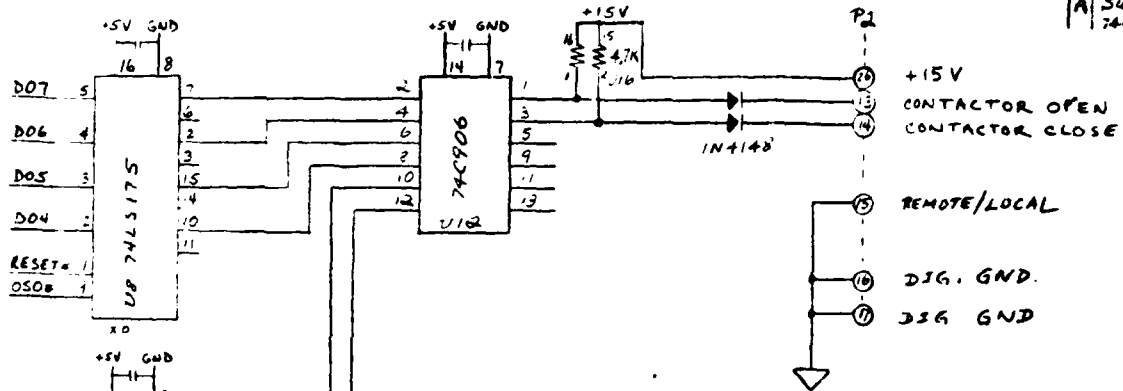
SCHEMATIC NO. 105562
PARTS LIST NO. 105587

7	214C 50V CER	C1, C2, C3
8		
5	105561	PWB
ITEM	DESCRIPTION	REF DESIGNATION
PRO-LOG CORPORATION		
ASSY PWB 7921		
IN RACK POWER SUPPLY		
MANUFACTURED	10-2-77	
DATE	12-5-77	
D	105588	

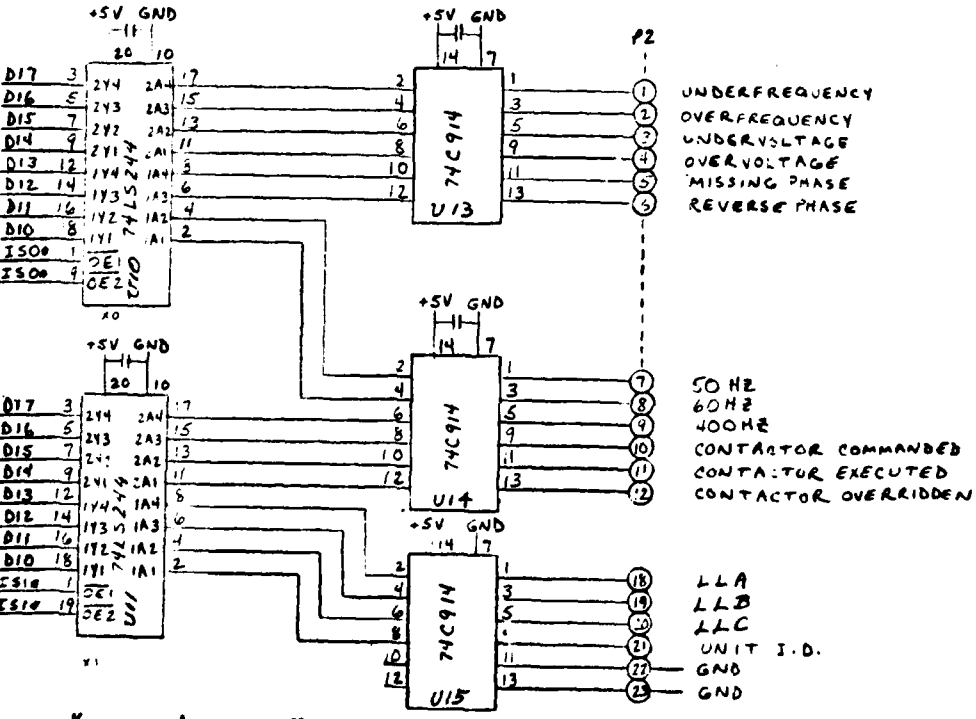
L-6







REV	DESCRIPTION	AUTH	DATE	APPROVED
A	SUBSTITUTED 74C906 FOR U12	ICC	11-6-81	(Signature)



REMOTE UNIT
STATUS AND COMMAND I/O
(CIRCUIT IS BUILT ON PRALOG
7904 DECODED I/O BOARD)
T. LA ROVERE P-6-P1

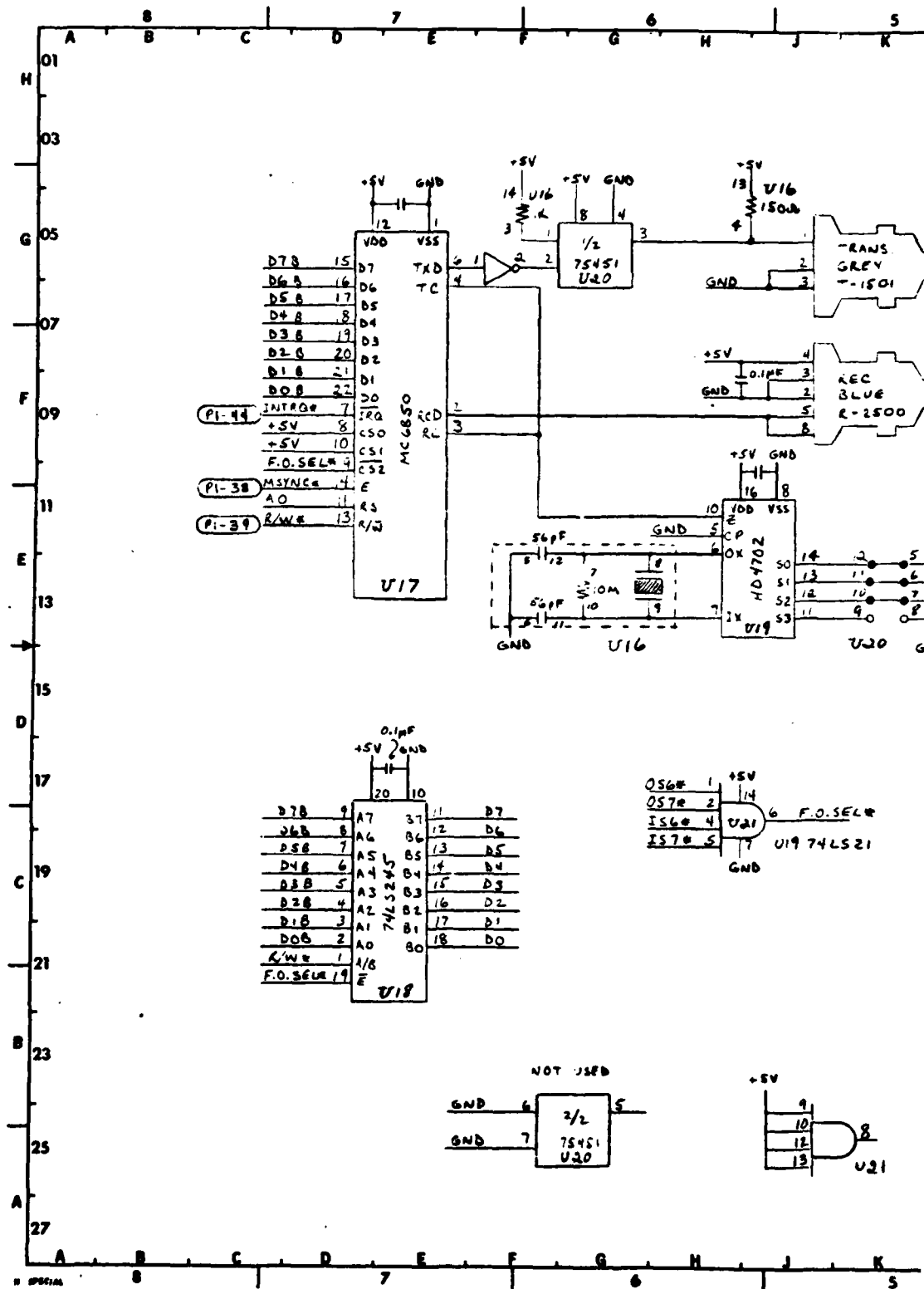
REV B 8-18-82 JRC

Delco Electronics			
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA			
TITLE REMOTE UNIT STATUS AND COMMAND I/O			
SIZE	CODE IDENT NO	DWG NO	REV
	13160	SK003918	3
SCALE	WEIGHT	SHEET 1 OF 1	

DATE	DESIGN	FILE NO	REV
H	13160	750811-3	A

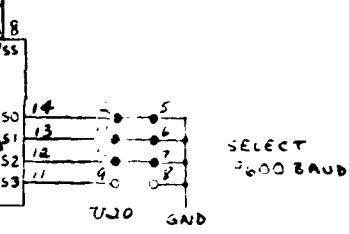
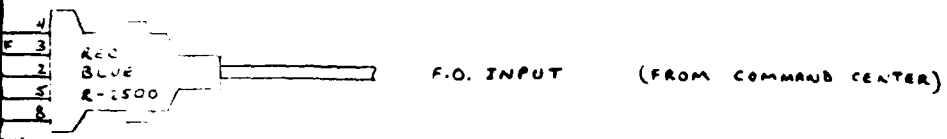
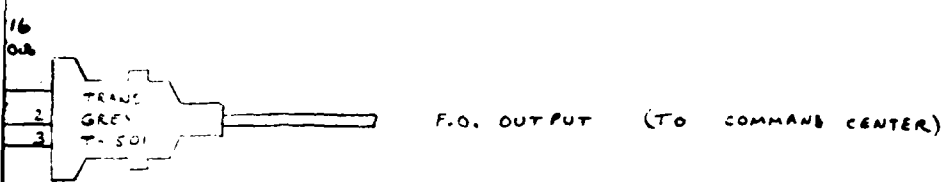
L-8

2



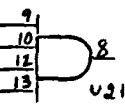
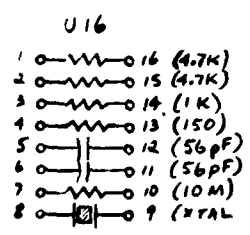
J K L M N P Q R S T U

REV	DESCRIPTION	REV. DUNS	AUTH	DATE	APPROVED
A	ADD INVERTER SET U17-6 AND U22-2		W ICC	11-68	X



F.O. SELECT
U19 74LS21

REMOTE UNIT
FIBER OPTIC INTERFACE



REV B 8-18-82 JRC

Delco Electronics		
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA		
TITLE REMOTE UNIT FIBER OPTIC INTERFACE		
SIZE	CODE IDENT NO	DATE
13160	SK003919	B
SCALE	WEIGHT	SHEET 1 OF 1

REV	DATE	DESCRIPTION	REV. DUNS	AUTH	DATE	APPROVED
H	13160	730811-3				

L-9

2

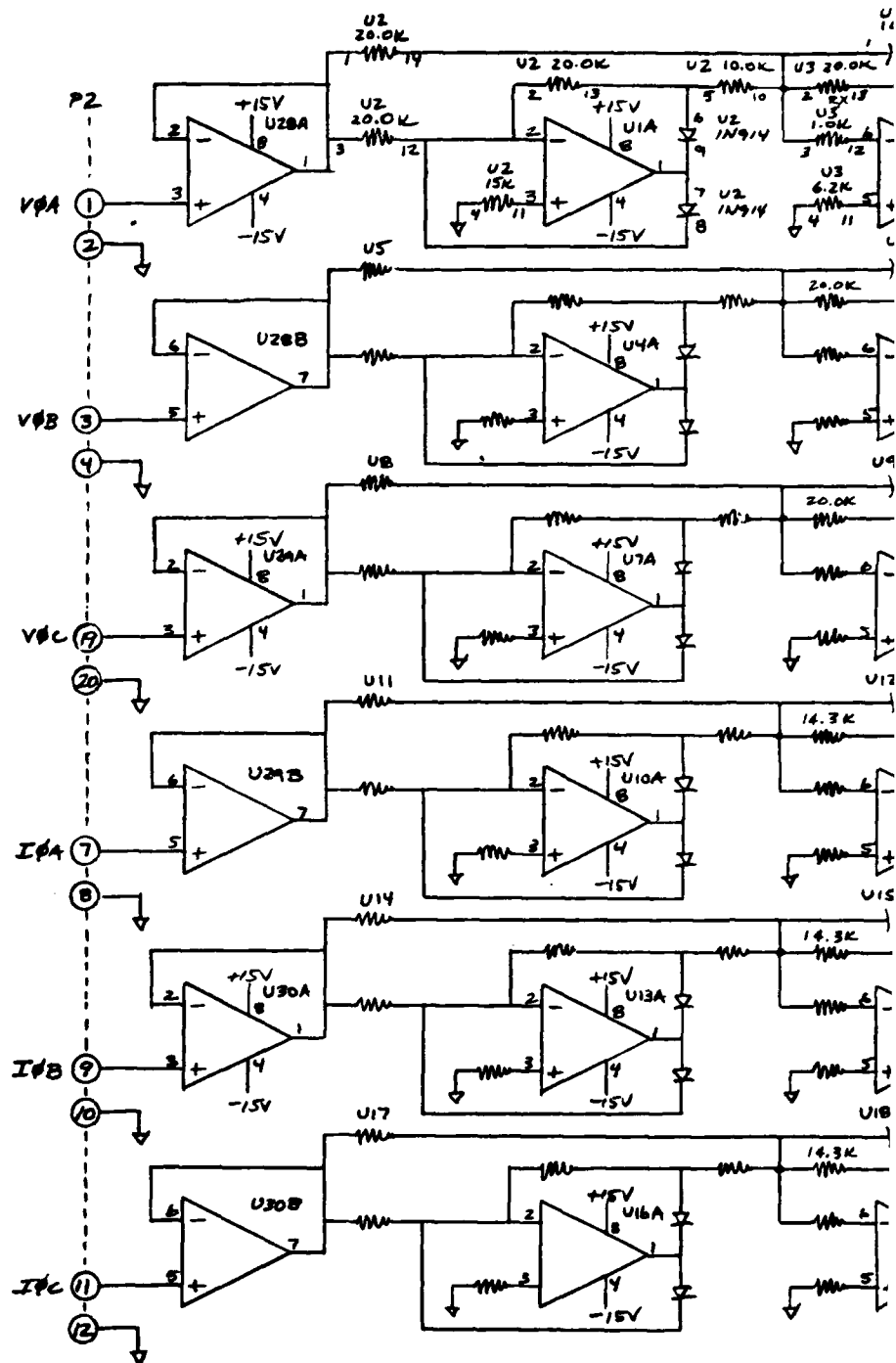
J K L M N P Q R S T U

D

C

B

A



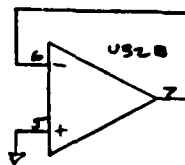
U20, U23, U26
SEE SCHEMATIC

1 20.0K 14
2 20.0K 13
3 20.0K 12
4 15K 11
5 10.0K 10
6 10K 9
7 10K 8

U2, U5, U8,
U11, U14, U17,

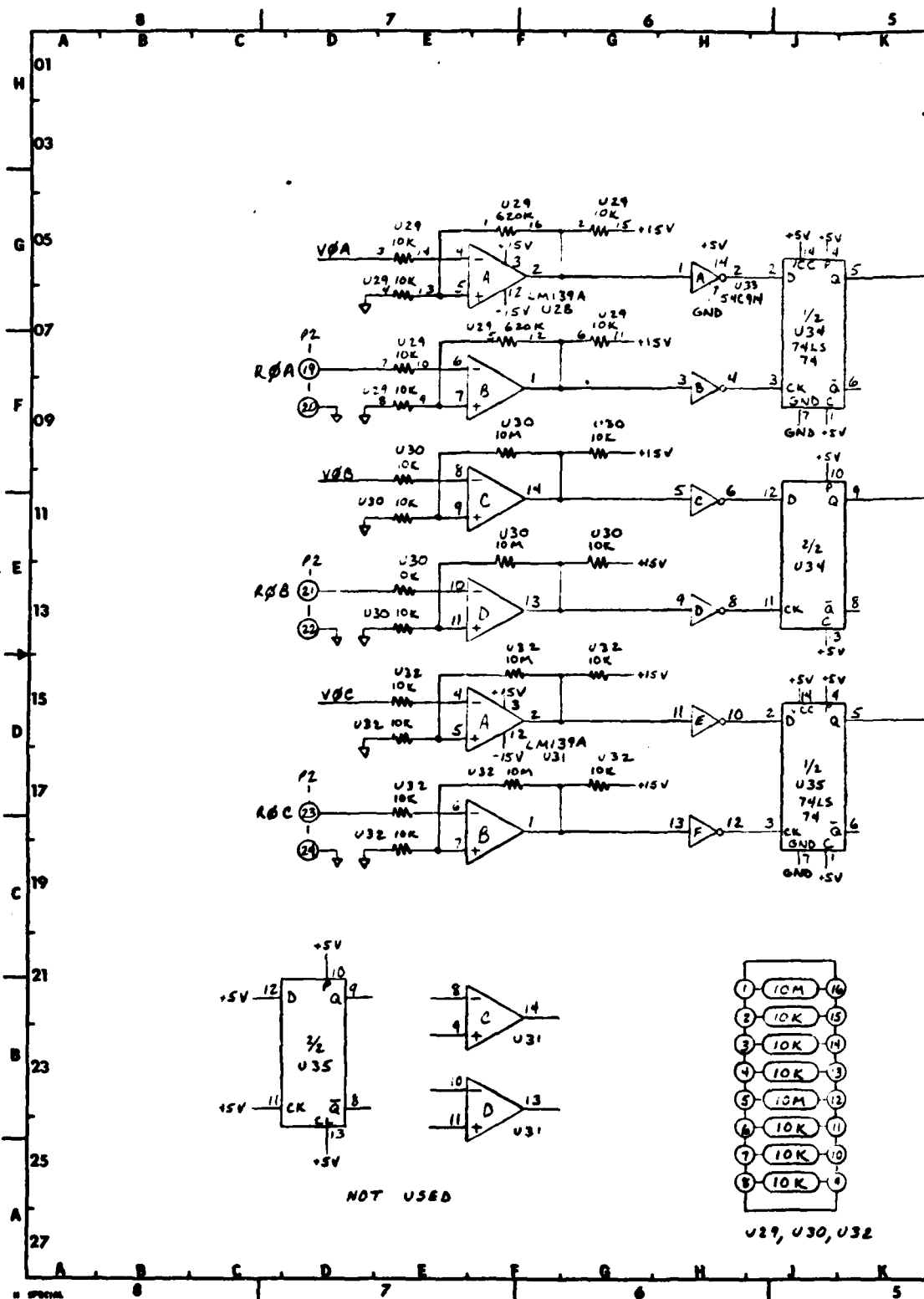
1 10K 14
2 10K 13
3 10K 12
4 10K 11
5 10K 10
6 10K 9
7 10K 8

U3, U6, U9,
U12, U15, U18,
U21, U24, U27



14
13
12
11
10
9
8

2 ↑



5 4 3 2 1
K L M N P Q R S T U
REV DESCRIPTION AUTH DATE APPROVED
I V I W I X

5V -5V
1/4 4
100 P
P3
14
LL A

1/2
U34
74LS
74

CK A
2ND C
17 1
GND -5V

5V
10
D Q
LLB

1/2
U34

CK A
3 C
+5V

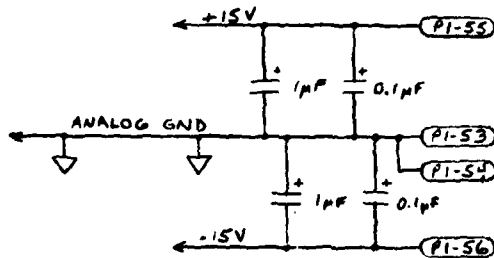
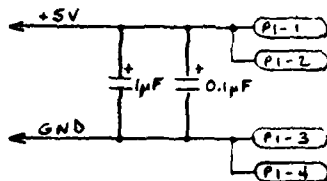
5V -5V
1/4 4
100 P
D Q
LLC

1/2
U35
74LS
74

CK A
3ND C
17 1
GND -5V

M 16
K 15
K 14
K 13
M 12
K 11
K 10
K 9

U30, U32



REMOTE CONDITIONING BOARD
PHASE INDICATORS
T. LA ROVERE E-4-P1

REV B P-18-P2 JRL

Delco Electronics			
GENERAL MOTORS CORPORATION, SANTA BARBARA, CALIFORNIA			
TITLE REMOTE UNIT PHASE INDICATORS			
SIZE	CODE IDENT NO	DWG NO	REV
	13160	SK003921	B
SCALE	WEIGHT	SHEET 1 OF	

REV	CODE IDENT NO	DWG NO	REV
H	13160	30811-2	
DATE		DRAWN BY	

L-11

2

REMOTE UNIT INTERCONNECT CABLE(S) PIN OUT

CONNECTOR: DD(X) - SDS W/ DD-24661 CLAMP

CABLE: HEWLETT PACKARD P/N 5040-7860

<u>CONNECTOR PIN NUMBER</u>	<u>WIRE COLOR</u>	<u>SIGNAL NAME</u>
1	WH-BK-GN	RU(1 OR 2) V ϕ A
2	WH-YL-GY	V ϕ B
3	WH-YL-VIO	V ϕ C
4	WH-YL-BU	V AVG DC
5	WH-YL-GN	I ϕ A
6	WH-OR-VIO	I ϕ B
7	WH-OR-BU	I ϕ C
8	WH-OR-GN	I AVG DC
9	WH-OR-YL	P ϕ A
10	WH-VIO	P ϕ B
11	WH-BU	P ϕ C
12	WH-GN	P TOTAL
13	WH-YL	LOAD P TOTAL
14	WH-OR	AU(1 OR 2) PHASE BIAS
15	WH-RD	RU(1 OR 2) AMPL BIAS
16	WH-BN	NOT USED
17	WH-BK	NOT USED
18	WH *	CONT OPEN
19	WH-GY *	CONT CLOSE
20	WH-BK-BN *	-15VDC
21	WH-BK-RD *	+15VDC
22	WH-RD-VIO	RU(OR 2) R ϕ A
23	WH-RD-GY	R ϕ B
24	WH-BK-OR	R ϕ C
25	OUTER BARE WIRE	SIGNAL COMMON (J10)

* INDICATES WIRE LOCATED INSIDE
INNER SHIELD

19

CONNECTOR PIN NUMBER	WIRE COLOR	SIGNAL NAME
26	WH-BK-BU	RX(102) UNDER FREQ
27	WH-RD-BU	OVER FREQ
28	WH-RD-GN	UNDER VOLTAGE
29	WH-RD-YL	OVER VOLTAGE
30	WH-RD-OR	MISSING PHASE
31	WH-BN-GN	REVERSE PHASE
32	WH-BN-YL	50HZ
33	WH-BU-OR	60HZ
34	WH-BN-RD	400HZ
35	VIO	CONT CLOSED COMMANDED
36	BU	CONT CLOSED EXECUTED
37	GN	CONT CLOSED OVERRIDEN
38	YL	NOT USED
39	OR	NOT USED
40	RD	EXTRA J10 - 15 or 33
41	BN	EXTRA J10 - 16 or 34
42	BK	EXTRA J10 - 17 or 35
43	INNER BARE WIRE	PWR COMMON (J11)
44	GY*	EXTRA J11 - 4 or 16
45	WH-BK-GY*	EXTRA J11 - 5 or 17
46	WH-BN-GY*	EXTRA J11 - 6 or 18
47	WH-BN-BU	REMOTE/LOCAL (J09)
48	WH-BN-VIO	EXTRA J11 - 3 or 15
49	WH-BK-YL	SIGNAL COMMON (J09)
50	WH-BK-VIO	PWR COMMON (J09)

REVA 12-NOV-1981 G.H.B. KENAMHE 16,17,38,39

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES FRACTIONS TO 1/16 DECIMALS TO 0.005		G.H.B. 11/810		L-12 ELECTRONIC	
2 PLACE 2 PLACE ANGLES DECIMALS DECIMALS		G.H.B. 11/81P		RU1 & RU2 REMOTE CABLES	
MATERIAL		C 13160		SK003922 A	
REF: ADG: ENG: CENT: 1		DATE: 11/81		SHEET 1 OF 1	

2

2

1

L-12

D

C

B

A

J10

J07

A2

A3

A4

A5

- 1 -15V
- A -15V
- 2 PWRCON
- B PWRCON
- 3 +15V
- C +15V
- 6 RESET
- 7 VMDAT
- H NEUTAR
- P VMDAT
- J NEUTBH
- 9 VMDAT
- K NEUTCN
- 10 VMDAT
- L VMDAT
- 11 VMDAT
- M VMDAT
- 12 VMDAT
- N VMDAT
- 13 VMDAT
- P VMDAT
- 14 REV M
- R SIGCON
- 15 APM
- S PM M
- 16 BPM
- T OV M
- 17 CPM
- 18 REV M
- V MPM
- 19 PM
- W PM
- Z EXTRA

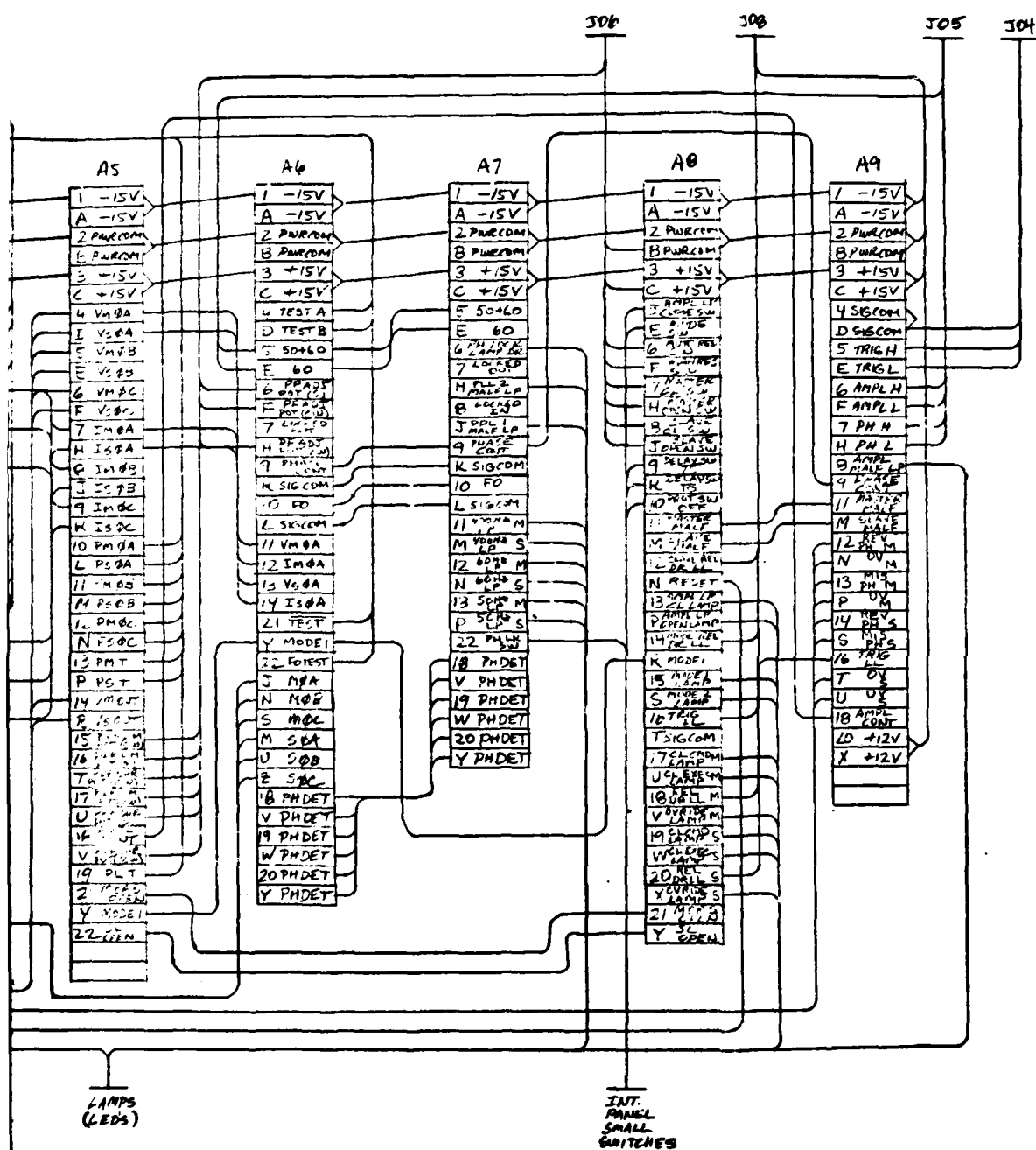
- 1 -15V
- A -15V
- 2 PWRCON
- B PWRCON
- 3 +15V
- C +15V
- 6 RESET
- 7 VMDAT
- H NEUTAR
- P VMDAT
- J NEUTBH
- 9 VMDAT
- K NEUTCN
- 10 VMDAT
- L VMDAT
- 11 VMDAT
- M VMDAT
- 12 VMDAT
- N VMDAT
- 13 VMDAT
- P VMDAT
- 14 REV M
- R SIGCON
- 15 APM
- S PM M
- 16 BPM
- T OV M
- 17 CPM
- 18 REV M
- V MPM
- 19 PM
- W PM
- Z EXTRA

- 1 -15V
- A -15V
- 2 PWRCON
- B PWRCON
- 3 +15V
- C +15V
- 7 INPAE
- H SIGCON
- R INDT
- 9 INDT
- 10 INDT
- L INDT
- 11 INDT
- M INDT
- 12 INDT
- N INDT
- 13 INDT
- P INDT
- 14 INDT
- R INDT
- 15 INDT
- 16 INDT
- 17 INDT
- U INDT
- 18 INDT
- X INDT
- D MPA
- E MPA
- F MPA
- K MPA
- Y MPA
- Z MPA

- 1 -15V
- A -15V
- 2 PWRCON
- B PWRCON
- 3 +15V
- C +15V
- 4 VMDAT
- 5 VMDAT
- 6 VMDAT
- 7 VMDAT
- 8 VMDAT
- 9 VMDAT
- 10 VMDAT
- 11 VMDAT
- 12 VMDAT
- 13 VMDAT
- 14 VMDAT
- 15 VMDAT
- 16 VMDAT
- 17 VMDAT
- 18 VMDAT
- 19 VMDAT
- 20 VMDAT
- 21 VMDAT
- 22 VMDAT

LAMP
(LEDs)

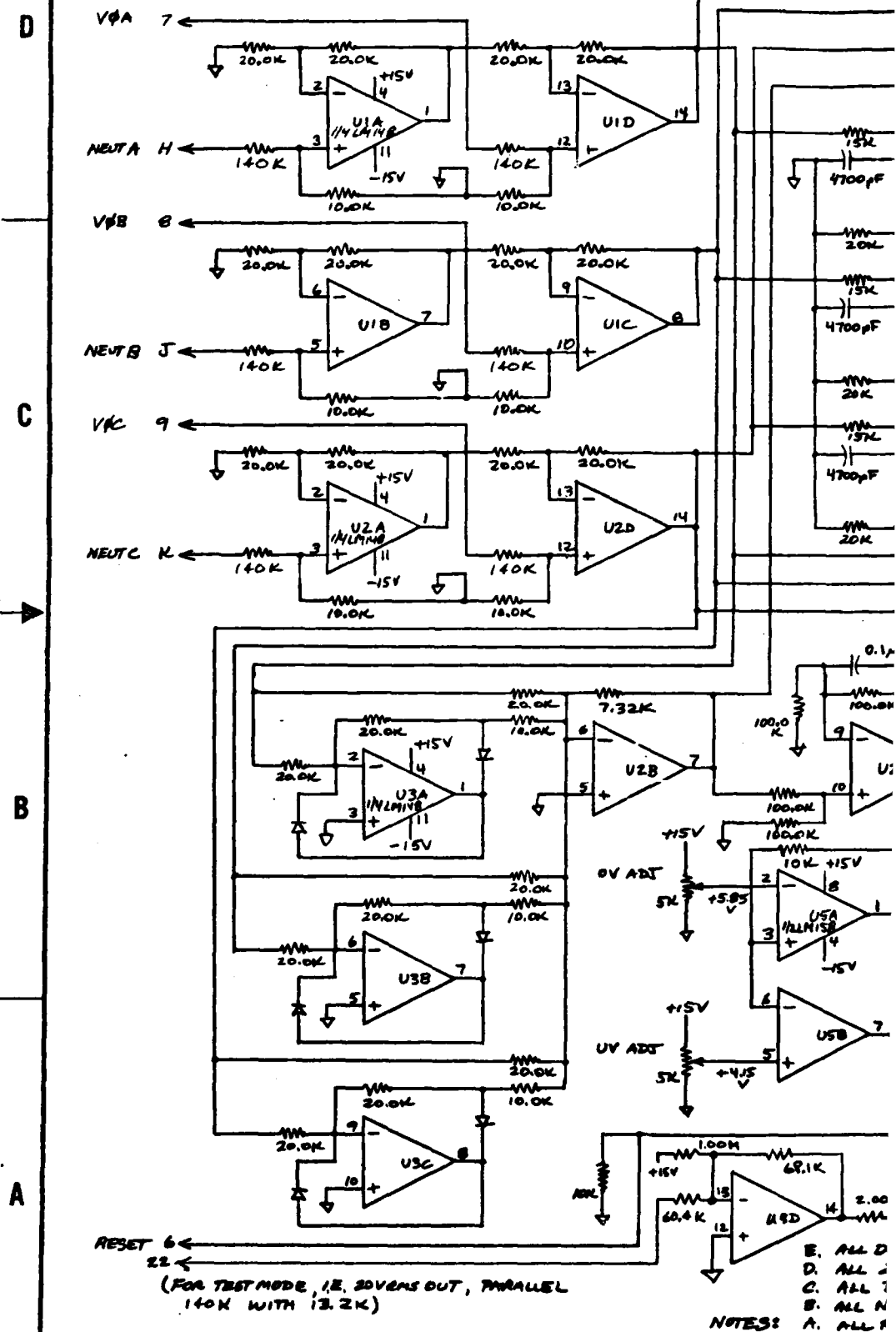
INCOMP
NOT OF
TOUCH
CONTR



INCOMPLETE DRAWING.
NOT UPDATED TO SHOW
TOUCH SCREEN CRT
CONTROLLER MODIFICATIONS.

09-28-82 JRC REV B
01-27-01 G.H.B. REV A

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 3 PLACE 3 PLACE ANGLES DECIMALS DECIMALS		CONTRACT NO. G.H.B. 3-80		DISTRIBUTION UNIT WIRING DIAGRAM	
MATERIAL		APPD G.H.B. 3-80		DISTRIBUTION UNIT WIRING DIAGRAM	
REF (AC OR) CNG CONTROL		APPD		DISTRIBUTION UNIT WIRING DIAGRAM	
OTHER APPROVAL		APPD		DISTRIBUTION UNIT WIRING DIAGRAM	
SCALE		WEIGHT		SHEET 1 OF	
C 13160		SK002749		REV B	





- E. ALL DIODES IN 414B-1
- D. ALL 2 DIGIT VALUE R'S RCR07
- C. ALL 3 OR 4 DIGIT R'S RNC5TH
- B. ALL NON POLAR CAPS CXL06 CERAMIC
- A. ALL POLAR CAPS CSR13 TANTALUM

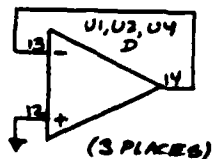
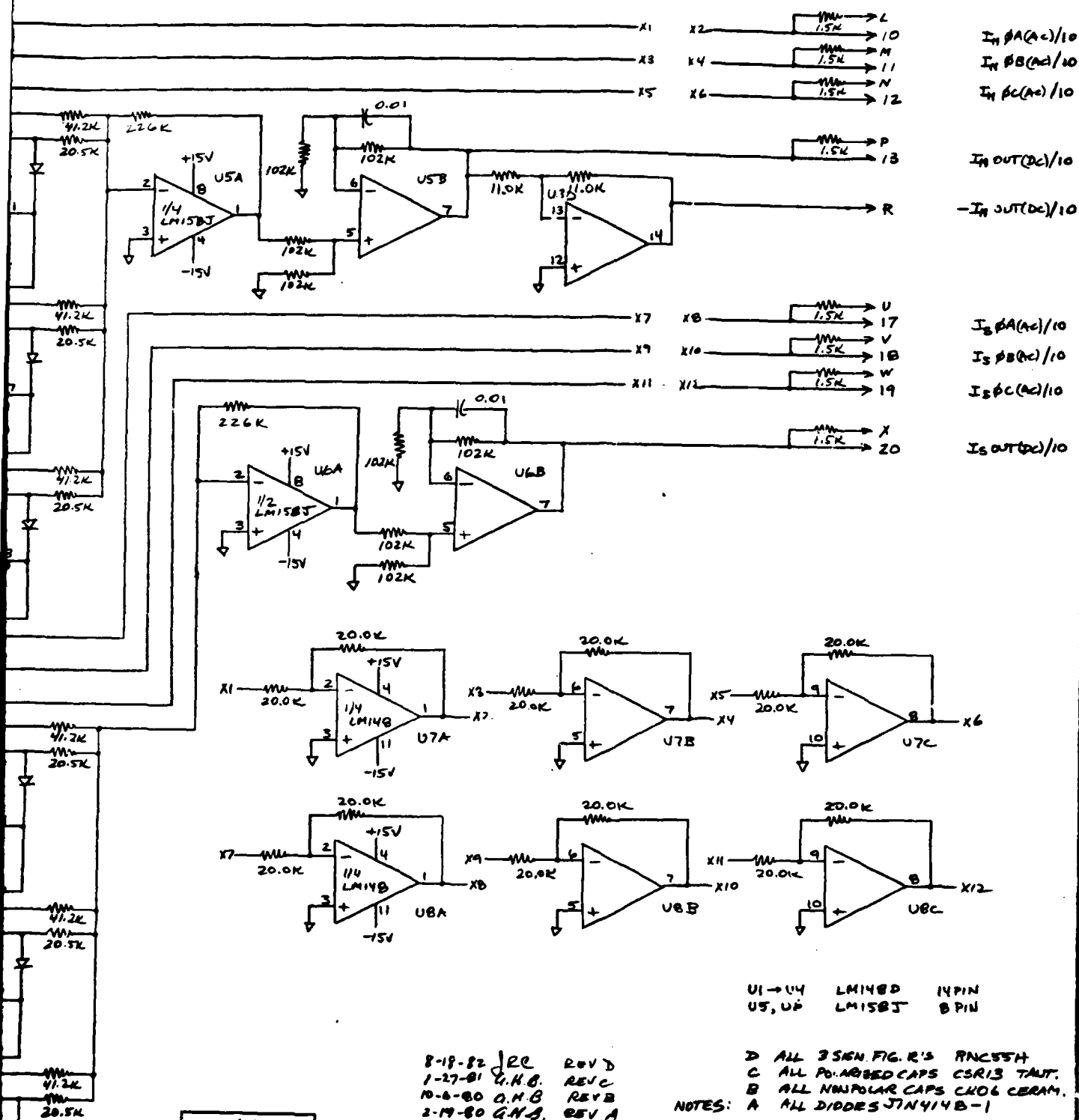
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE 3 PLACE ANGLES DECIMALS DECIMALS + + + - - -	CONTRACT		Elico Electronics	
	DATE <i>ONR 11-4</i>		GENERAL MOTOR CORPORATION SANTA BARBARA, CALIF.	
MATERIAL	NGR		DISTRIBUTION UNIT	
	APPD		VOLTAGE DETECTION/MALFUNCTION CLA	
	APPD		A2 & A3	
	QUANTITY		SIZE	ENG NO.
REF (AC ONLY) CHG CONTROL	OTHER APPROVAL		C 13160	SK002753
		SCALE	WEIGHT	SHEET 1 OF 1



3

2

1



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 3 PLACE 2 PLACE ANGLES DECIMALS DECIMALS		DATE: 8-19-82 BY: JEC CHECKED: G.H.B. APPROVED: G.H.B.		Rev: 1-80 2-80	
MATERIAL		APPROVAL		SIZE: C	
REF. IAC. DAL. CAG. CONTROL		OTHER APPROVAL		CODE: 13160	
				DWG NO: SK002754	
				SHEET: 1 OF 2	

↑2

2

1

M-3a

D

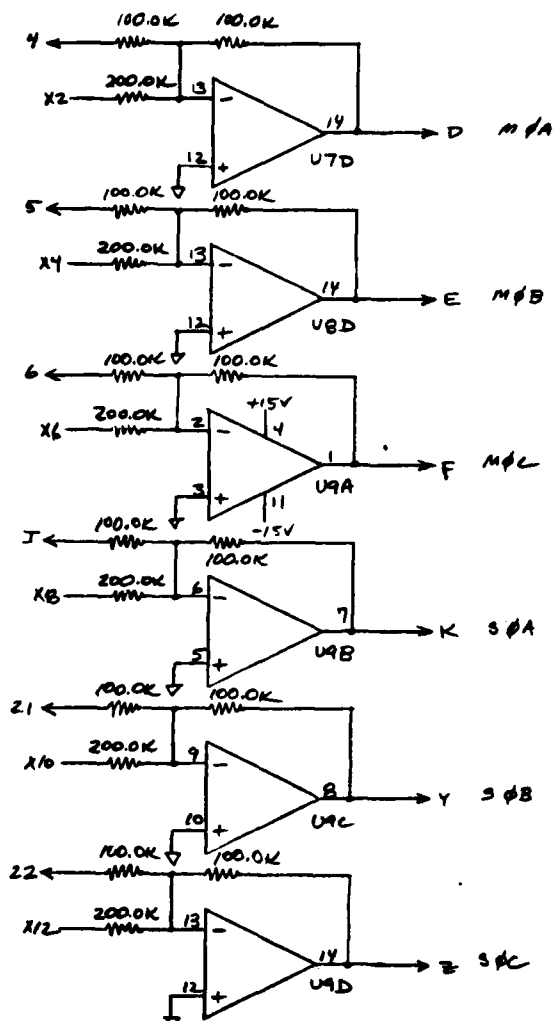
 $V_H \phi A (AC) / 24$ $V_H \phi B (AC) / 24$ $V_H \phi C (AC) / 24$

C

 $V_S \phi A (AC) / 24$ $V_S \phi B (AC) / 24$ $V_S \phi C (AC) / 24$

B

A



3

2

1

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON	CONTR NO		Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF.			
2 PLACES DECIMALS	JEFF H. <i>A.H.B.</i>	10-6 86	TITLE CURRENT SENSE / CONDITIONING AMPLIFIERS			
3 PLACES DECIMALS	<i>A.H. Bamber</i>	10-6 60	DISTRIBUTION UNIT <i>AY</i>			
MATERIAL	APPD		SIZE	CODE IDENT NO	DWG NO	REV
	APPD		<i>C</i>	13160	SK002754	D
REF LAC ONLY	DESIGN ACT VITY APPD		SCALE		WEIGHT	SHEET 2 OF 2
CHG CONTROL	OTHER APPROVAL					

4

3

D

VM0A/24

IM0A/10

VM0B/24

IM0B/10

C

VM0C/24

IM0C/10

→

VS0A/24

IS0A/10

B

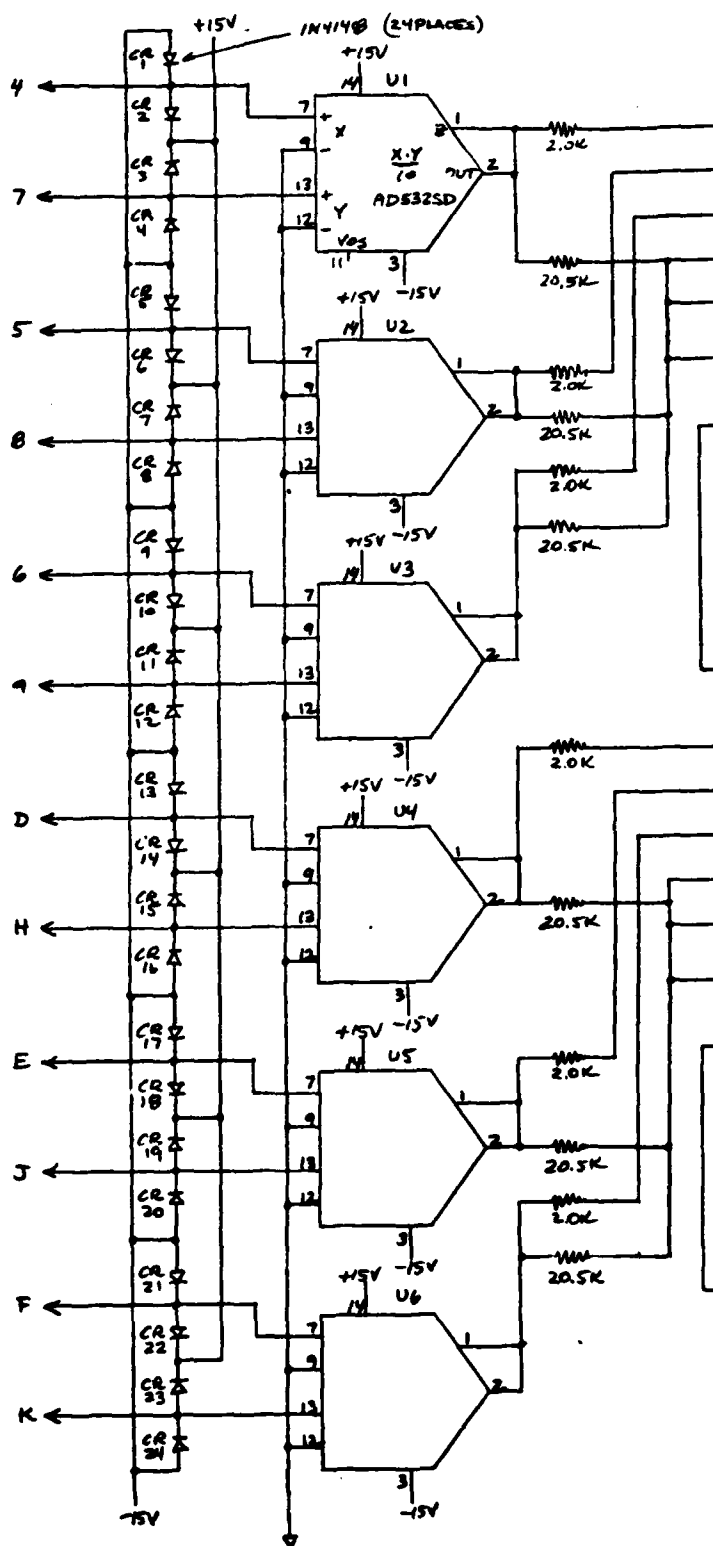
VS0B/24

IS0B/10

VS0C/24

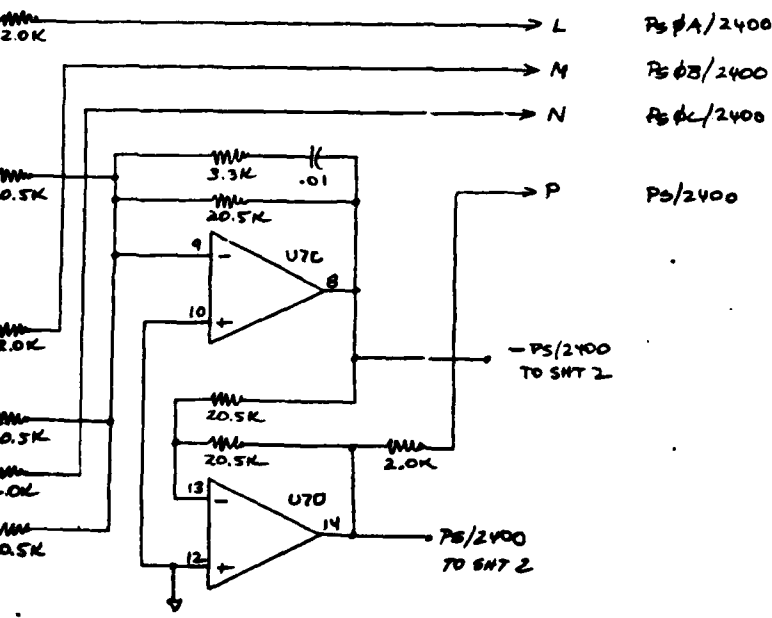
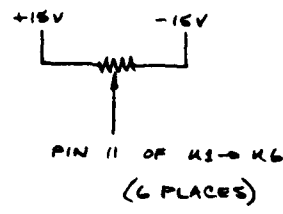
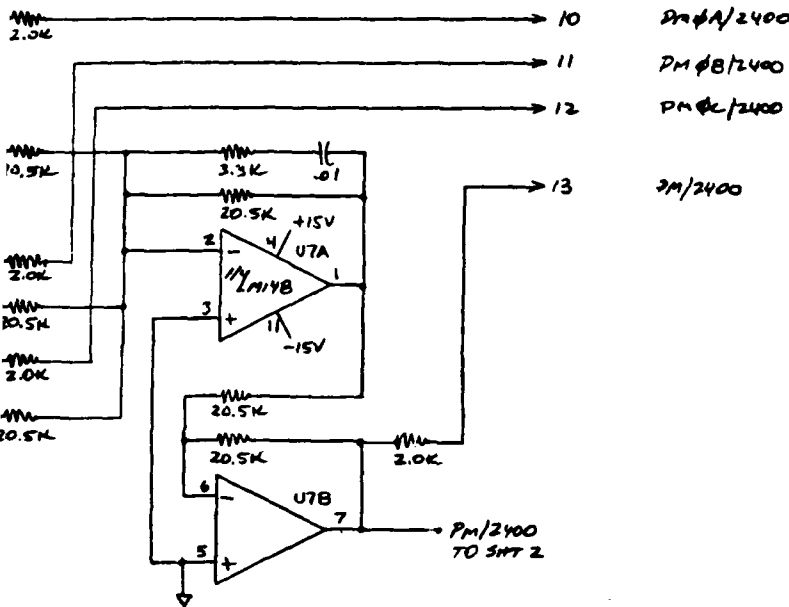
IS0C/10

A



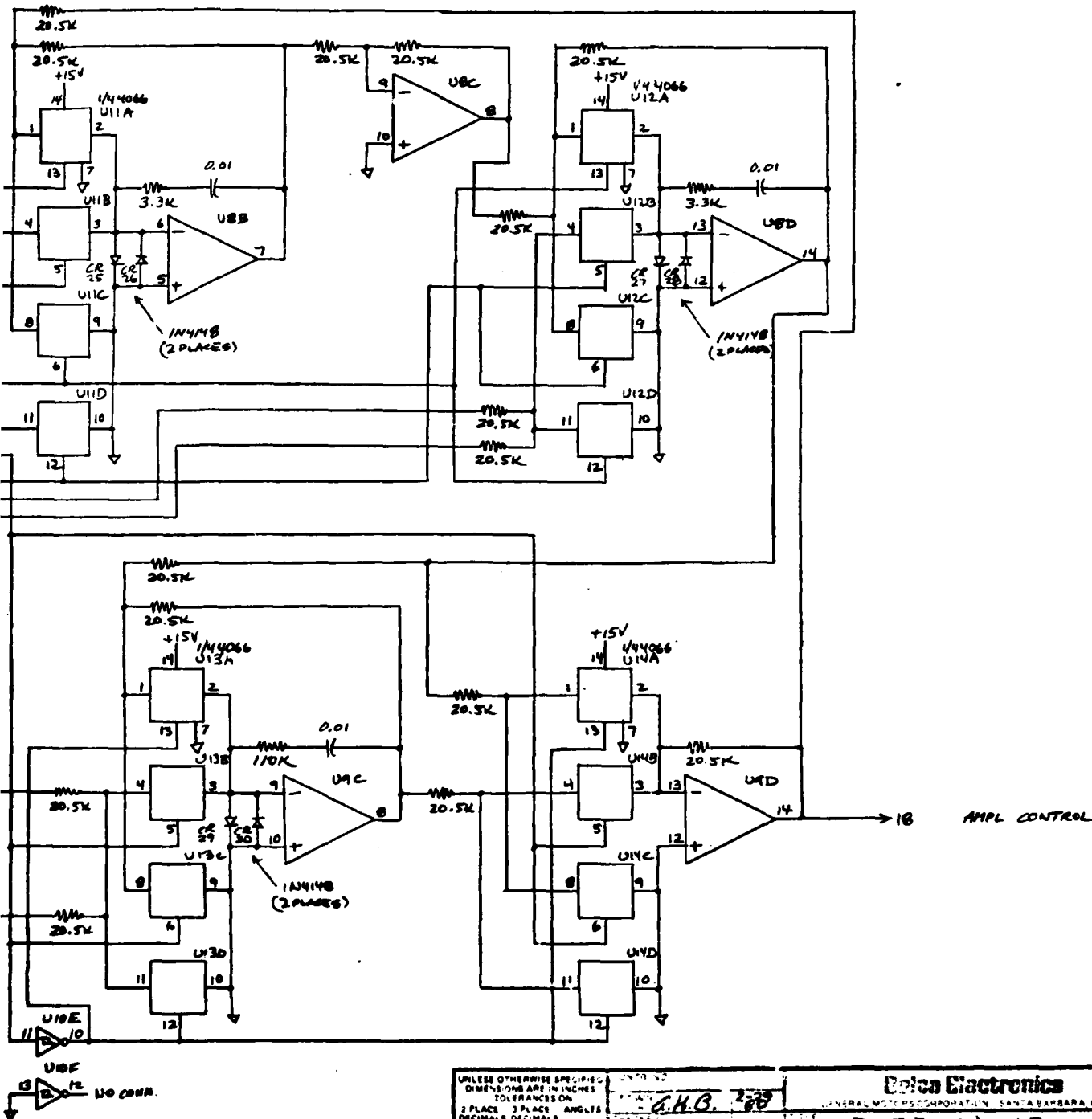
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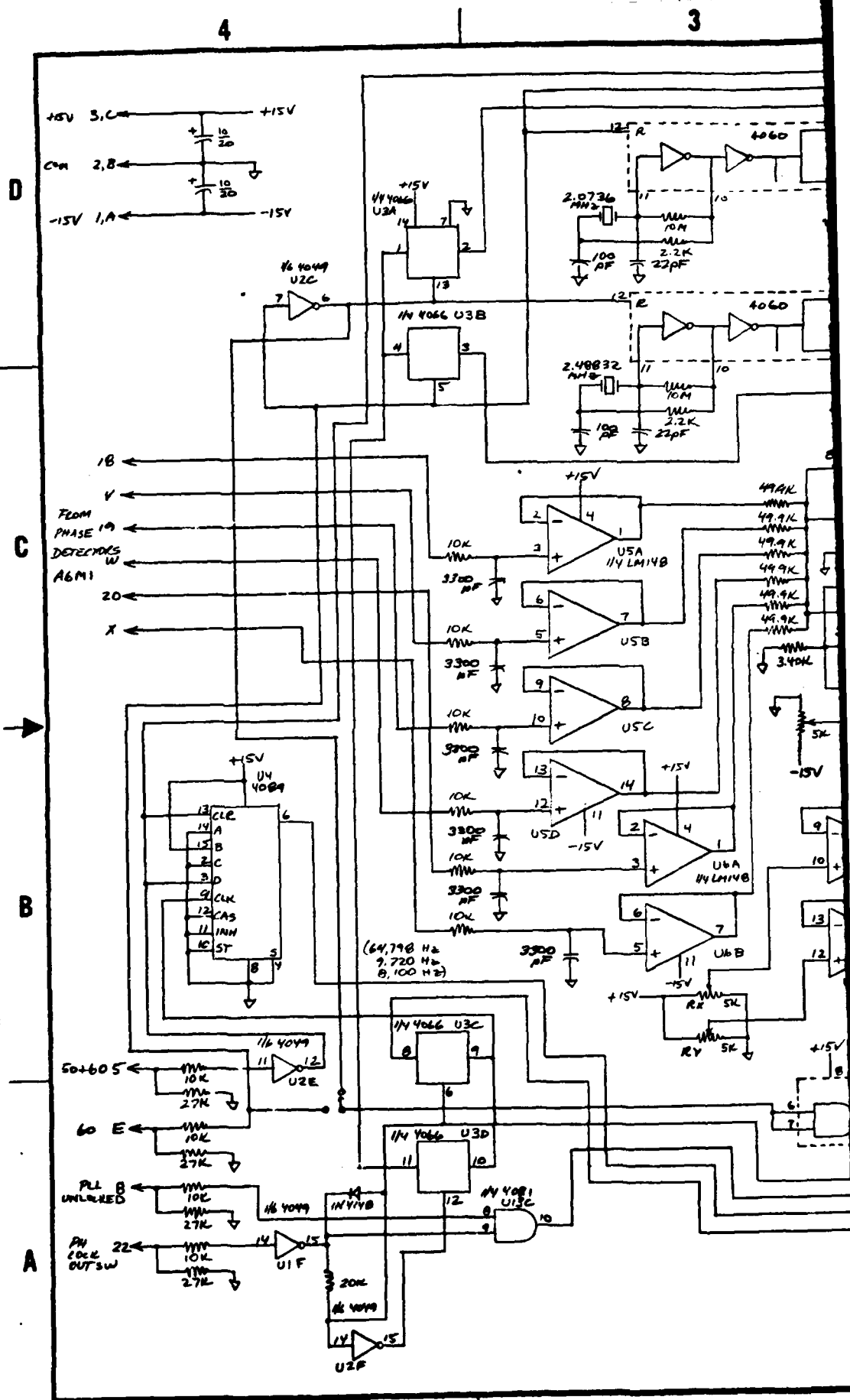
3

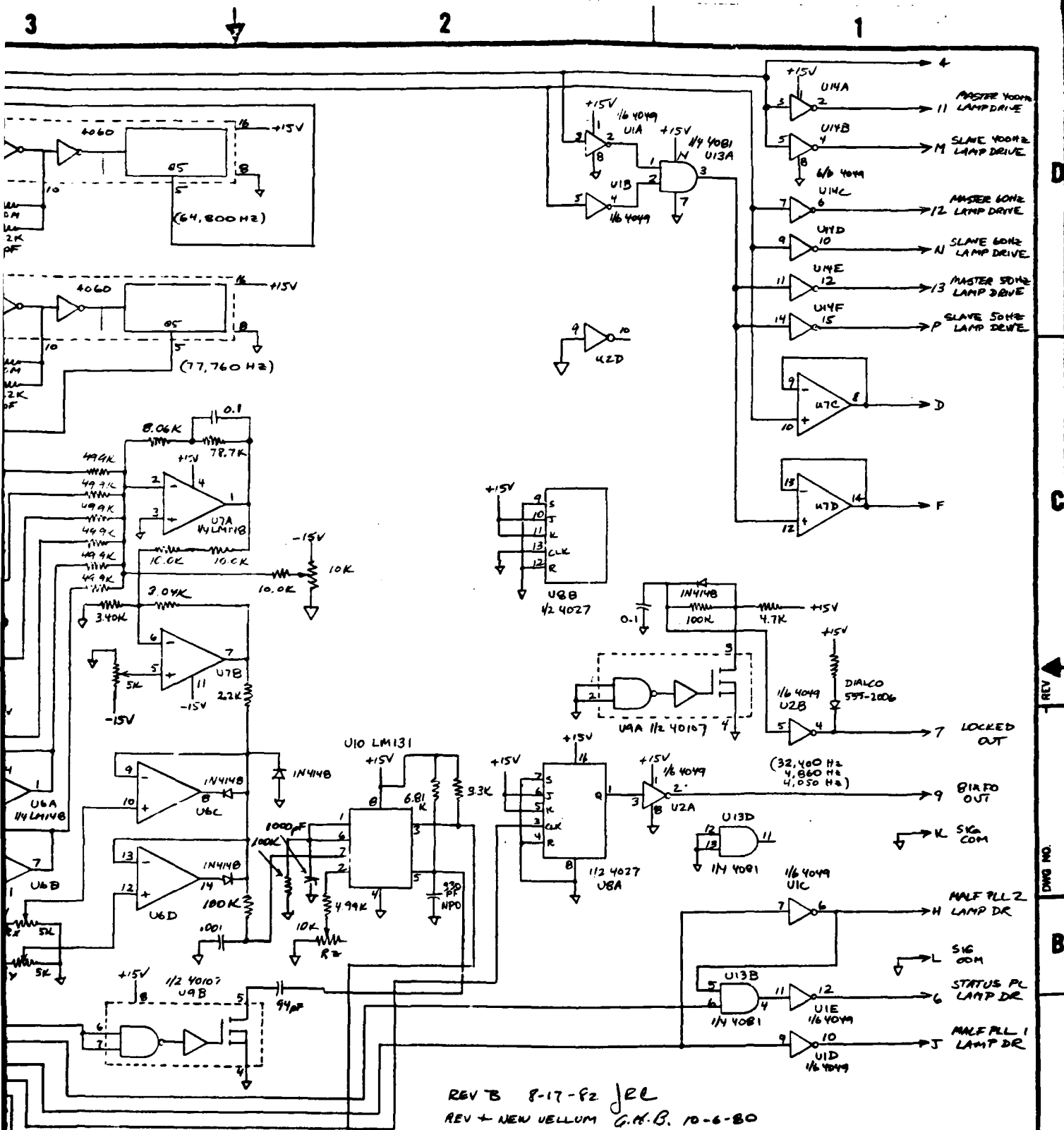


08-17-82 J.R.C REV B
01-27-81 G.H.D. REV A

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON		Festo Electronics	
2 PLACE DECIMALS	3 PLACE DECIMALS	GENERAL MOTION CORPORATION SANTA BARBARA, CALIF.	
MATERIAL		DISTRIBUTION UNIT AMPLITUDE CONTROL CIRCUITS A5	
REF INQ DLT	CHG CONTROL	SIZE	REV
		C	B
		13150	SK002755
		SCALE	WEIGHT
			SHEET 1 OF 2



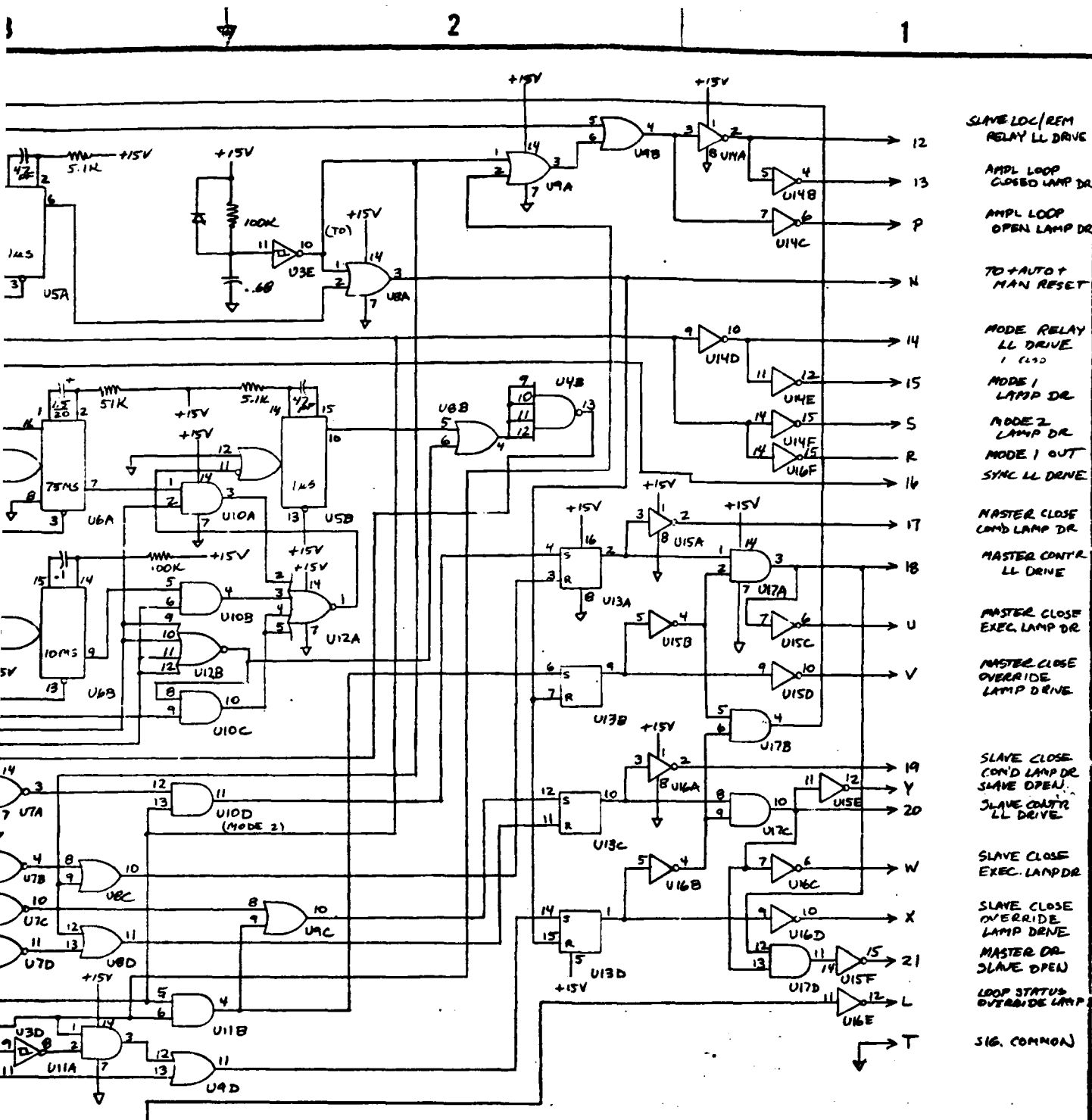




REV B 8-17-F2 JEL
 REV + NEW UELLUM G.H.B. 10-6-80

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 3 PLACE 3 PLACE ANGLES DECIMALS DECIMALS		DOWLING NO G.H.B. 10-6-80		DOLCO Electronics GENERAL MOTORS CORPORATION SANTA BARBARA CALIF	
MATERIAL		G.H. Carver 10-6-80		PLL & BIFFO GENERATOR	
REF TAC DRL CNG CONTROL		APPD		DISTRIBUTION UNIT A7	
OTHER APPROVAL		UJUN ACTIVITY APPD		SIZE C 13160	
				ENG NO SK002757	
				REV B	
				SCALE	
				WEIGHT	
				SHEET 1 OF 1	

M-5



8-17-FZ JER REV F
 01-27-B, G.H.B. REV M
 12-1-80 G.H.B. REV C, D
 3-5-80 G.H.B. REV B

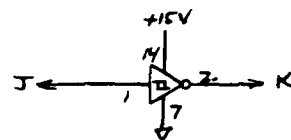
- U1-U3 54C914
- U4 40128
- U5 4098B
- U6 14530B
- U7 4001B
- U8,9 4071B
- U10,11,17 4081B
- U12 4002B
- U13 4043B
- U14-U16 40490B

R13 TANTALUM

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 3 PLACE 3 PLACE ANGLES DECIMALS DECIMALS		DATE 1-24-80 BY G.H.B.		Delta Electronics CENTRAL MOUNTAIN CORPORATION SANTA BARBARA CALIF	
MATERIAL		G.H.B. 1-24-80		RELAY CONTROL LOGIC	
REF ID ORL CHG CONTROL		OTHER APPROVAL		DISTRIBUTION UNIT AB	
				SIZE C	CODE DESK NO. 13160
				OWG NO. SK002758	REV F
				SCALE -	WEIGHT
				SHEET 1 OF 1	

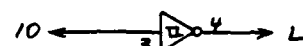
REV A
 DWG NO
 B

D

FROM
AB-17MASTER CLOSE
CON'D LAMP DR

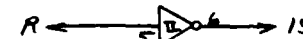
RU1 CONT'R CLOSE C

AB-V

MASTER CLOSE
OVERRIDE LAMP DR

RU1 CONT'R CLOSE

AB-19

SLAVE CLOSE
CON'D LAMP DR

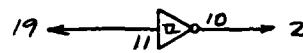
RU2 CONT'R CLOSE

AB-X

SLAVE CLOSE
OVERRIDE LAMP DR

RU2 CONT'R CLOSE

AB-U

MASTER CLOSE
EXEC LAMP DR

RU1 CONT'R CLOS

C

AB-W

SLAVE CLOSE
EXEC LAMP DR

RU2 CONT'R CLOS

U8
54C914

B

A

3 2 1

↓

CONT'R CLOSE COMMANDED

CONT'R CLOSE OVERRIDDEN

CONT'R CLOSE COMMANDED

CONT'R CLOSE OVERRIDDEN

CONT'R CLOSE EXECUTED

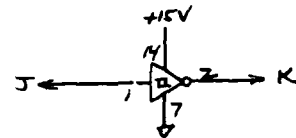
CONT'R CLOSE EXECUTED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 3 PLACE 3 PLACE ANGLES DECIMALS DECIMALS		DISTR NO C.H.B. 10-81		Delco Electronics GENERAL MOTORS CORPORATION SANTA RAE, CALIF.	
MATERIAL		C.H. BENTON 10-81		DISTRIBUTION UNIT COMMUNICATIONS DRIVERS A9	
APP'D		C		SIZE 13160	
DESIGN ACTIVITY APP'D		C		IDW NO SK002759	
REVISIONS		OTHER APPROVAL		SCALE — WEIGHT — SHEET 2 OF 2	

4

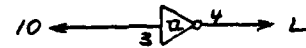
3

D

FROM
AB-17MASTER CLOSE
CON'D LAMP DR

RU1 CONTR CLOSE COI

AB-V

MASTER CLOSE
OVERRIDE LAMP DR

RU1 CONTR CLOSE

AB-19

SLAVE CLOSE
CON'D LAMP DR

RU2 CONTR CLOSE

AB-X

SLAVE CLOSE
OVERRIDE LAMP DR

RU2 CONTR CLOSE

AB-U

MASTER CLOSE
EXEC LAMP DR

RU1 CONTR CLOSE

C

AB-W

SLAVE CLOSE
EXEC LAMP DR

RU2 CONTR CLOSE

U8
54C914

B

A

4

3

3

2

1

CONT'R CLOSE COMMANDED

CONT'R CLOSE OVERRIDDEN

CONT'R CLOSE COMMANDED

CONT'R CLOSE OVERRIDDEN

CONT'R CLOSE EXECUTED

CONT'R CLOSE EXECUTED

REV

DWG NO.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE 3 PLACE ANGLES DECIMALS DECIMALS		DATE 10-NOV-61 A.H.B.		De'co Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF.	
MATERIAL		A.H.B. 10-NOV-61		DISTRIBUTION UNIT COMMUNICATIONS DRIVERS A9	
REF (AC/DRL) CHG CONTROL		DESIGN APPROVAL		SCALE C	WEIGHT 13160 SK002759
				SHEET 2 OF 2	

3

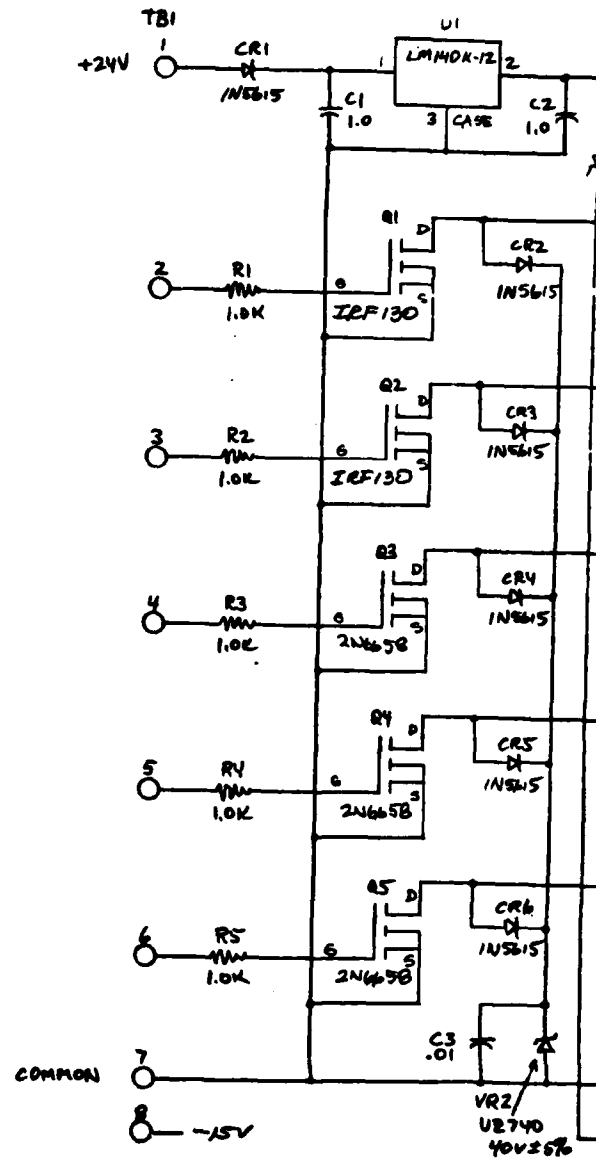
2 ↑

2

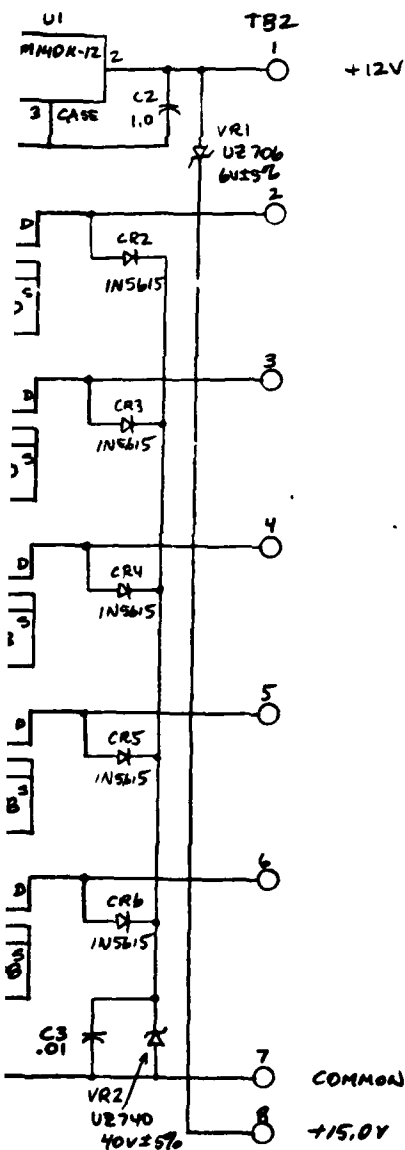
1

M-7B

D
C
B
A



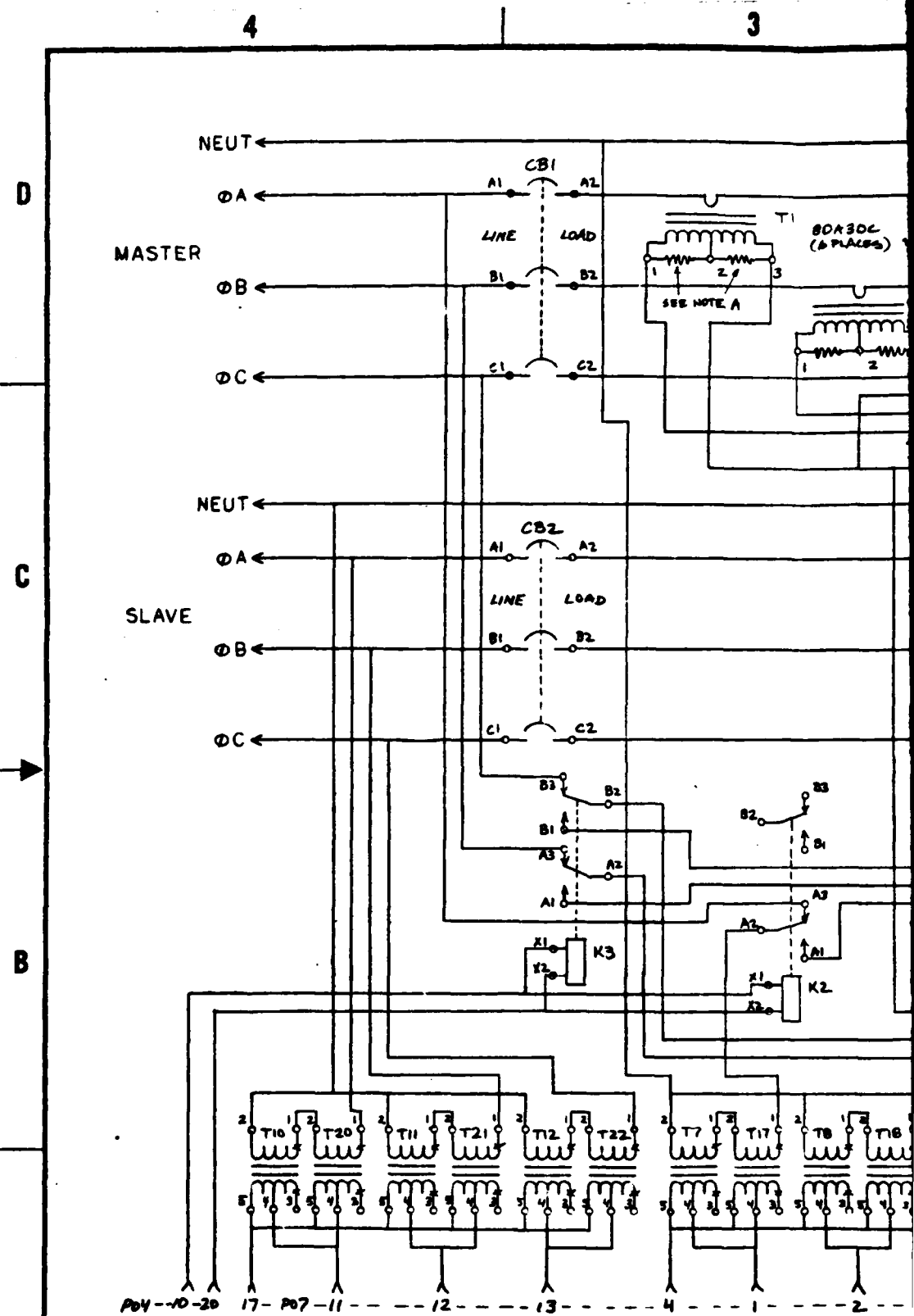
NOTES:
 1. ALL RESISTORS RC076102J6
 2. ALL CAPS CK05 OR CK06 CERAMICS



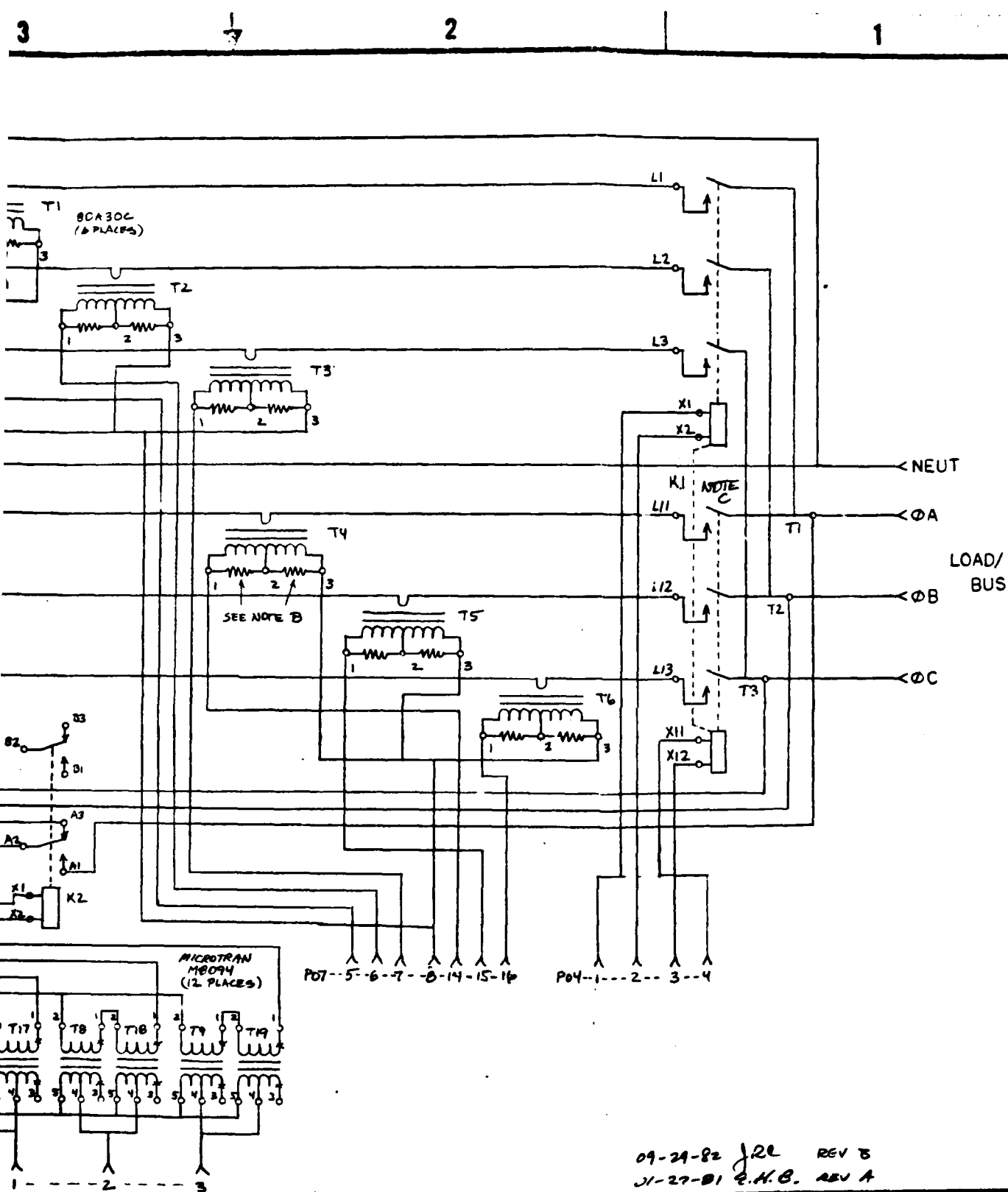
09-29-82 JRC REV B
01-27-81 G.H.B. REV A

K06 CERAMIC
7610236

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 3 PLACE 3 PLACE ANGLES DECIMALS DECIMALS		CONTR NO C.H.B. 2-83		Geco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF	
MATERIAL		C.H.B. 2-83		DISTRIBUTION UNIT	
REF IAC ONLY CHG CONTROL		C.H.B. 2-83		12V LAMP SUPPLY AND RELAY DRIVERS AB	
APPROVAL		APPROVAL		SIZE C	CODE 13160
ACTIVITY APPD		ACTIVITY APPD		DWG NO SK002763	REV B
OTHER APPROVAL		OTHER APPROVAL		SCALE	WEIGHT
				SHEET	1 of 1



NOTE C K1 HAS MECHANICAL MOD. FOR 6P OPERATION
 NOTE B R 24.9Ω, 1%, 18W, RNC60H 2499FM (6 PLACES)
 NOTE A R 24.9Ω, 1%, 18W, RNC60H 2499FM (6 PLACES)



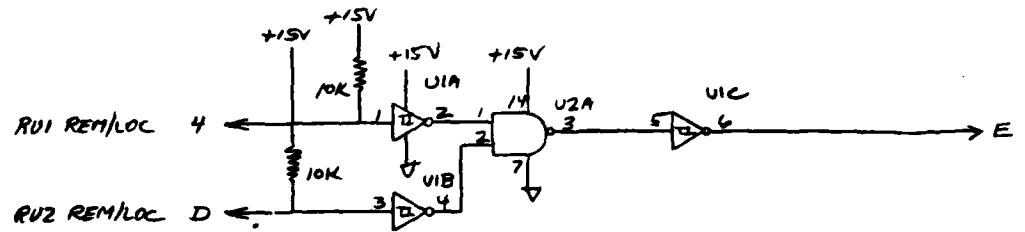
09-24-82 JRE REV B
 01-27-81 E.H.B. REV A

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES 2 PLACE 3 PLACE ANGLES DECIMALS DECIMALS		DRAWN BY E.H.B. JRE		CHECKED BY E.H.B. JRE		DATE 09-24-82		DESIGNED BY E.H.B. JRE		DATE 09-24-82		REVISED BY E.H.B. JRE		DATE 09-24-82	
MATERIAL		APPROVED BY E.H.B. JRE		DATE 09-24-82		DESIGNED BY E.H.B. JRE		DATE 09-24-82		REVISED BY E.H.B. JRE		DATE 09-24-82		DATE 09-24-82	
REF. IAC. ORL.		CHG. CONTROL		JUN. ALTY. AND		OTHER APPROVAL		SCALE		WEIGHT		SHEET		1 OF 1	
								C 13160		SK002764		B			

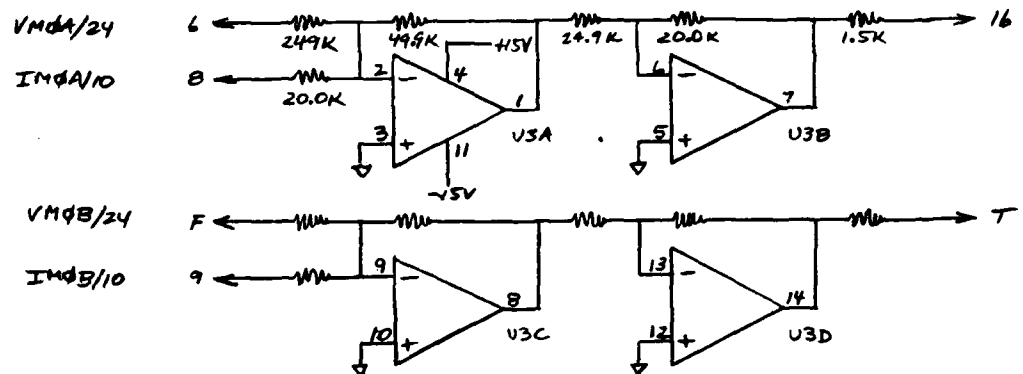
REV
 DWG NO.

M-9

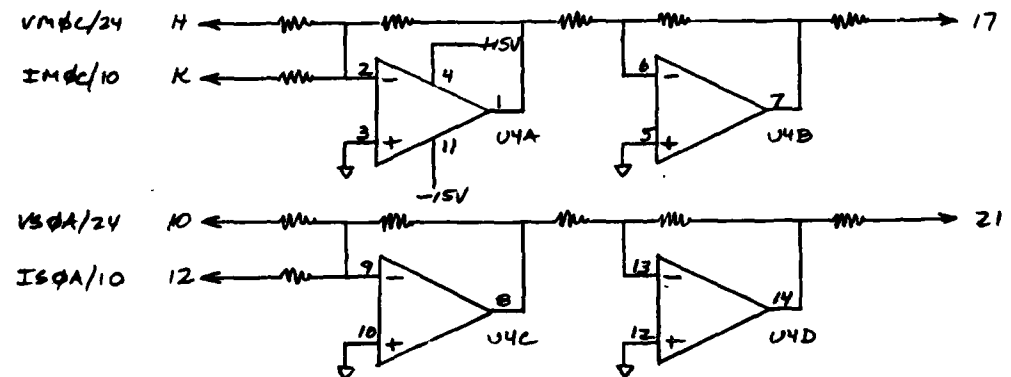
D



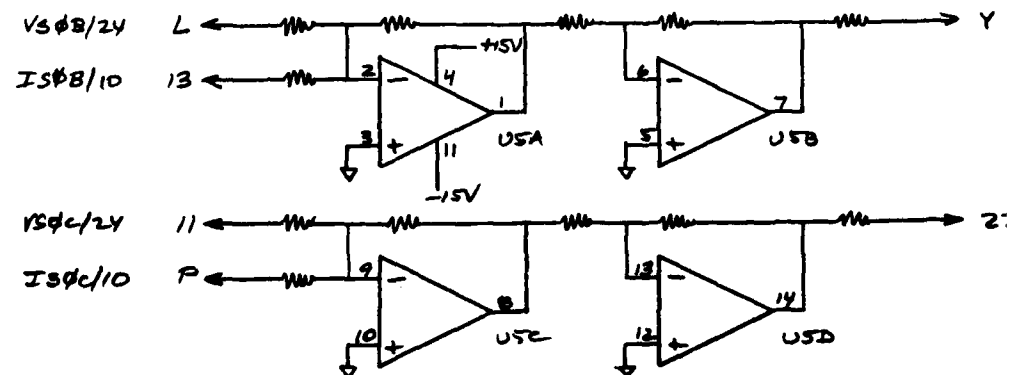
C



B



A



3 2 1

→ E REM/LOC

→ 16 R6A(RU1)

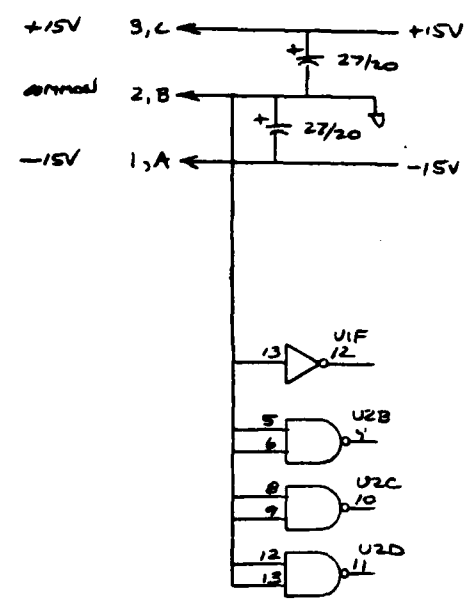
→ T R6B(RU1)

→ 17 R6C(RU1)

→ 21 R6A(RU2)

→ Y R6B(RU2)

→ 22 R6C(RU2)



U1 54C914
U2 CD4011BF
U3-U5 LM148T

REV B F-17-F2 JRL
REV A ADD SHEET 2 BDEC B1 G.H.B.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 3 PLACE 3 PLACE ANGLES DECIMALS DECIMALS + - + -		Leico Electronics ELECTRONIC COMPONENTS CORPORATION, SAN CARLOS, CALIF.	
MATERIAL REF. TO CDR. CHG. CONTROL		DISTRIBUTION UNIT REM/LOC AND REF PHASE GENERATORS A6B	
DATE 12/1/81 BY G.H.B.		P.C. NO. C 13180	ENG. NO. SK003912 B
APPROVAL FOR APPROVAL		SCALE AS SHOWN	SHEET 1 OF 2

3 2 1 M-100a

D
SD/60

M/A

400

C

S/A

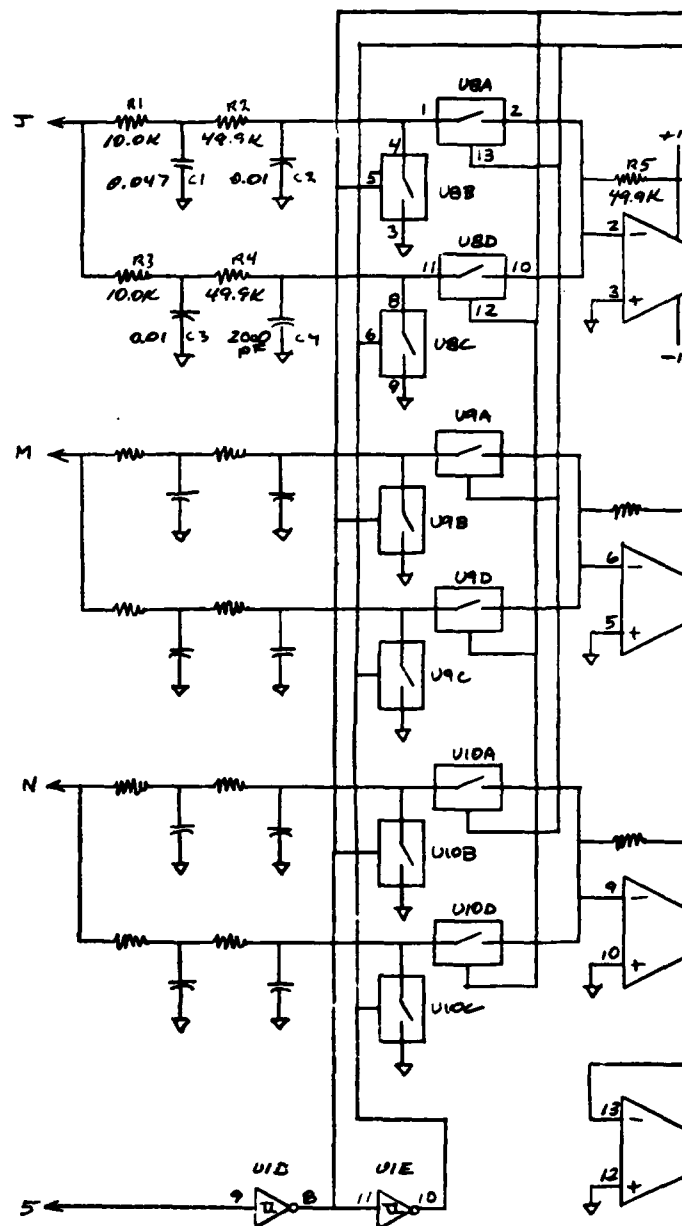
→

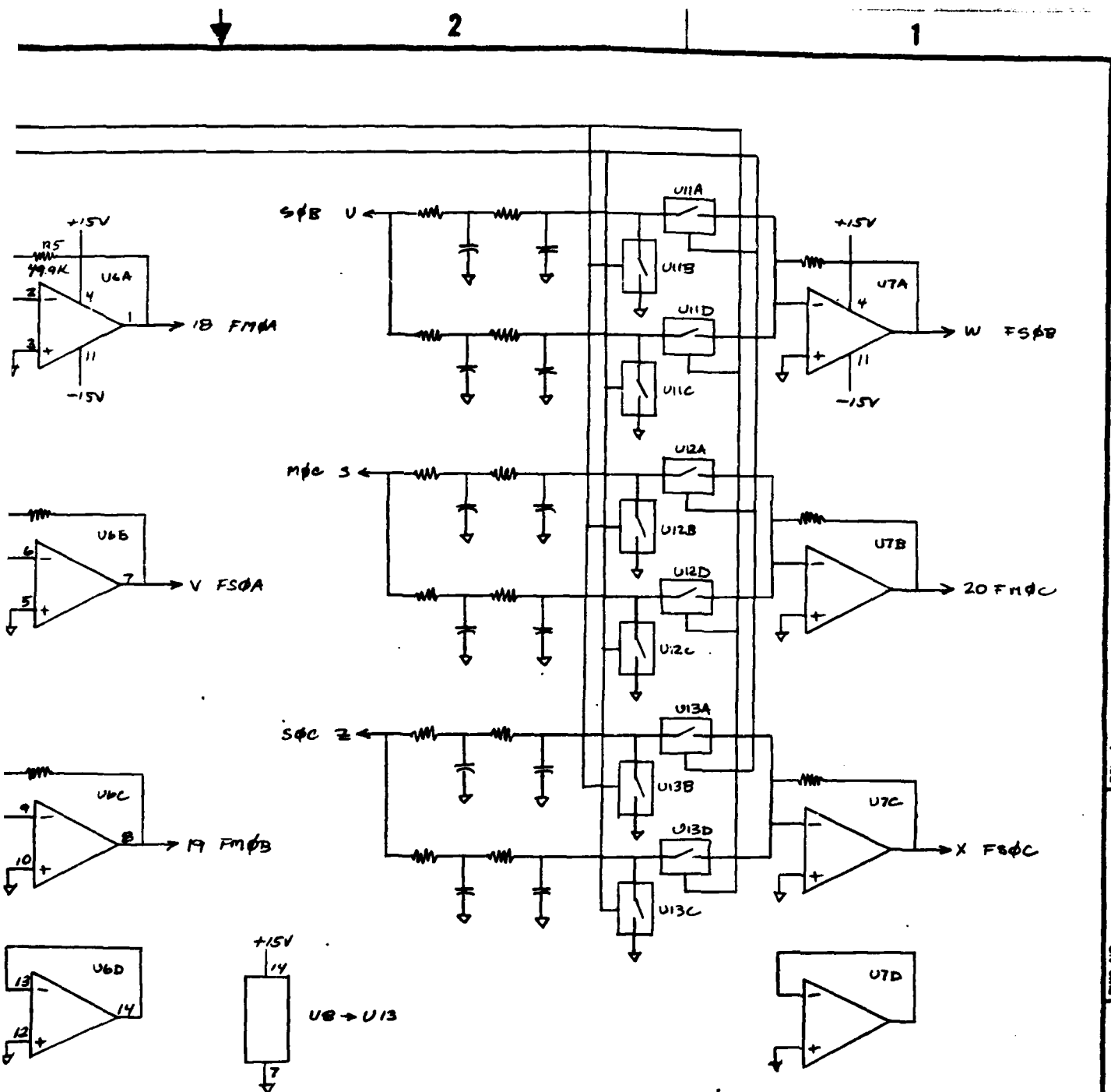
M/B

B

A

SD+60





U6, U7 LM145T
 U8 → U13 CD4066BF

ALL RESISTORS RNC55H

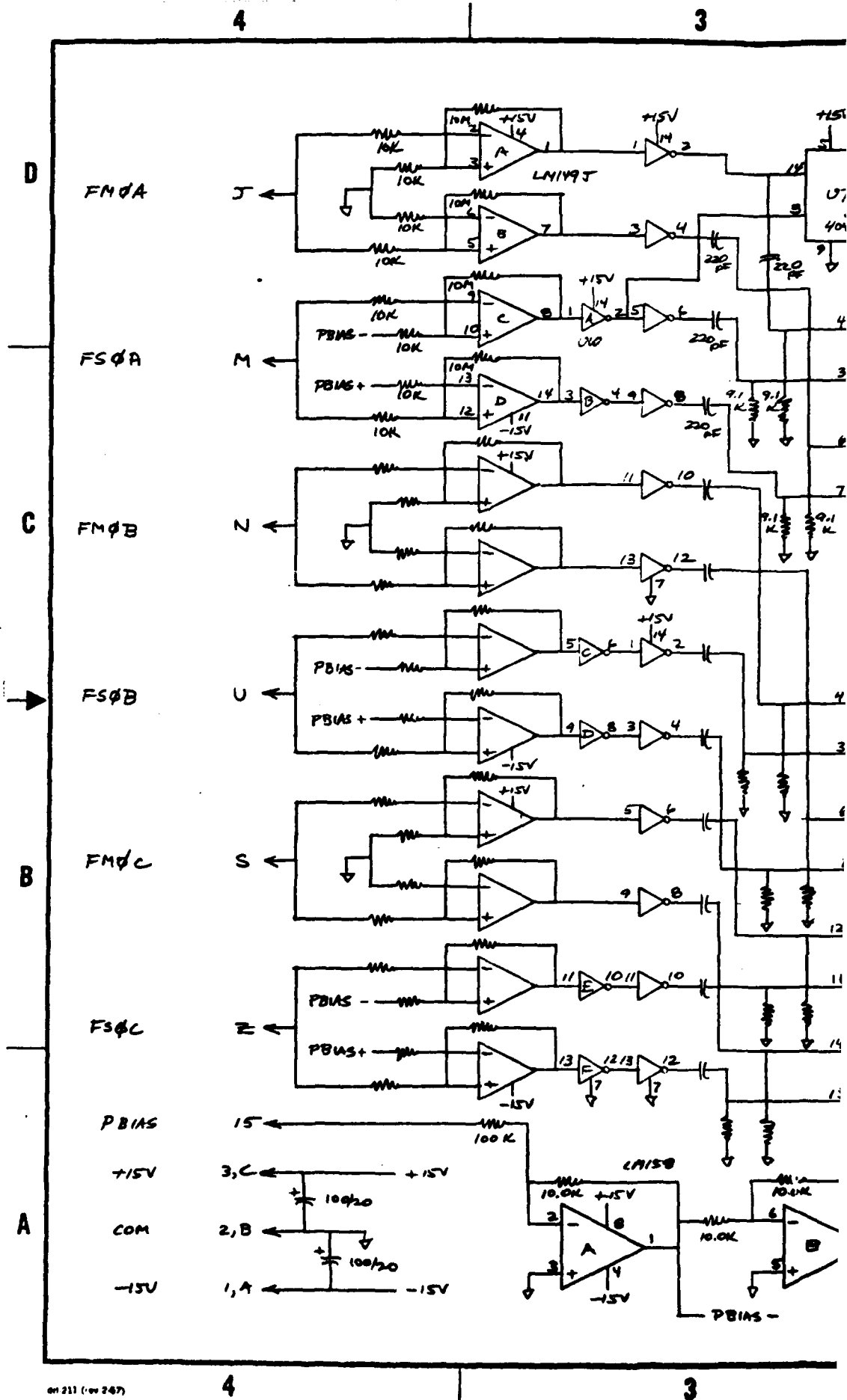
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE 3 PLACE ANGLES DECIMALS DECIMALS	C.H.B. G.D.C. C.H.B. G.D.C.	Osica Electronics			
		GENERAL MANUFACTURING CORPORATION SANTA BARBARA CALIF.			
MATERIAL	APPRO	DISTRIBUTION UNIT			
		RENYLOC, REF PHASE, & PVOCT FILTERS			
DET. AC OR. CNG. CONTROL	DET. ACT. CNG. APPD	C 13150		SK003912	
		SCALE		SHEET 2 OF 2	

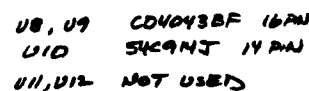
2

2

1

M-10B

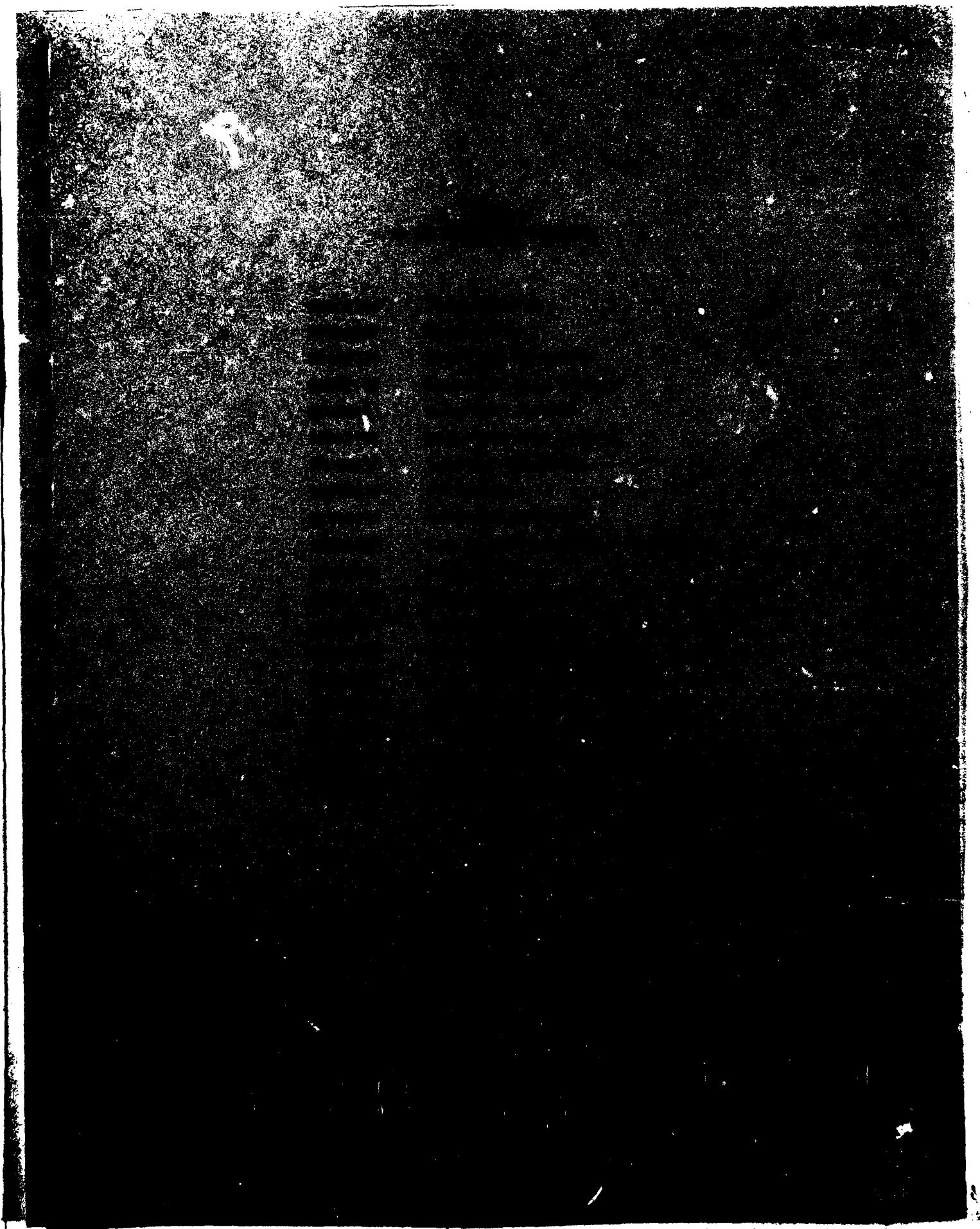




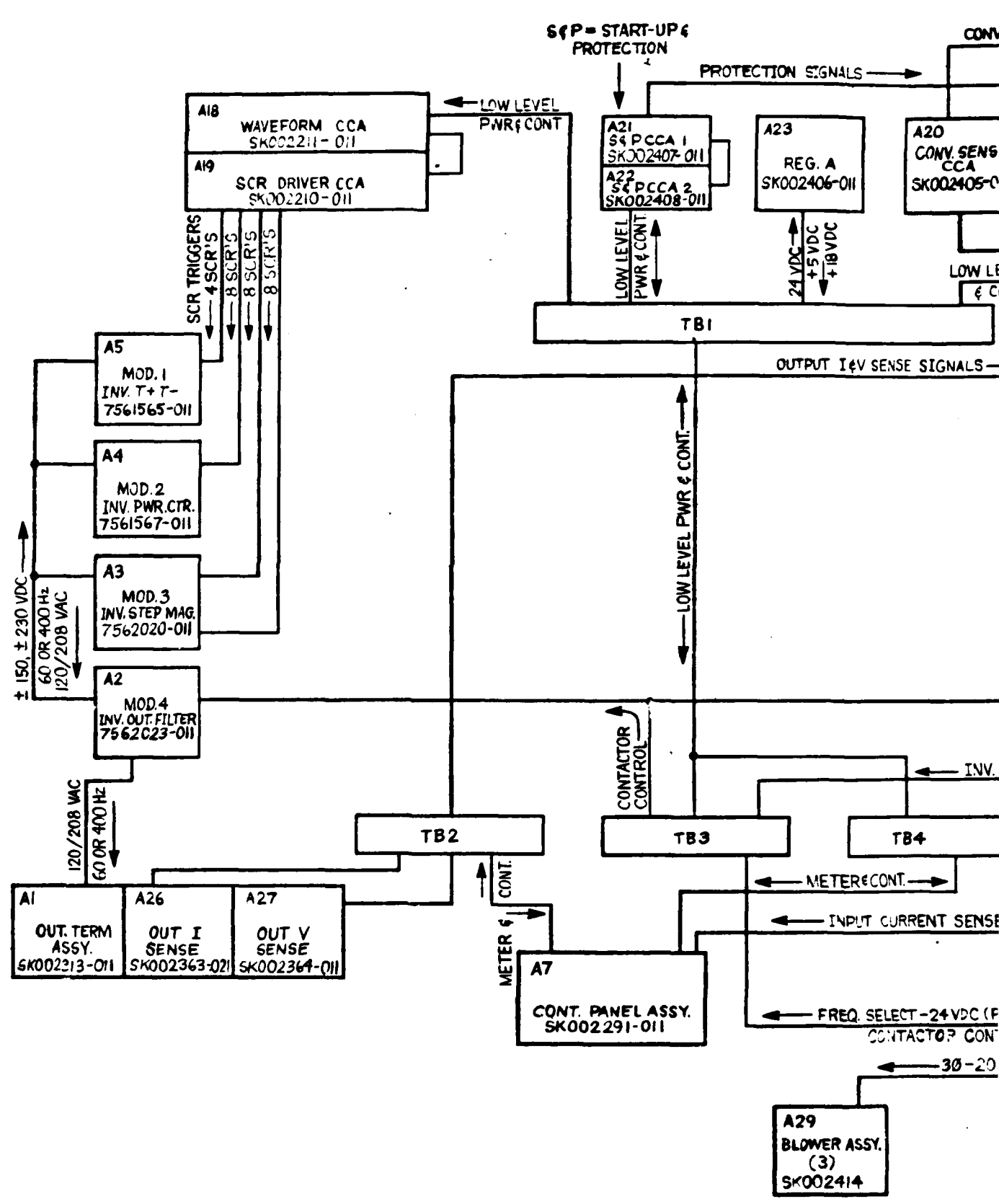
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON	CONTROL NO.	P.O. Co Electronics		
	7 PLACE DECIMALS	17-0000	GENERAL MOTORS CORPORATION CANTABRIA, CALIF.	
3 PLACE DECIMALS	17-0000	DISTRIBUTION UNIT		(A10)
MATERIAL	17-0000	PHASE ERROR COMPARATOR CCA		
REF (AC ONLY)	CHG CONTROL	SIZE	CODE	QTY
		13160	SK003913	3
		WEIGHT	SHEET	OF

A

M-11

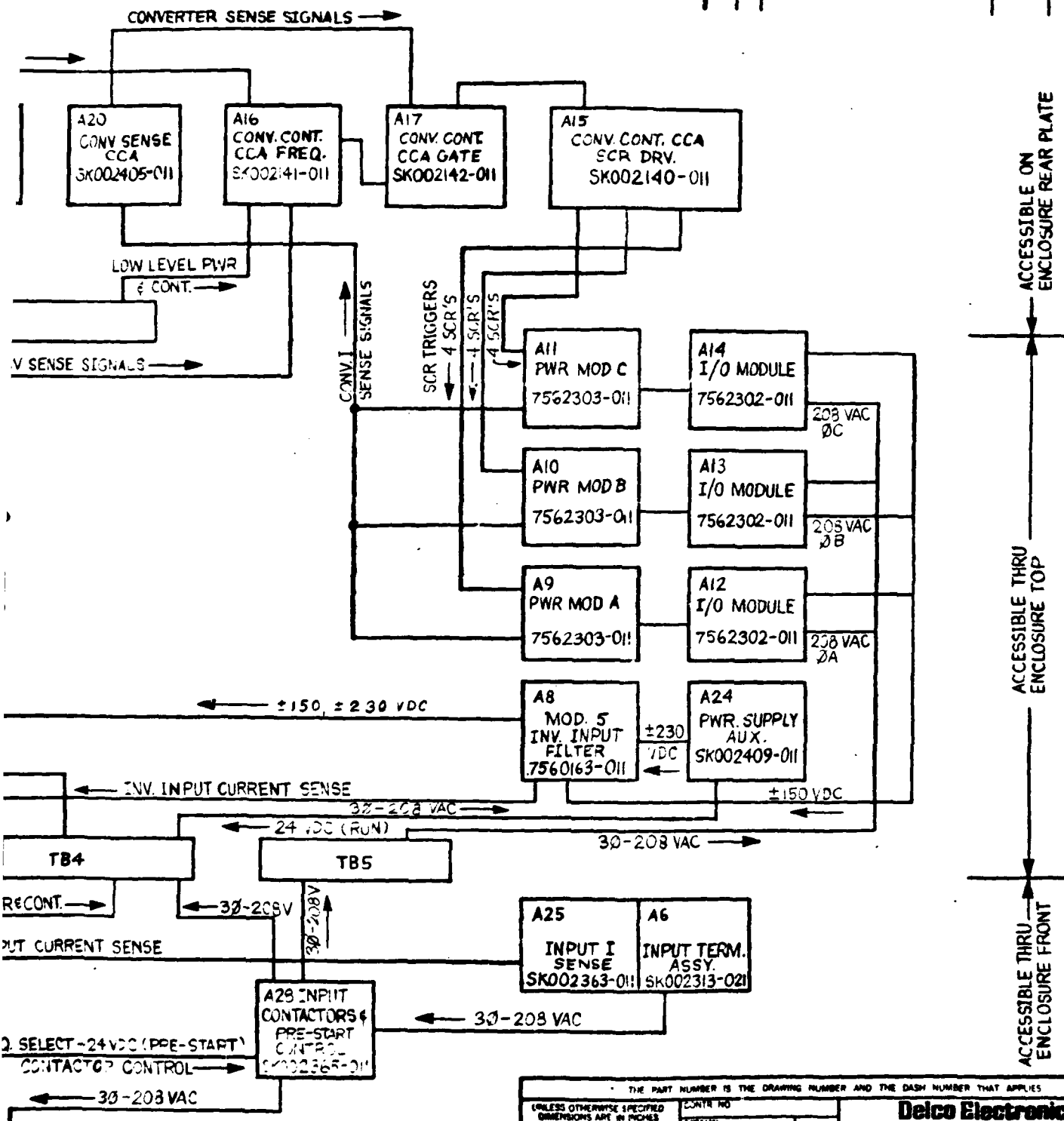


8 7 6 5



8 7 6 5

REVISIONS					
ZONE	LTR	DESCRIPTION	AUTH	DATE	APPROVED
1	A	ADDED ACYS		7-20-68	JEC



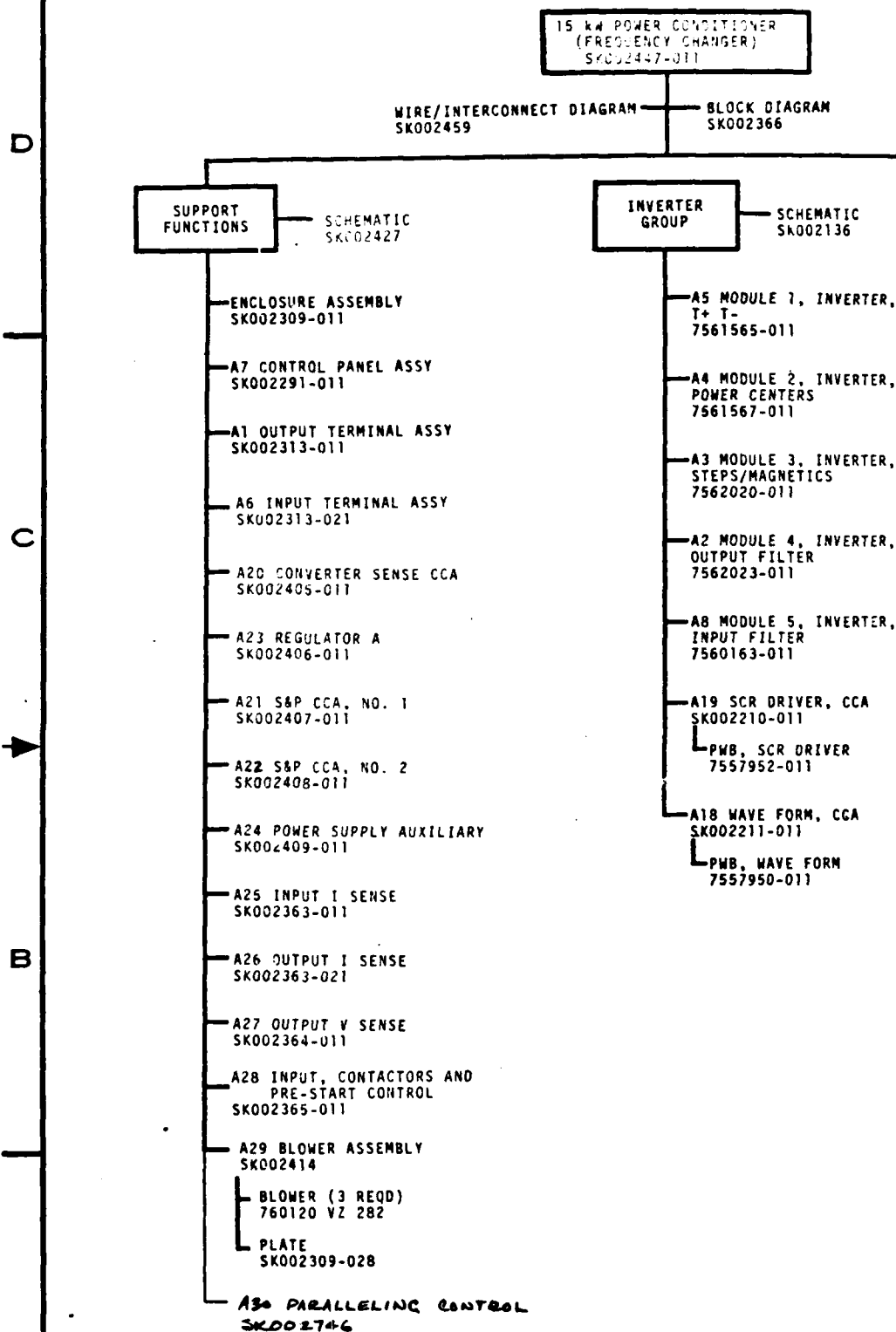
ACCESSIBLE ON ENCLOSURE REAR PLATE

ACCESSIBLE THRU ENCLOSURE TOP

ACCESSIBLE THRU ENCLOSURE FRONT

NOTE:
A30 NOT SHOWN

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES (IN)			Delco Electronics GENERAL MOTORS CORPORATION, SAN ANTONIO, TEXAS, CALIFORNIA	
2 PLACE DECIMALS	3 PLACE DECIMALS	ANGLES	BLOCK DIAGRAM, 15 KW FREQUENCY CHANGER	
MATERIAL			DATE: 7-20-68 REV: A	
REF: CHG CONTROL			PART NO: 13160 SK002366	



3

2

1

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPD
	A	CHANGED TITLE, ADDED A30	9-30-82	JRC

CONVERTER
GROUPSCHEMATIC
SK002135

A9, A10, A11
POWER MODULE
7562303-011
(3 REQD)

A12, A13, A14
I/O MODULE
7562302-011
(3 REQD)

A15 CONVERTER CONTROL CCA,
SCR DRIVER
SK002140-011

PWB, CONVERTER CONTROL,
SCR DRIVER
7558461-011

A16 CONVERTER CONTROL CCA,
FREQUENCY
SK002141-011

PWB, CONVERTER CONTROL,
FREQUENCY
7558459-011

A17 CONVERTER CONTROL CCA,
GATE
SK002142-011

PWB, CONVERTER CONT.
7558460-011

-001
DASH
NO.

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

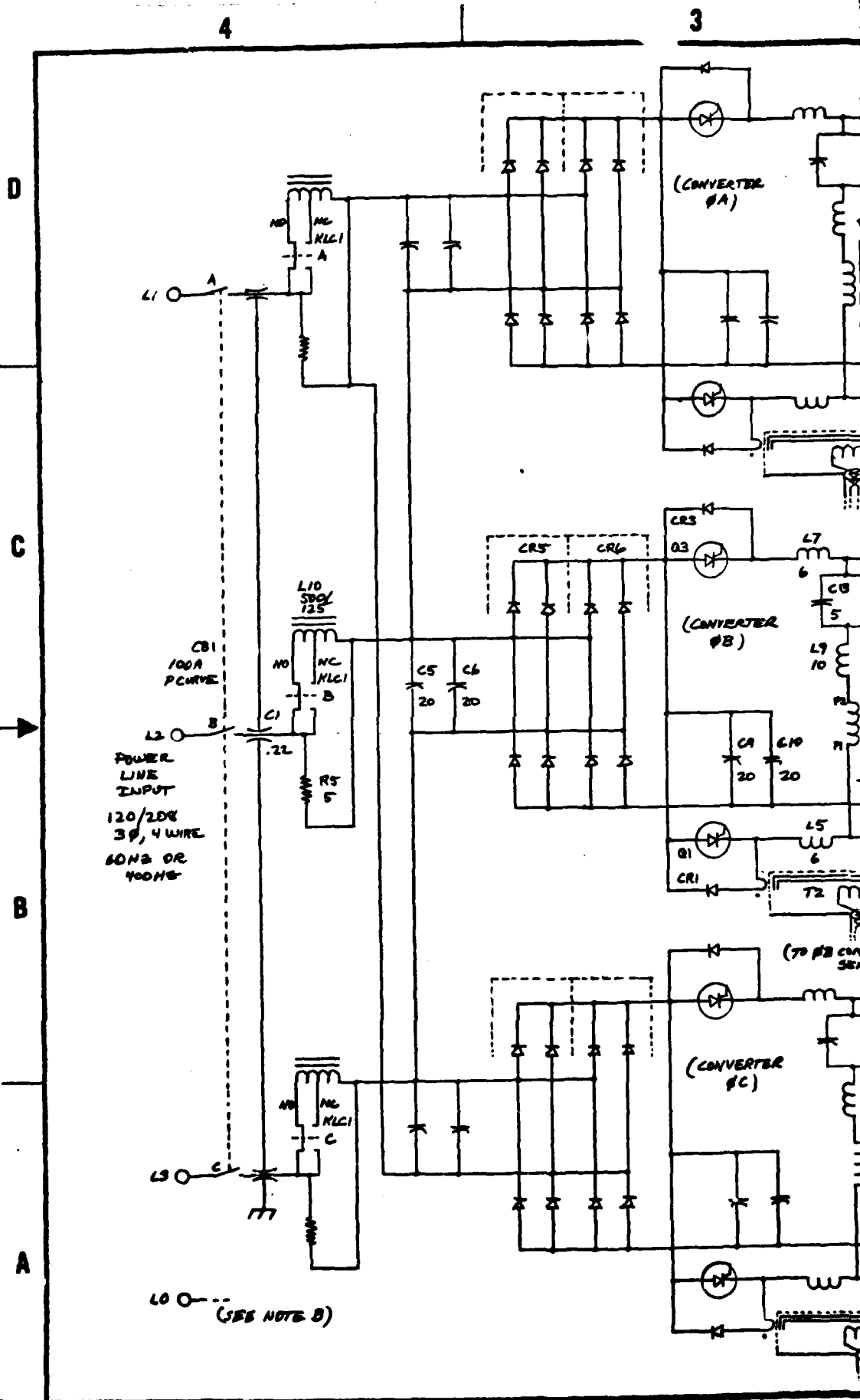
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON			CONTR. NO.		Delco Electronics			
2 PLACE DECIMALS	3 PLACE DECIMALS	ANGLES	DFTSMN /DSGR	WT.	5/7/79	GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA		
±	±	±	CHECKER	TITLE				
MATERIAL			ENGR	R. TEMPLE	5/22/79	FAMILY TREE, 15KW FREQUENCY CHANGER		
REF			APPD	SIZE				
D06			APPD	CODE IDENT NO				
CHG CONTROL			DSGN ACTIVITY APPD	DWG NO.				
OTHER APPROVAL			C 13160 SK002367 A					
SCALE			NONE					
WEIGHT			SHEET 1 OF 1					

24

2

1

N-2





Rev A G. H. Bennett 4-3-80

2	2	1	N-3

4

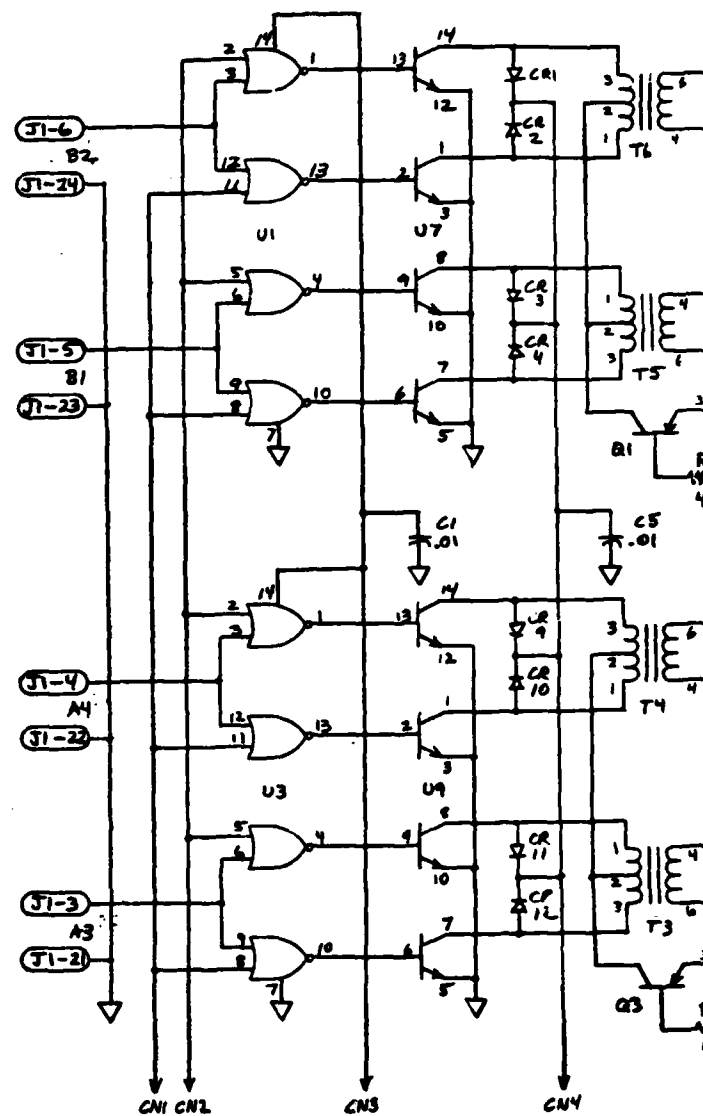
3

D

C

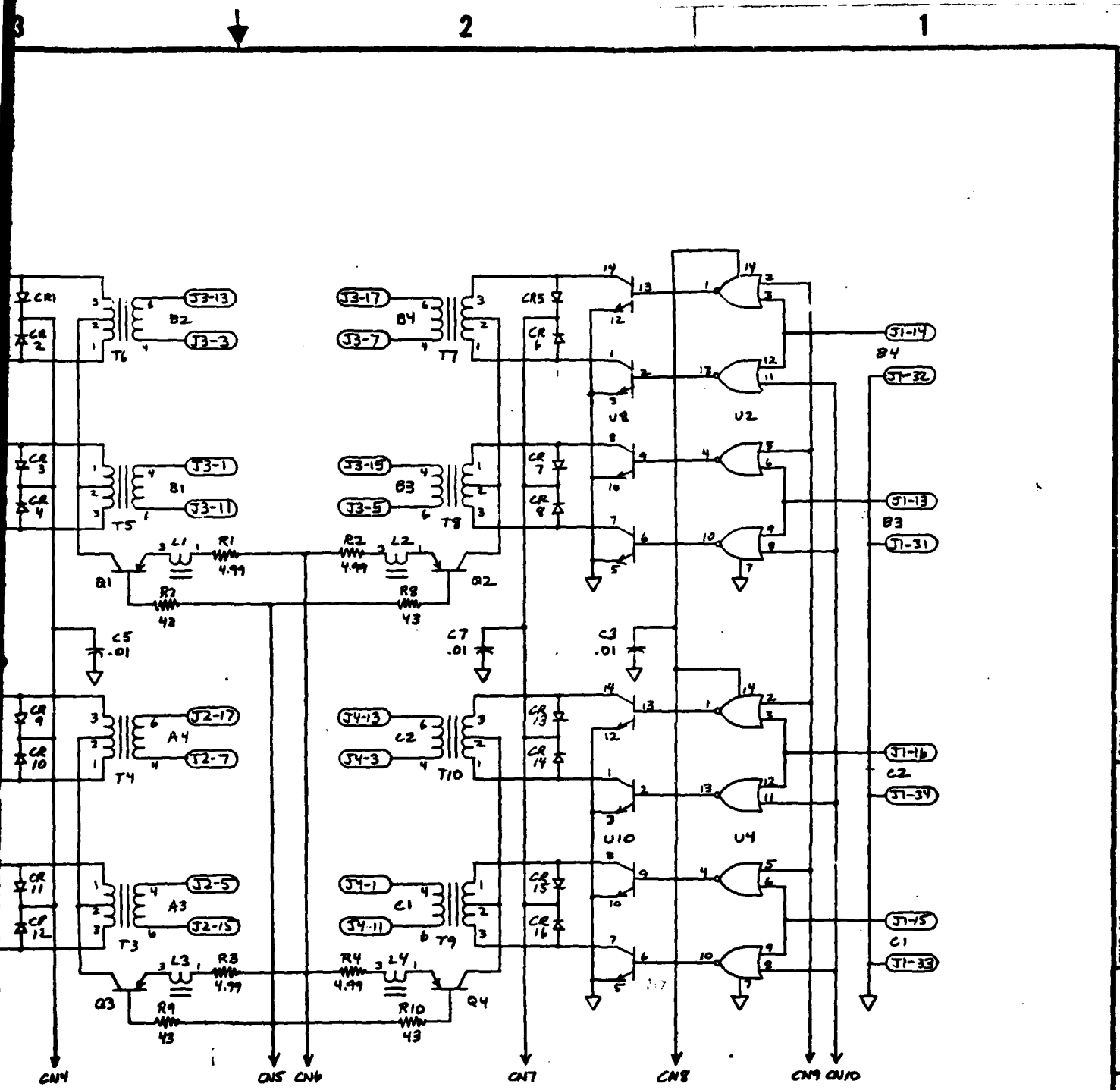
B

A



4

3

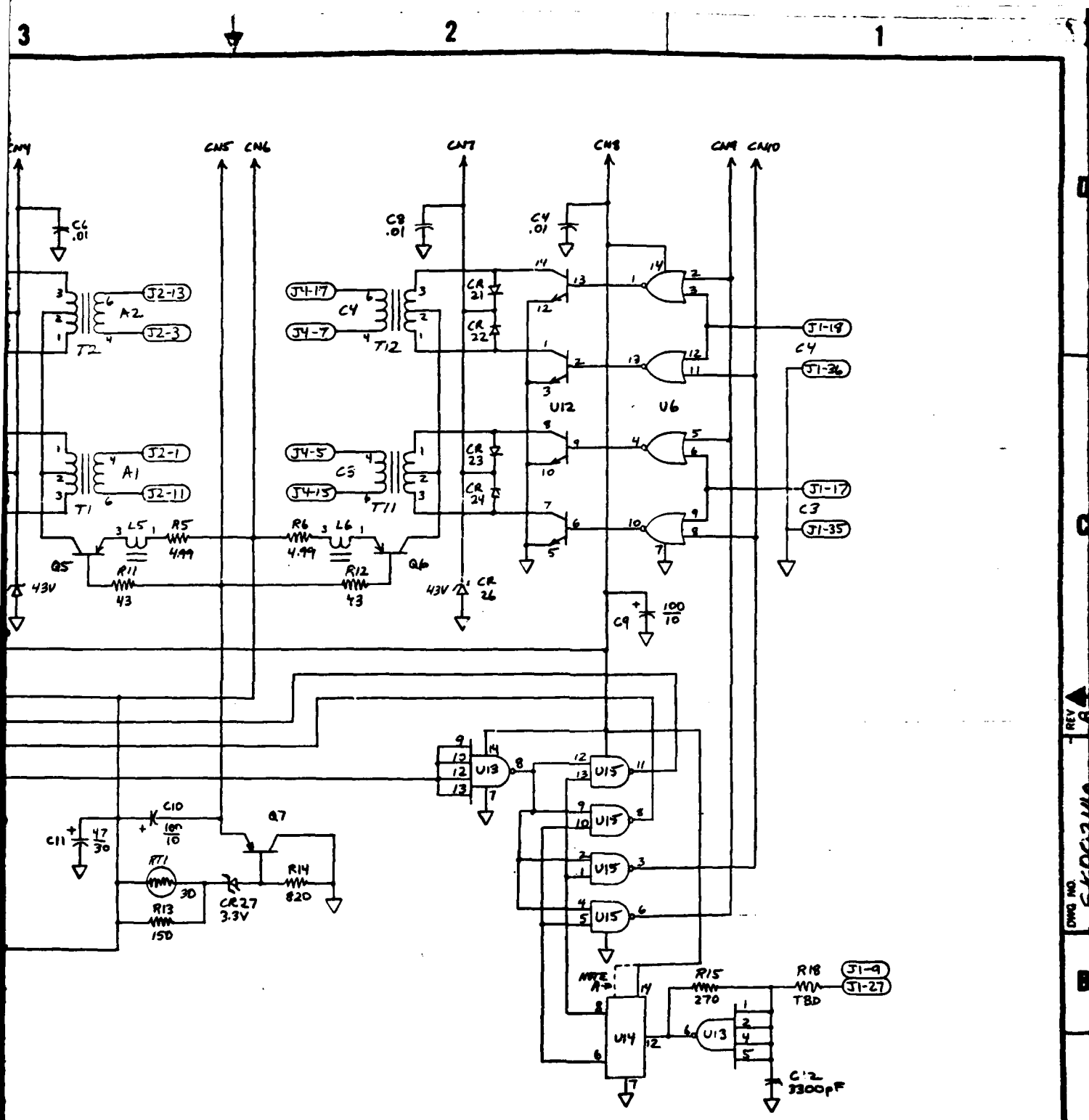


REV B 9-3-80 G.H.B.
 REV A 10/23/78 G.H.B.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 3 PLACE 3 PLACE ANGLES DECIMALS DECIMALS		Calco Electronics GENERAL MOTORS CORPORATION, SANTA BARBARA, CALIF.	
MATERIAL APPD DESGN ACTIVITY APPD OTHER APPROVAL		FILE 15kW FREQUENCY CHANGER CONVERTER GATE DRIVERS	
REF TAC-DWL CHG CONTROL		SIZE C	CODE IDENT NO. 13160
		DWG NO. SK002140	REV B
		SCALE WE GHT	

REV B
 DWG NO. SK002140

N-4a



TIE PINS 2, 3, 4, 5, 9, 10, 11 AND 13
TO PIN 14 (+5V)

Rev B 9-3-80 C.H.B.
Rev A 10/23/79 C.H.B.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 3 PLACE DECIMALS ANGLES 3 PLACE DECIMALS		C.H.B. 3/15/78		C.H.B. 3/15/78		C.H.B. 3/15/78	
MATERIAL		APPROVED		CODE IDENT NO		DATE	
REF (AC OR DC) CHG CONTROL		OTHER APPROVAL		C 13160		SK002140	
				SCALE		TYPIC	

REV A
SK002140

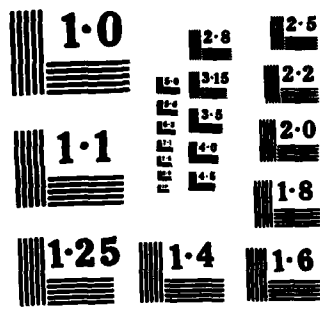
UNCLASIFIED

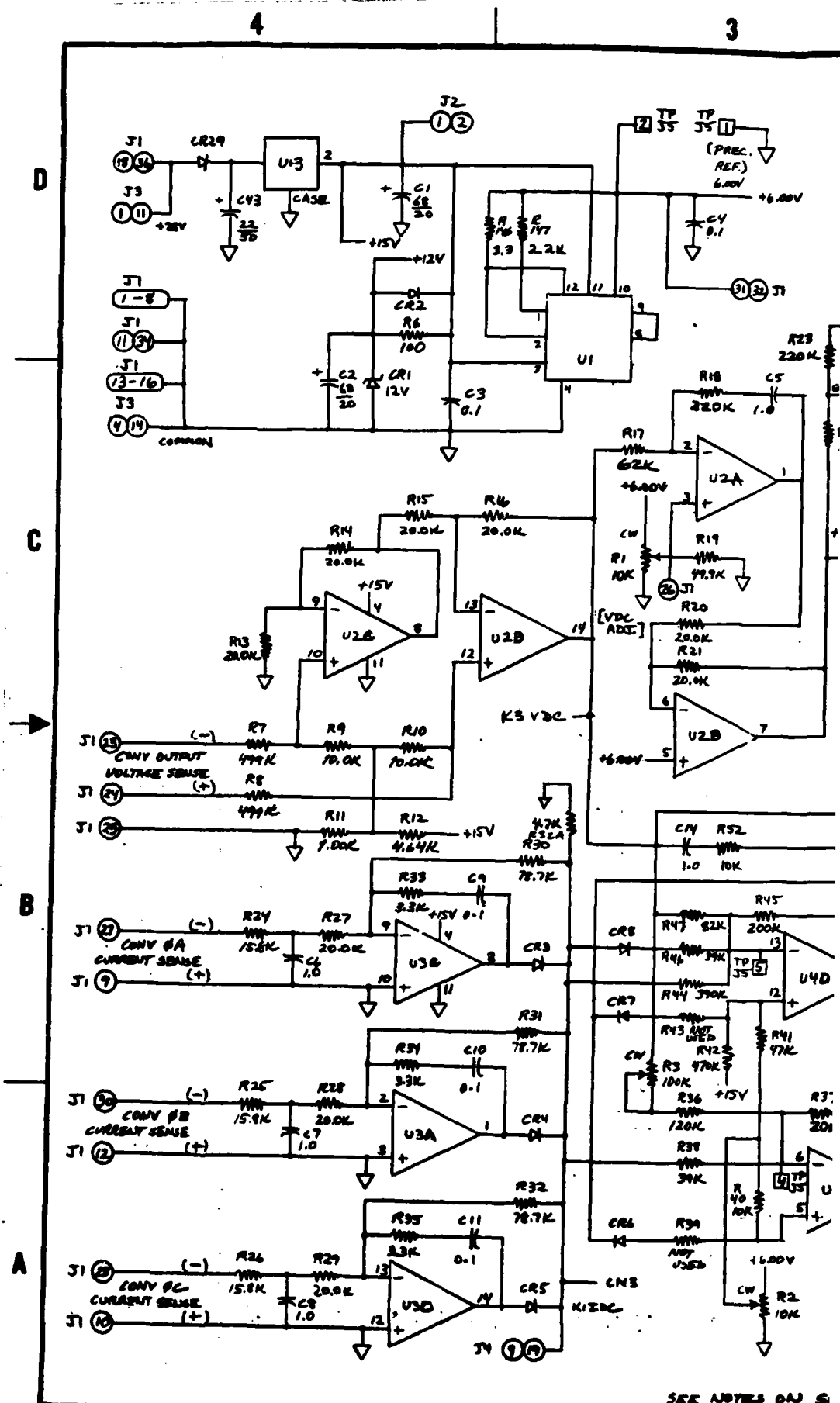
4/4.

F/G 10/2

NI

END
DATE
FILED
10 84

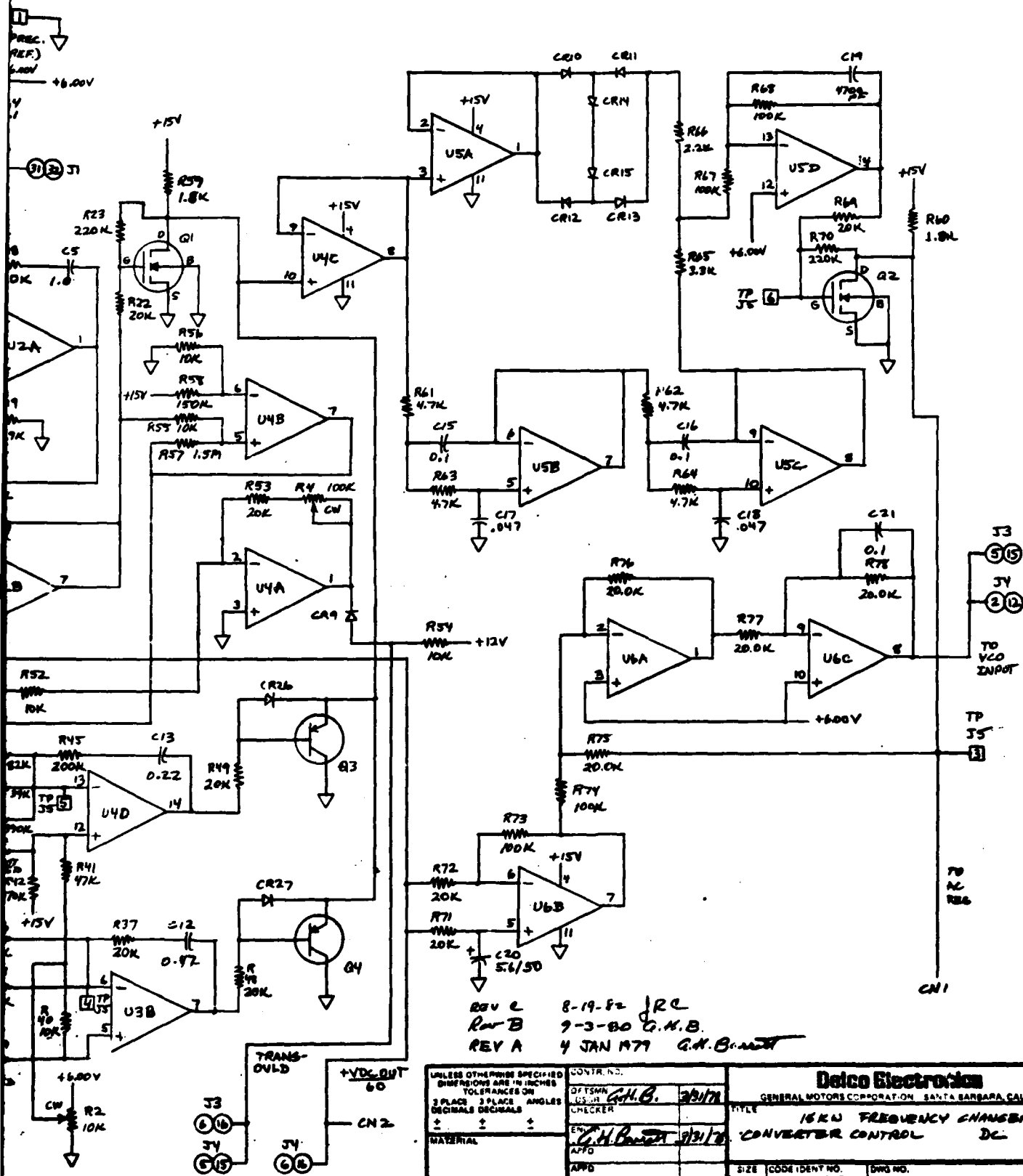




3

2

1



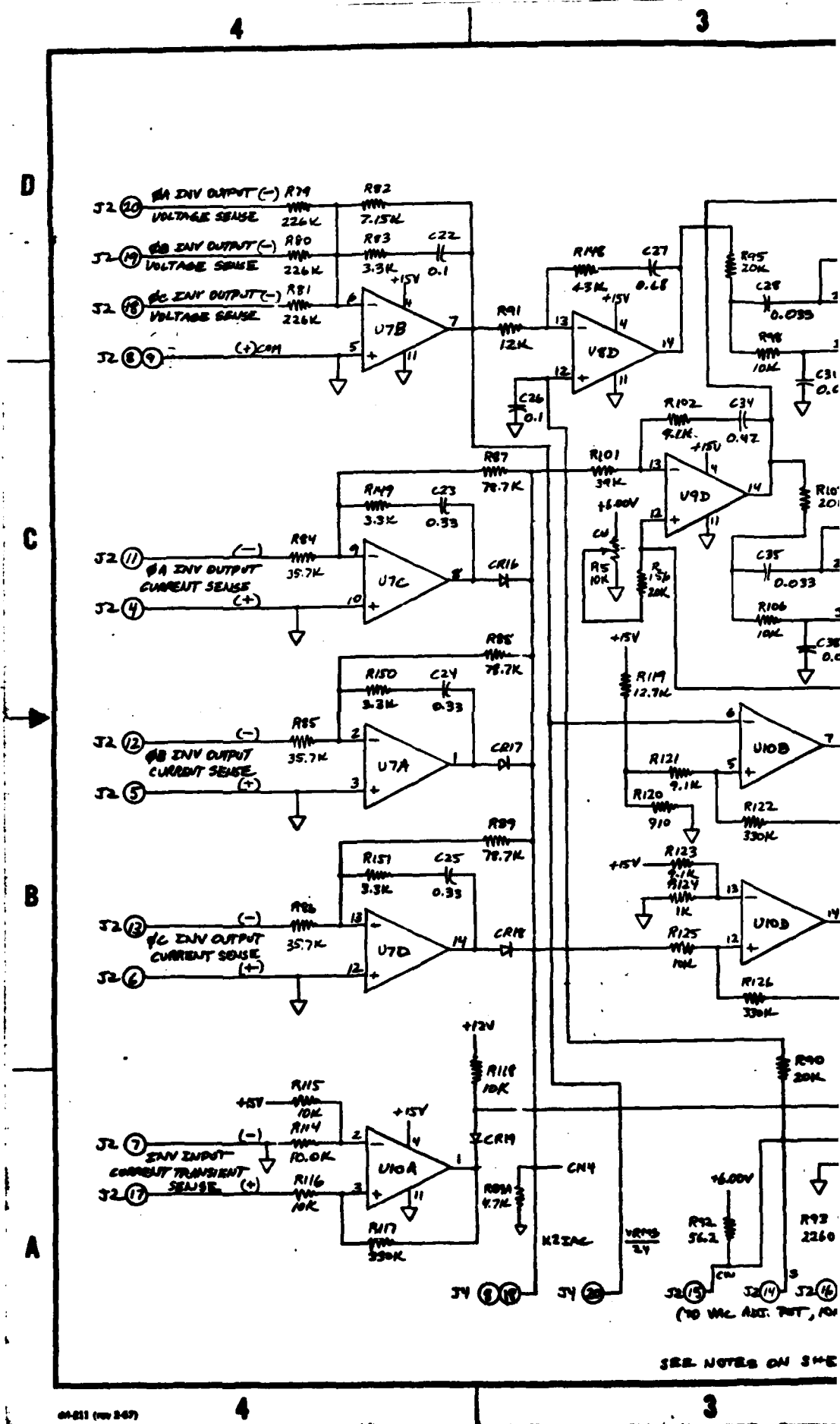
UNLESS OTHERWISE SPECIFIED
 DIMENSIONS ARE IN INCHES
 TOLERANCES ON
 3 PLACES 3 PLACES ANGLES
 DECIMALS DECIMALS
 ± ± ±
 MATERIAL
 REF (AC) CONTROL

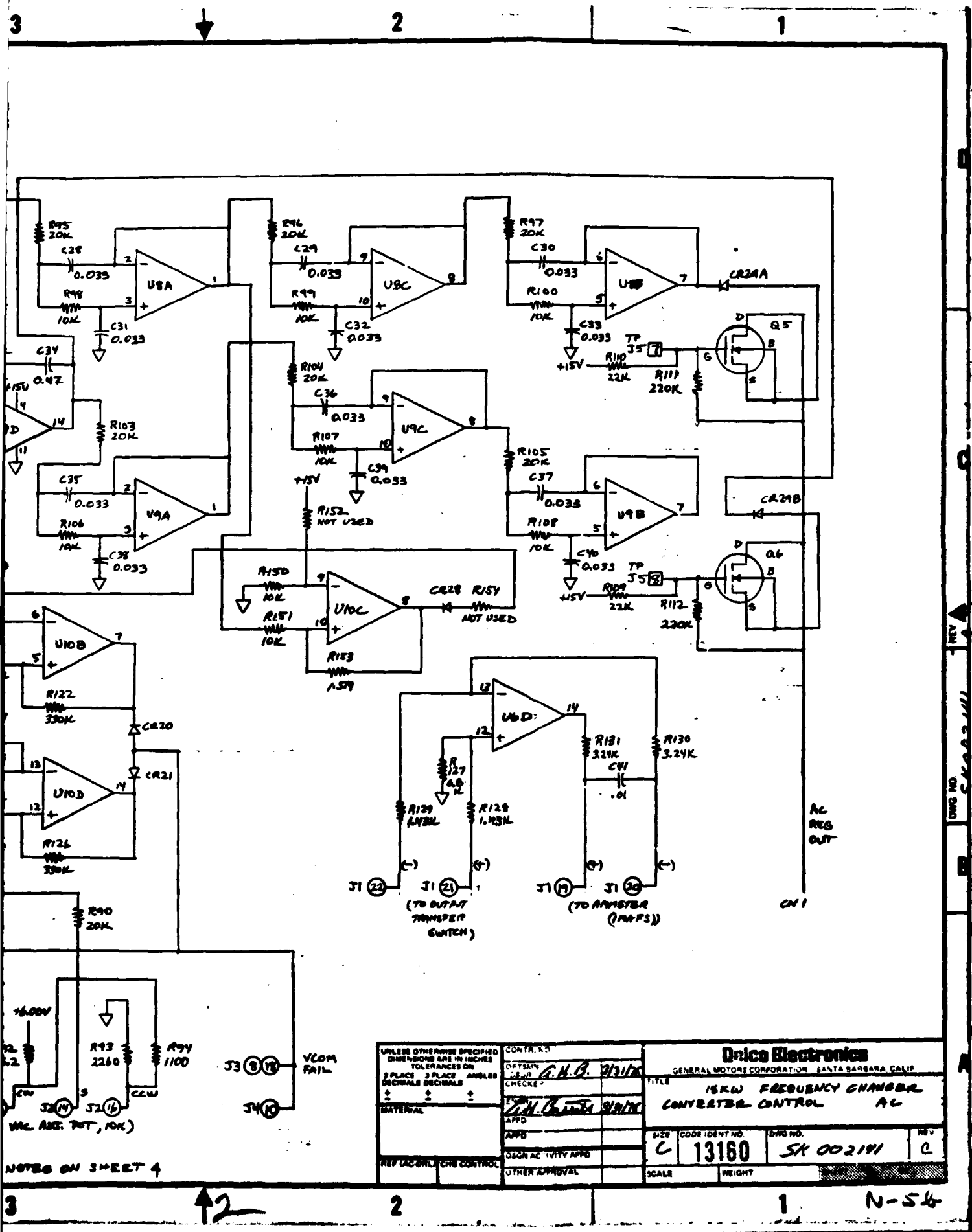
CONTR. NO.
 OF TSMN
 CHECKER
 ENGR
 APPD
 USN ACT JTY APPD
 OTHER APPROVAL

Delco Electronics
 GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF.
 TITLE
 15KW FREQUENCY CONVERTER
 CONVERTER CONTROL DC
 SIZE CODE IDENT NO. DWG NO. REV
 C 13160 SK 002141 C
 SCALE WEIGHT

NOTES ON SHEET 4

N-5a



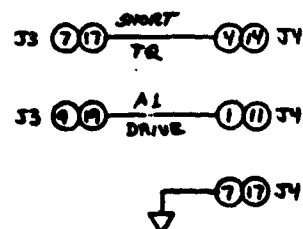
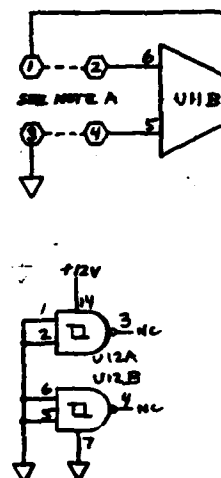


NOTES ON SHEET 4

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 3 PLACE 3 PLACE ANGLES DECIMALS DECIMALS			CONTRACT NO. DATE SHIP CHECKED BY		Unico Electronics GENERAL MOTORS CORPORATION SANTA BARBARA CALIF. 15KW FREQUENCY CHANGER CONVERTER CONTROL AC			
MATERIAL			APPD		SIZE	CODE IDENT NO.	DWG NO.	REV
REF (AC ONLY) CHG CONTROL			OTHER APPROVAL		C	13160	SK 002141	C
					SCALE	WEIGHT		

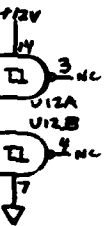
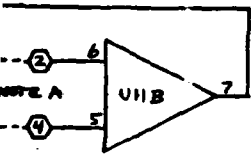
REV NO. 1
DWG NO. SK 002141

N-56



NOTE C: COMPAN
CI-CB
CR1-4
RI-R
RI-Q
UI-UI

NOTE B: JS IS
NOTE A: INSR
E1 AN
E3 AN



NOTE C: COMPONENT DESIGNATIONS ARE:
 CI-C84
 CR1-CR24
 RI-R156 (EXCEPT RI13, RI55)
 RI-07
 UI-U13

NOTE B: JS IS A TEST POINT CONNECTOR
 NOTE A: INSTALL JUMPERS BETWEEN
 E1 AND E2 AND BETWEEN
 E3 AND E4

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON		CONTR. NO.		DATE		REV	
2 PLACE	3 PLACE	ANGLES	DESIGN	BY	DATE	BY	DATE
DECIMALS	DECIMALS	ANGLES	CHECKER				
±	±	±	BY				
MATERIAL			APPD				
REF. DESIG. ONE CONTROL			DESIGN ACTIVITY APPD				
OTHER APPROVAL			SCALE	WEIGHT			
Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF.				TITLE 15KW FREQUENCY CHANGER CONVERTER CONTROL AC			
SIZE		CODE IDENT NO.		DWG NO.		REV	
C		13160		SK 002141		C	

REV 1
 DWG NO. 13160

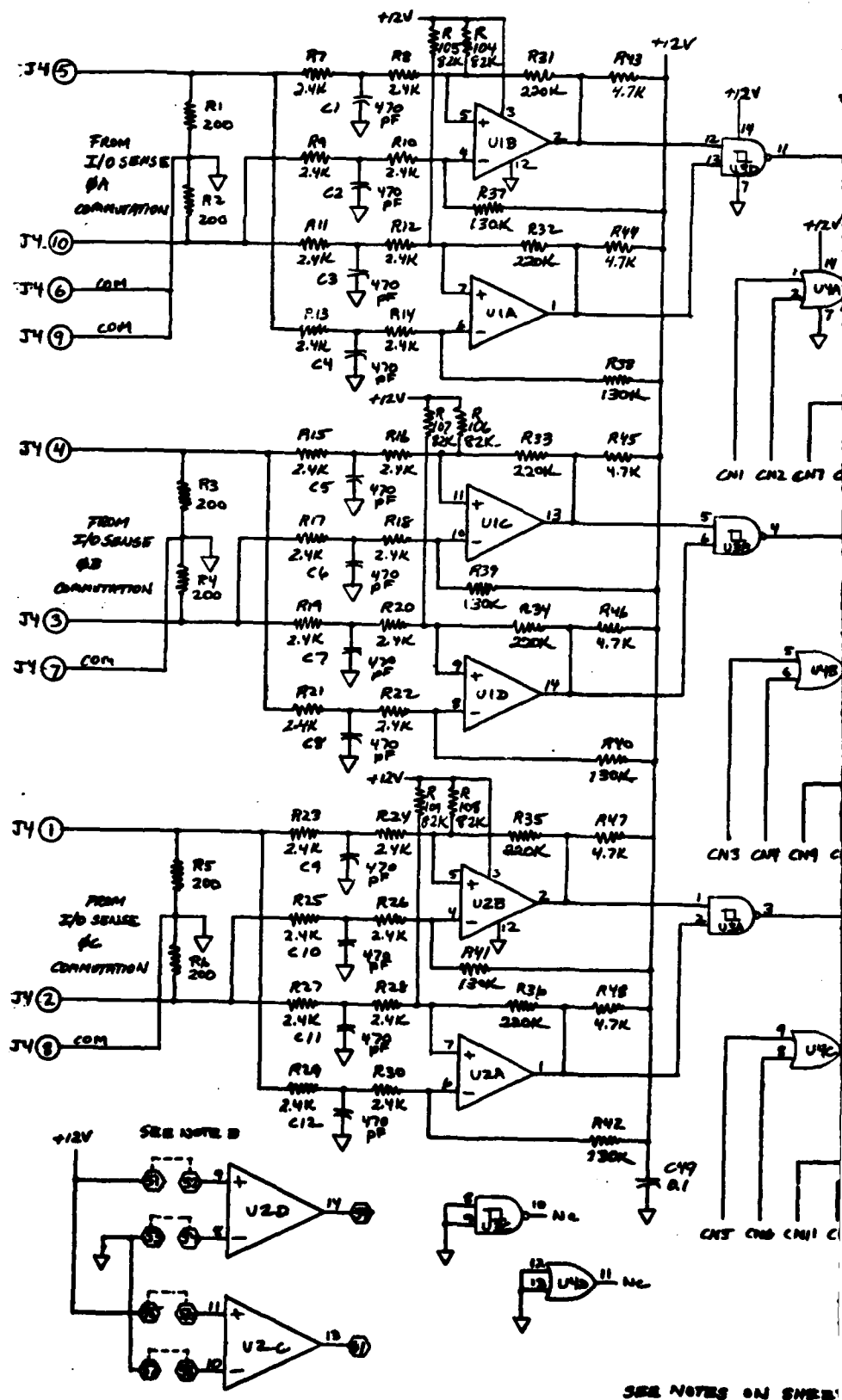
N-5C

D

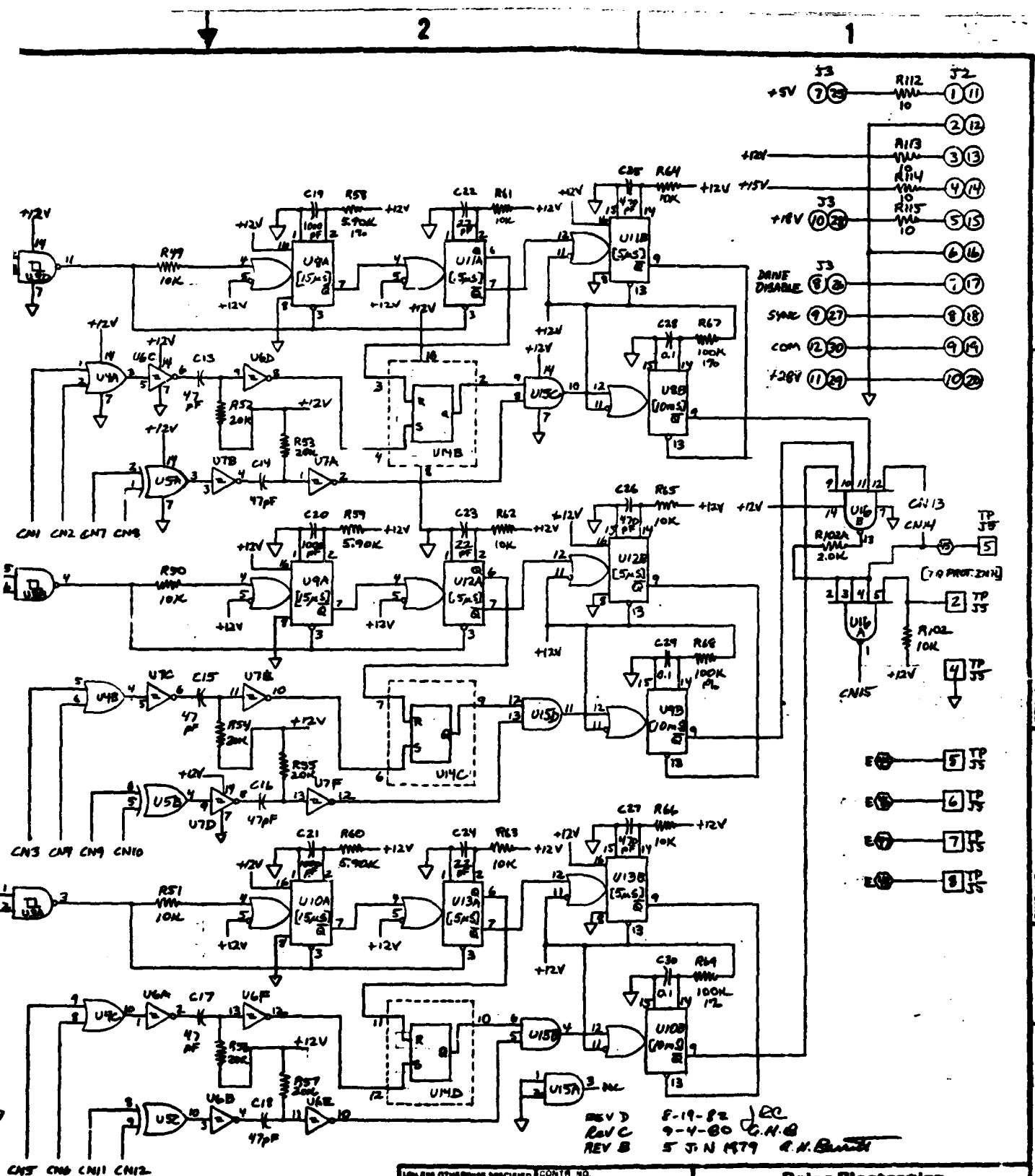
C

B

A



SEE NOTES ON SHEET



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 3 PLACE 3 PLACE ANGLES DECIMALS DECIMALS		CONTR. NO. JF7SV C553 UNSPEC	DATE 3/2/79	Dolco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA CALIF.	
MATERIAL		APPROV. J.E. R. R. 3/2/79		TYPE 15KW FREQUENCY CHANGER CONVERTER GATE CONTROL (TQ PROT.)	
NET (AC-BALANCE) CONTROL		APPROV.		SIZE C	CODE IDENT. NO. 13160
		OTHER APPROVAL		DWG. NO. SK002142	REV D
				SCALE	WEIGHT

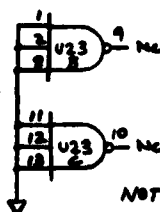
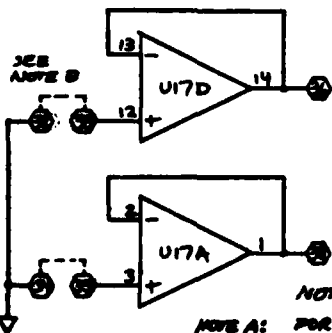
NOTES ON SHEET 3

↑ 2

2

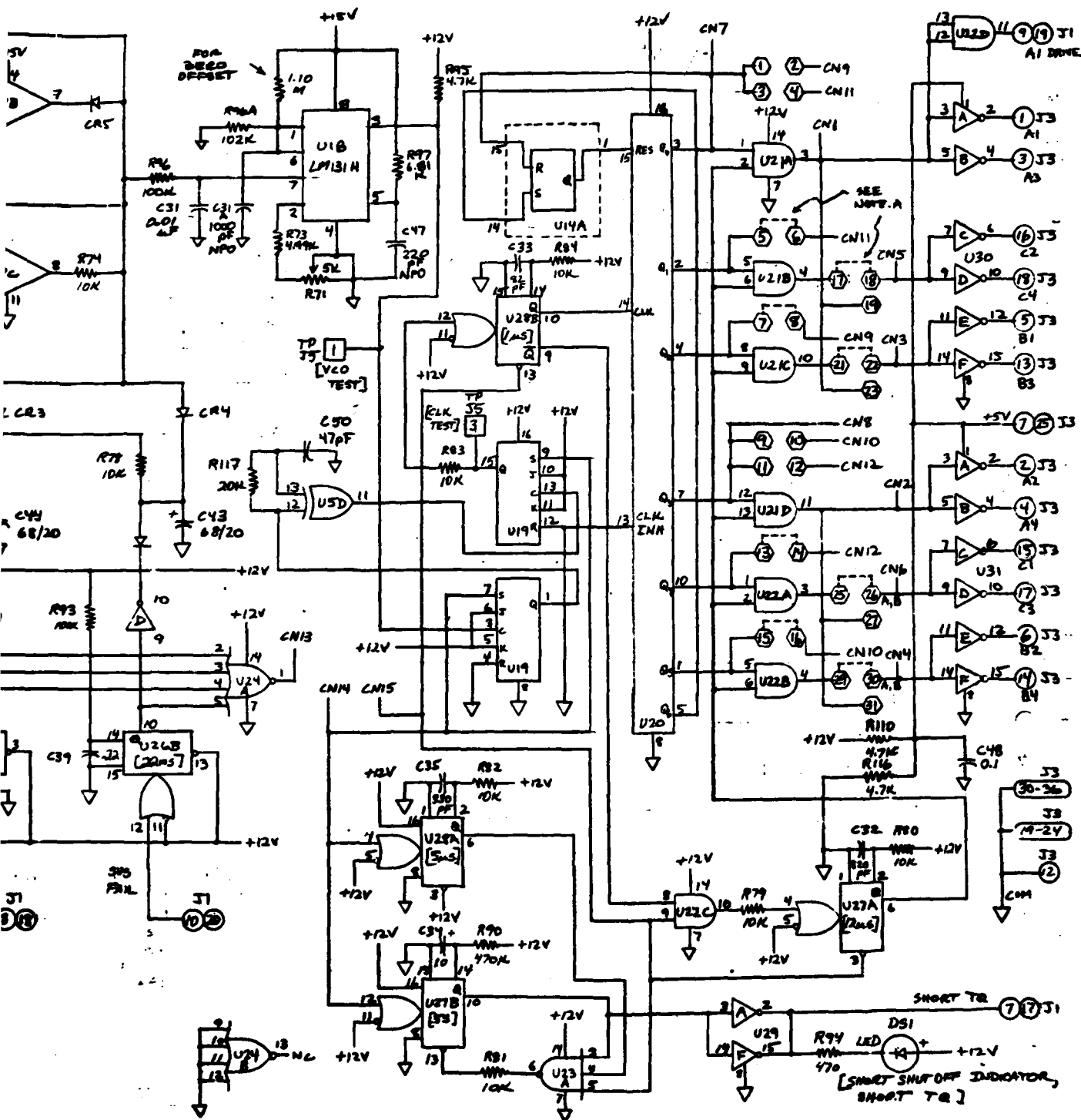
1

N-6a



NOTE: INSTALL JUMPERS AS INDICATED WITH DASH

NOTE A: FOR NORMAL MODE (STAGED FIRING) OPERATION, INSTALL AS SHOWN WITH DASHED LINES (IE, E5 TO E6, E7 TO E8, E1 MODE (SIMULTANEOUS FIRING) OPERATION, DELETE NORMAL THE FOLLOWING JUMPER: E1 TO E2, E3 TO E4, E9 TO E22 TO E23, E26 TO E27, E30 TO E31.



COMPONENT DESIGNATIONS ARE:

R1-R17, U1-U31, DS1

INDICATED WITH DASHED LINES.

OPERATION, INSTALL JUMPERS BETWEEN E POINTS TO 56, 57 TO 53, 513 TO 514, ETC.). FOR ALTERNATE IN, DELETE NORMAL MODE JUMPERS AND ADD 1, 53 TO 54, 59 TO 510, 511 TO 512, 515 TO 519, 5231.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCE: 10% 3 PLACE 3 ANGLES DECIMALS DECIMALS		CONTR. NO. UPTOWN CHECKER DATE MATERIAL REF. FAC. ONLY CNS CONTROL		Deico Electronics GENERAL MOTORS CORPORATION - SANTA BARBARA, CALIF. TITLE 15KW FREQUENCY CHANGER VCO AND CONV GATE CONTROL	
APPROV. U234 ACTIVITY APPD. OTHER APPROVAL		SIZE C		CODE IDENT NO. 13160	DWG NO. SK 002142
SCALE		WEIGHT		REV D	

REV. NO. 01/00012

N-6.B

4

3

D

C

B

A

COMMON
DC

500
L200

+AUX LINE

+ LINE

24
L201
C201, C203, ... C211 (150 aa) 900

60
C1
CR9
R3
4.99
C13
3

C202, C204, ... C212 (150 aa) 900

HL101A

- LINE

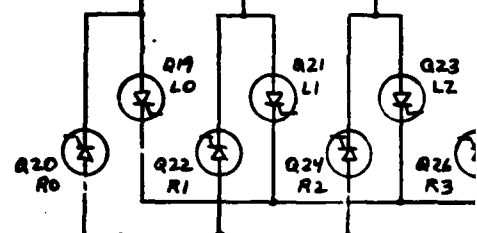
24
L202

125
C3
125
C5
R1
1K
C11
4.99
1N583
CR10
C14
4.99
L15
5

- AUX LINE

60
C2

INTERNAL ODM

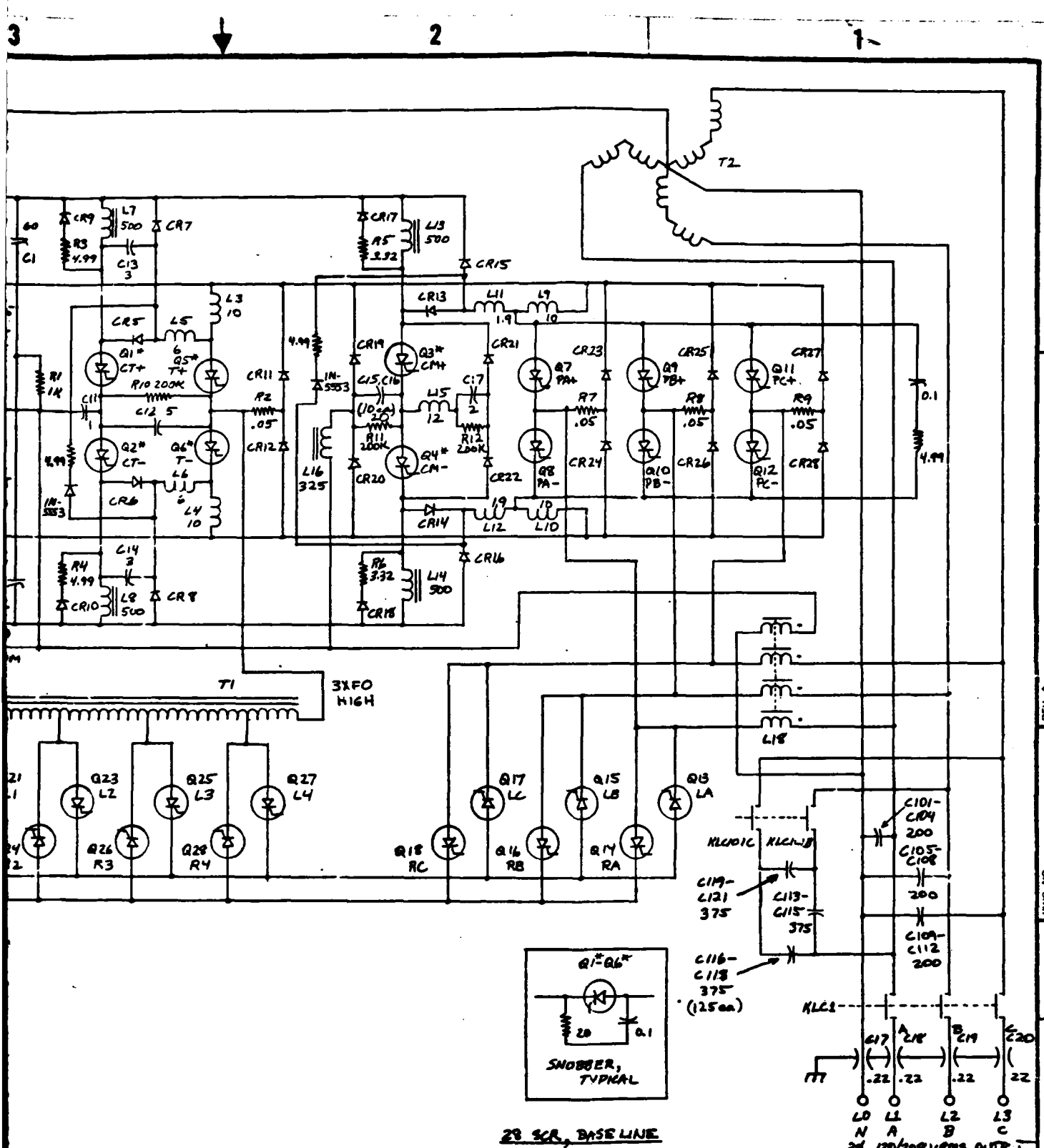


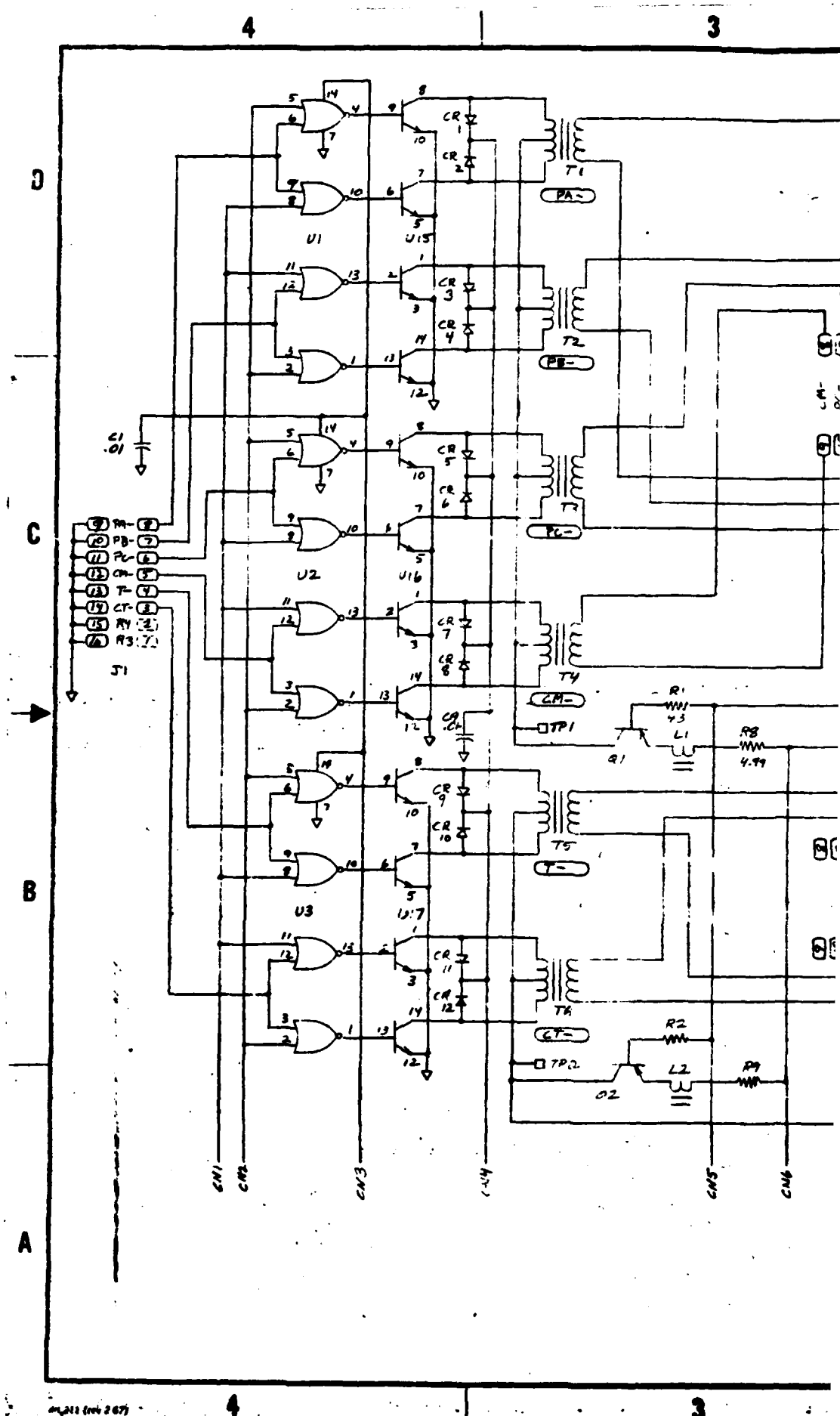
Rev

NOTE
NOTE
NOTE
NOTE

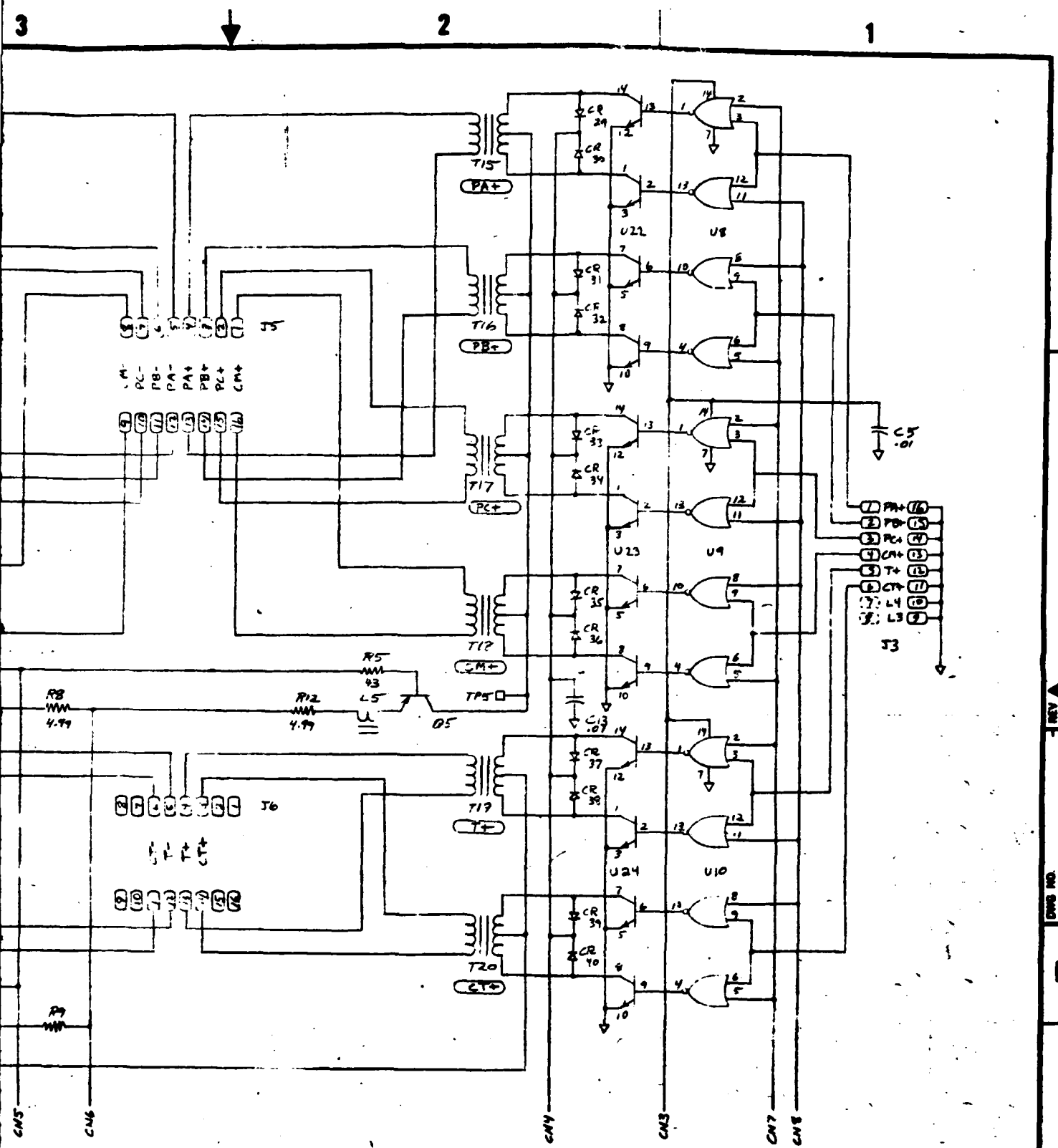
4

3





10-211 (Rev. 2-67)



Rev B 04 Bussitt 9-3-80

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 3 PLACES 3 PLACES ANGLES DECIMALS DECIMALS		DATE 11/29/75 DESIGN L.H.B. CHECKER		DATE 11/29/75 APPD	
MATERIAL		OTHER MATERIAL		SCALE	
REVISION		DESCRIPTION		WEIGHT	
13160		SK002210		5	

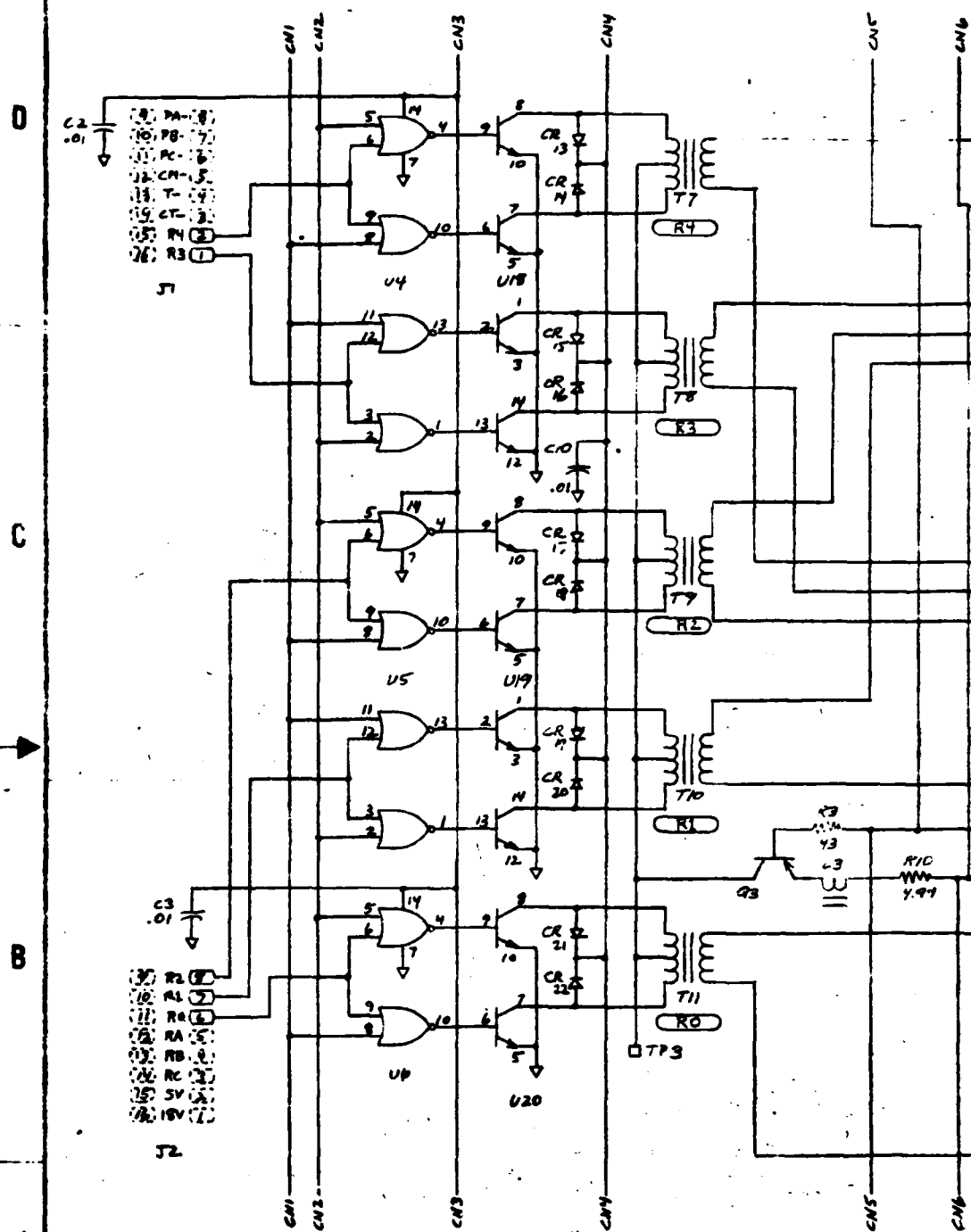
Dalco Electronics

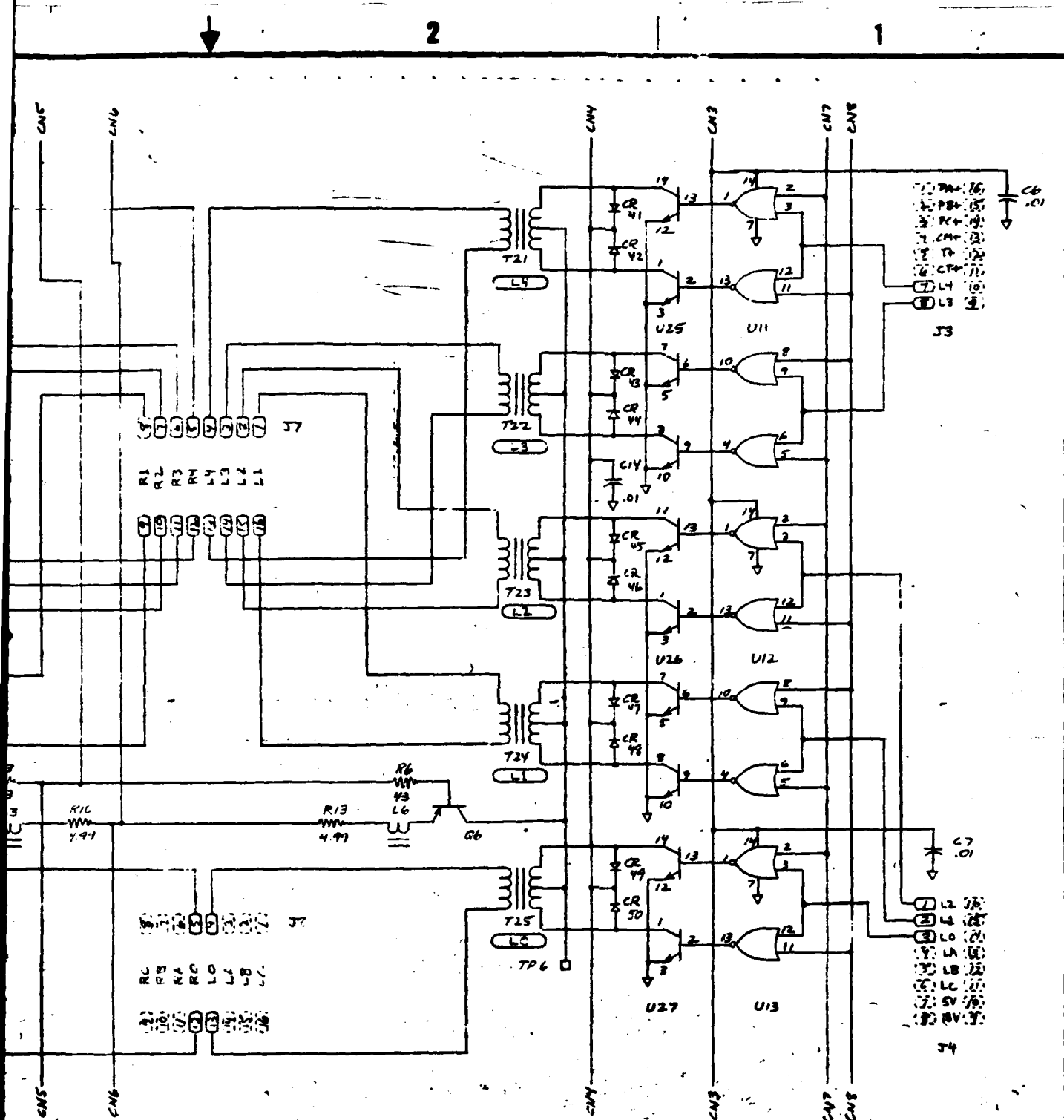
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF.

SCR DRIVER SCHEMATIC

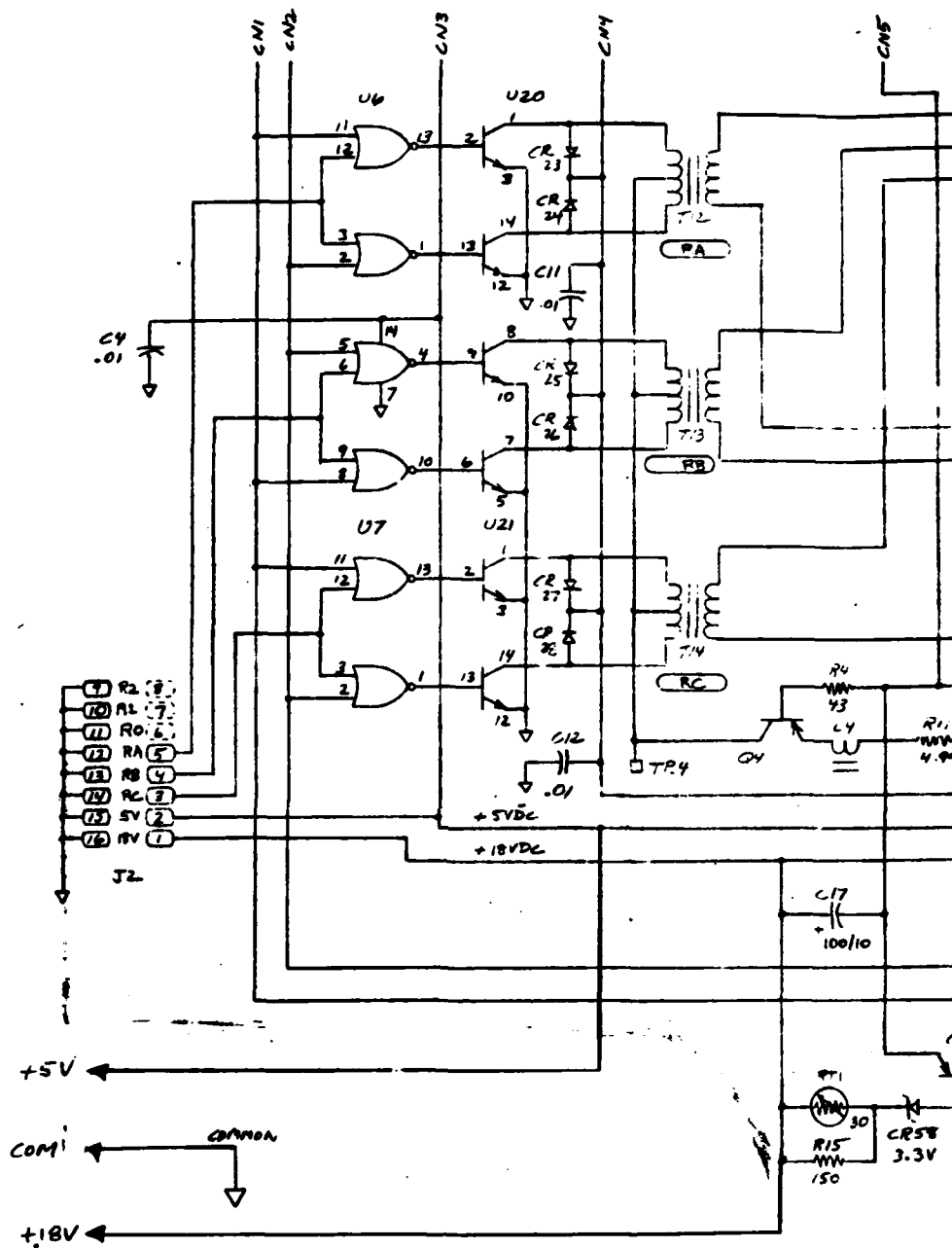
SIZE C IDENT NO 13160 Dwg No SK002210 REV 5

N-8A





UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON DIMENSIONS ARE: FRACTIONS DECIMALS ANGLES ± .010 ± .005 ± .010		CONTR NO. DESIGN CHECKER DATE APPD DESIGN ACTIVITY APPD OTHER APPROVAL		Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF. FILE SCR DRIVER SCHEMATIC SIZE CODE IDENT NO. QWG NO. C 13160 SK002210 SCALE WEIGHT	
MATERIAL		REV		REV	
REV THE BULKY CNG CONTROL		REV		REV	



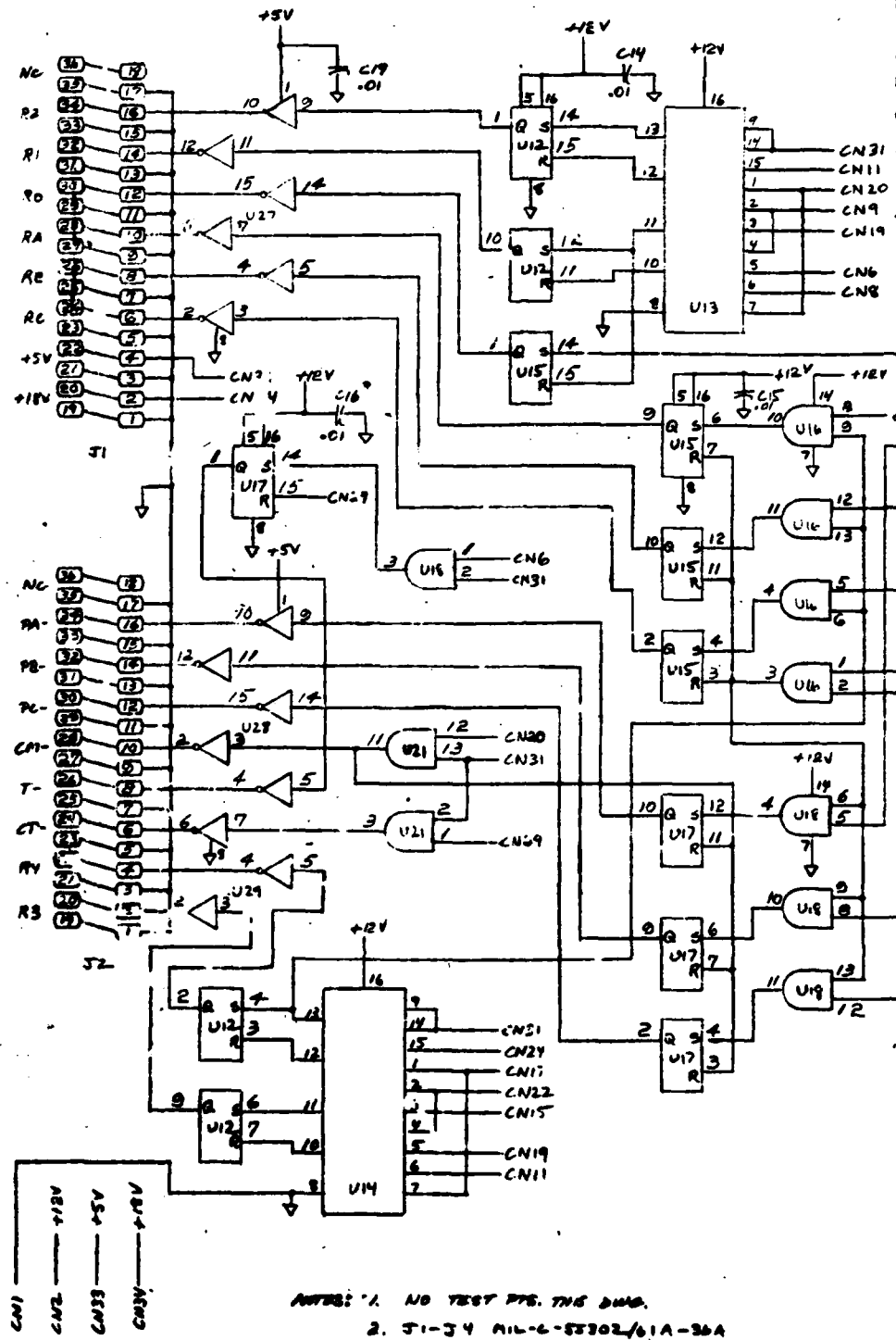
RT601
 C601 - C621
 CR601 - CR658
 L601 - L607
 T601 - T628
 R601 - R608
 R601 - R617
 TP601 - TP615
 U601 - U631



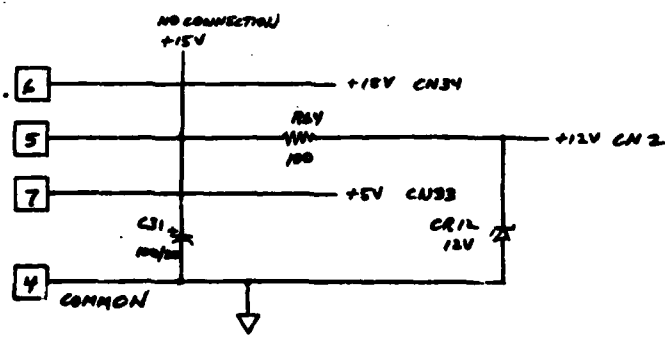
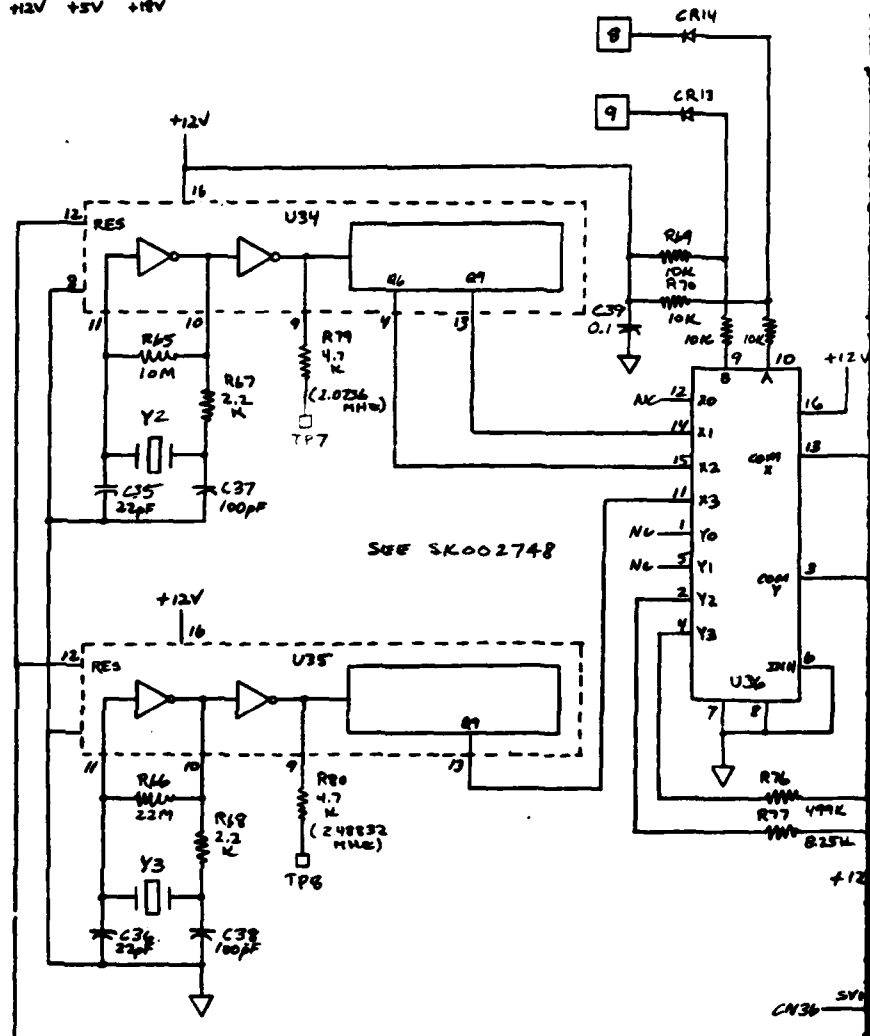
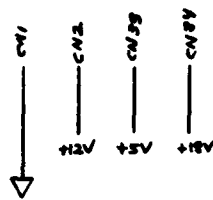
CN1
CN2
+2V

CN3
CN4
CN5

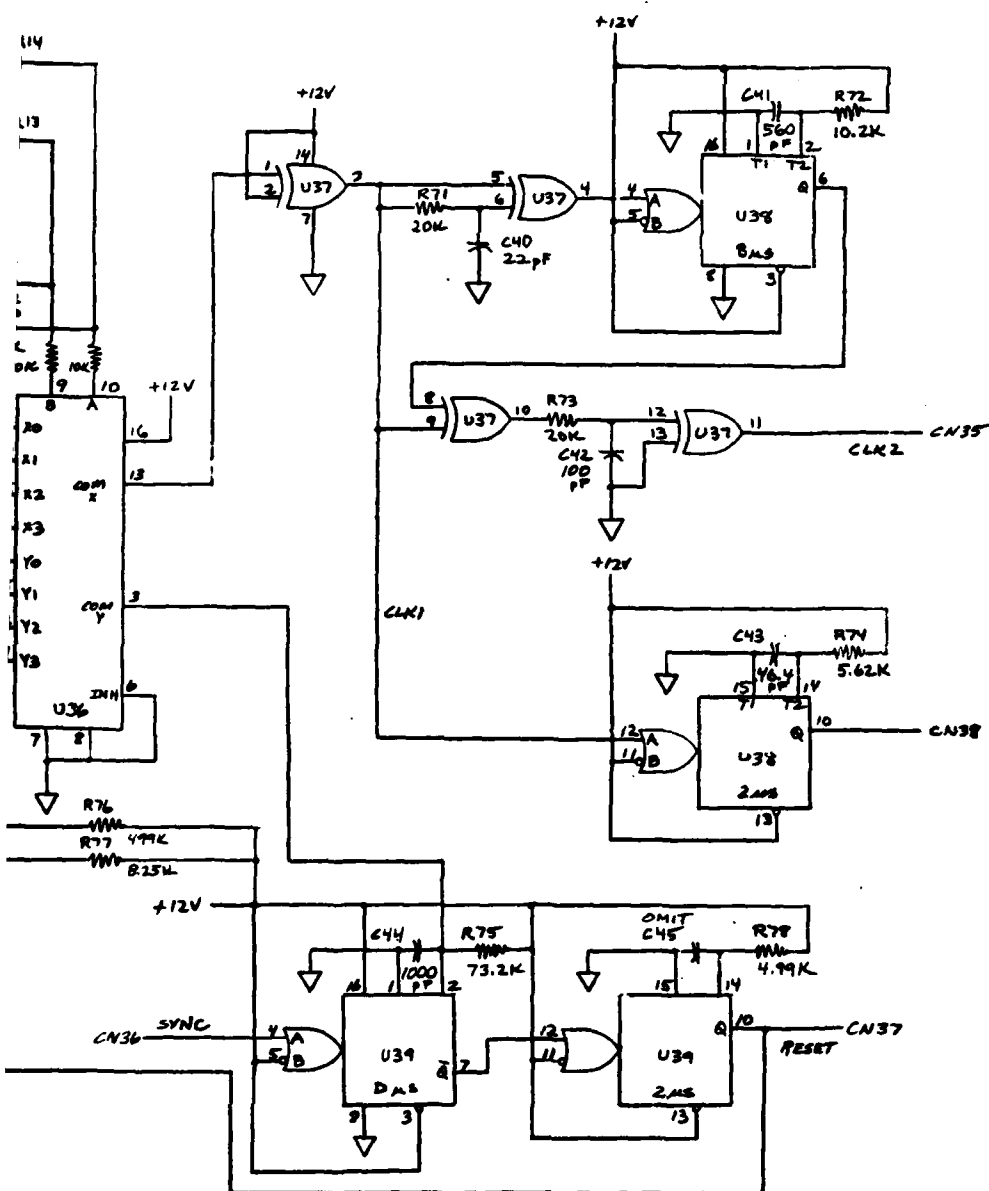
CN6
CN7
CN8
CN9
CN10
CN11
CN12



NOTES: 1. NO TEST PTS. THIS DMD.
2. J1-J4 MIL-C-88302/61A-36A



NOTE: DENOTES CONNECTION ON THE TERMINAL BLOCK A27B1



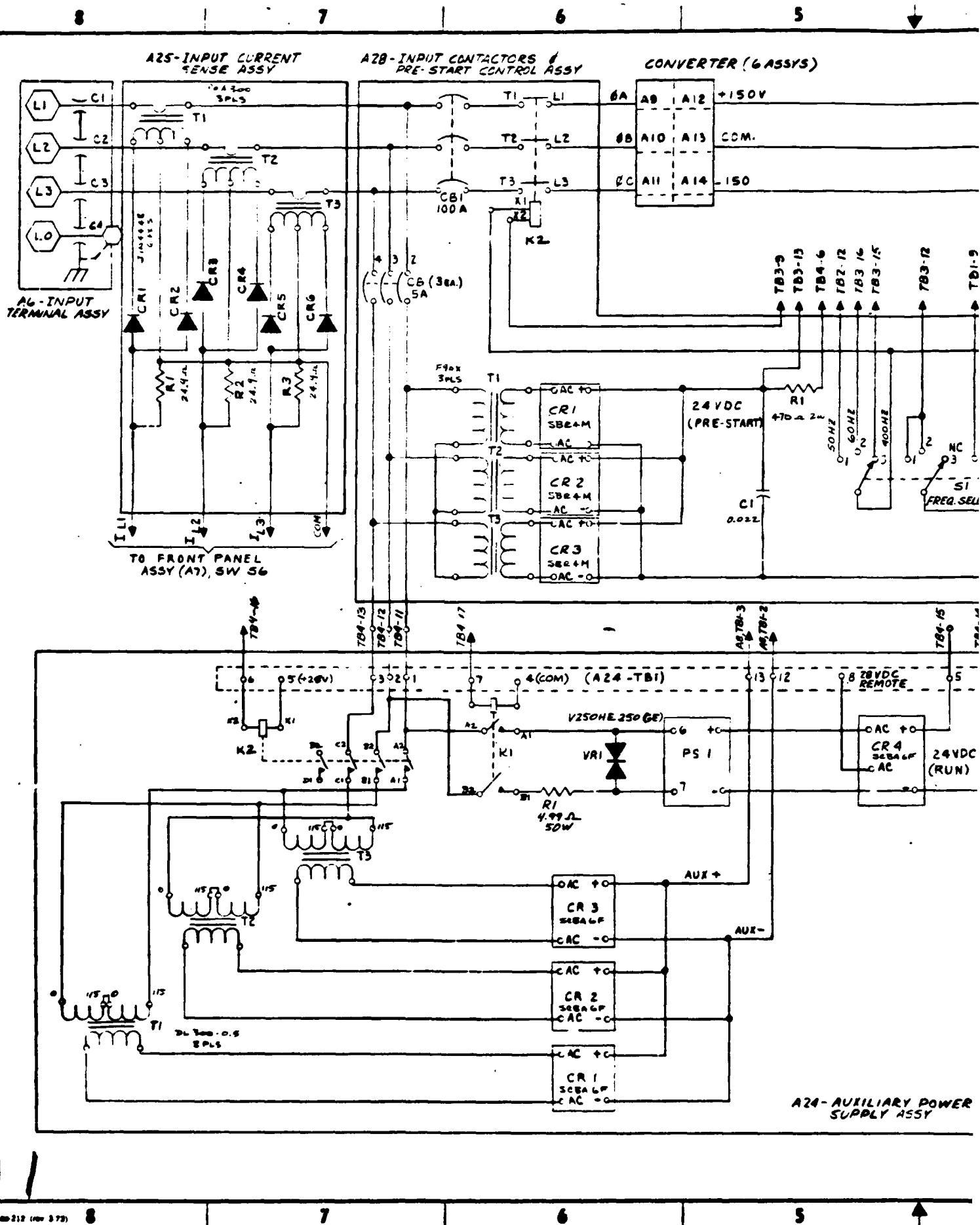
ON THE TERMINAL

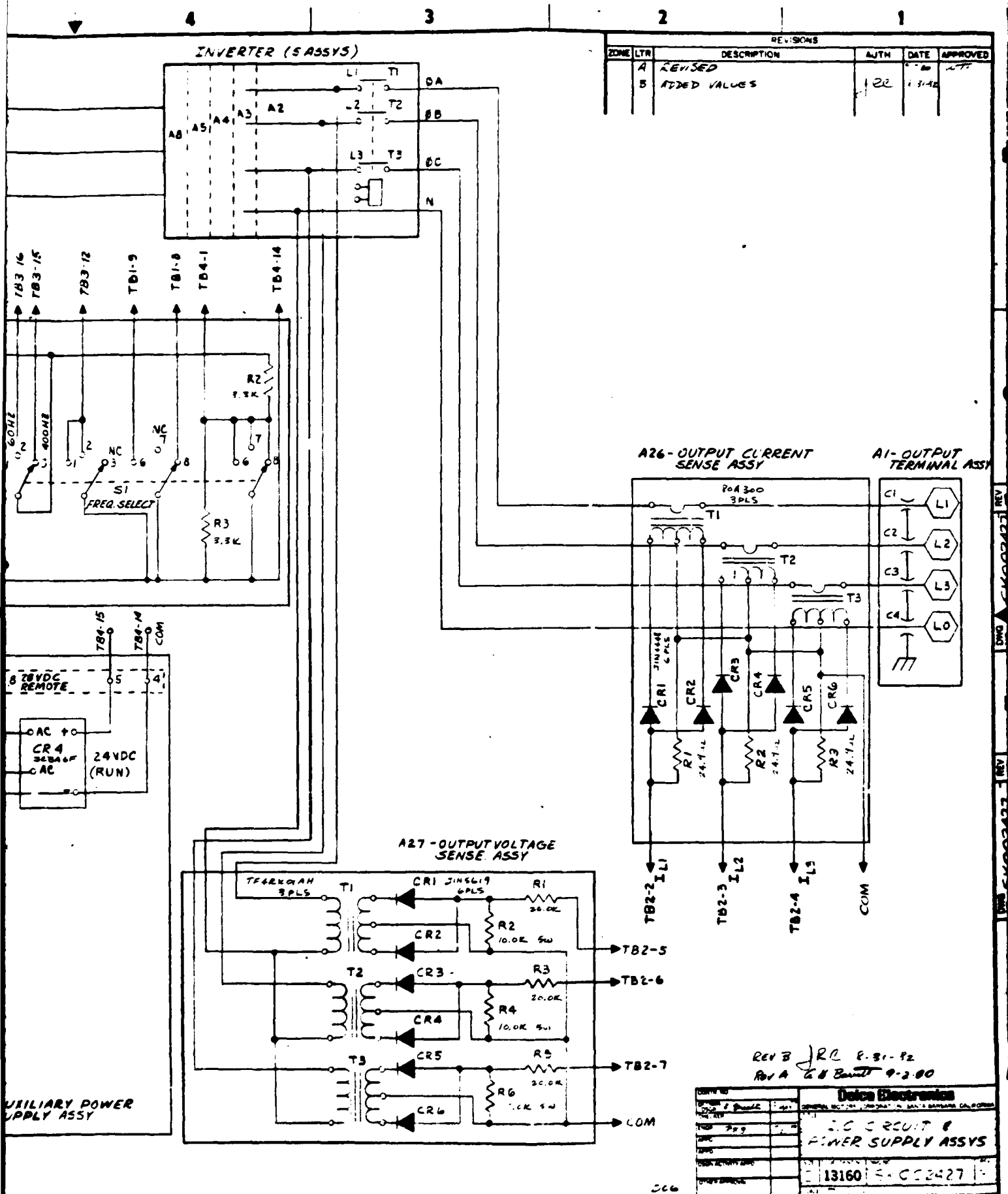
A. B. 6/4/78
A. B. 6/4/78

15KV FREQUENCY
CHANGER MODIFICATIONS

SK008211

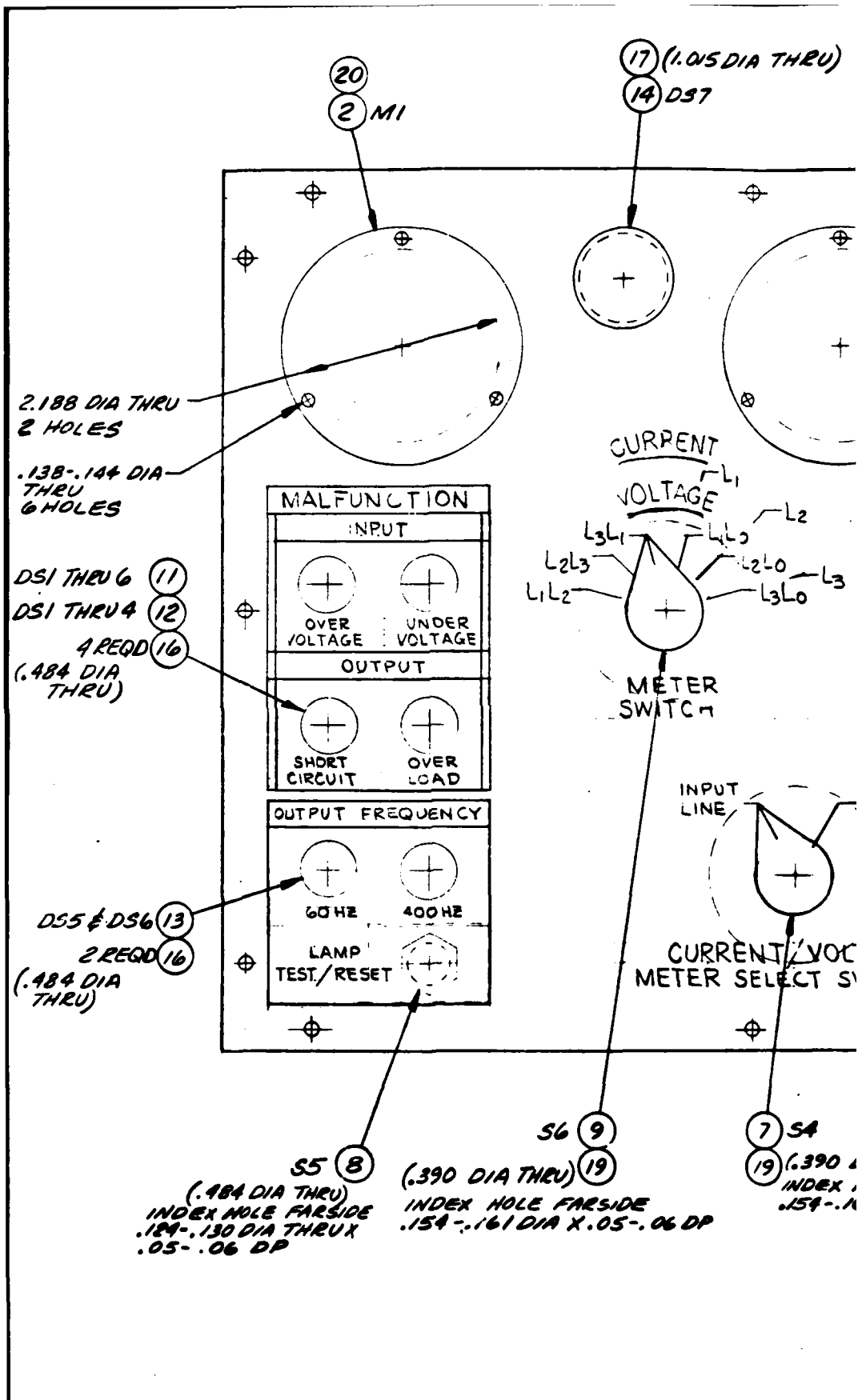
N-9C

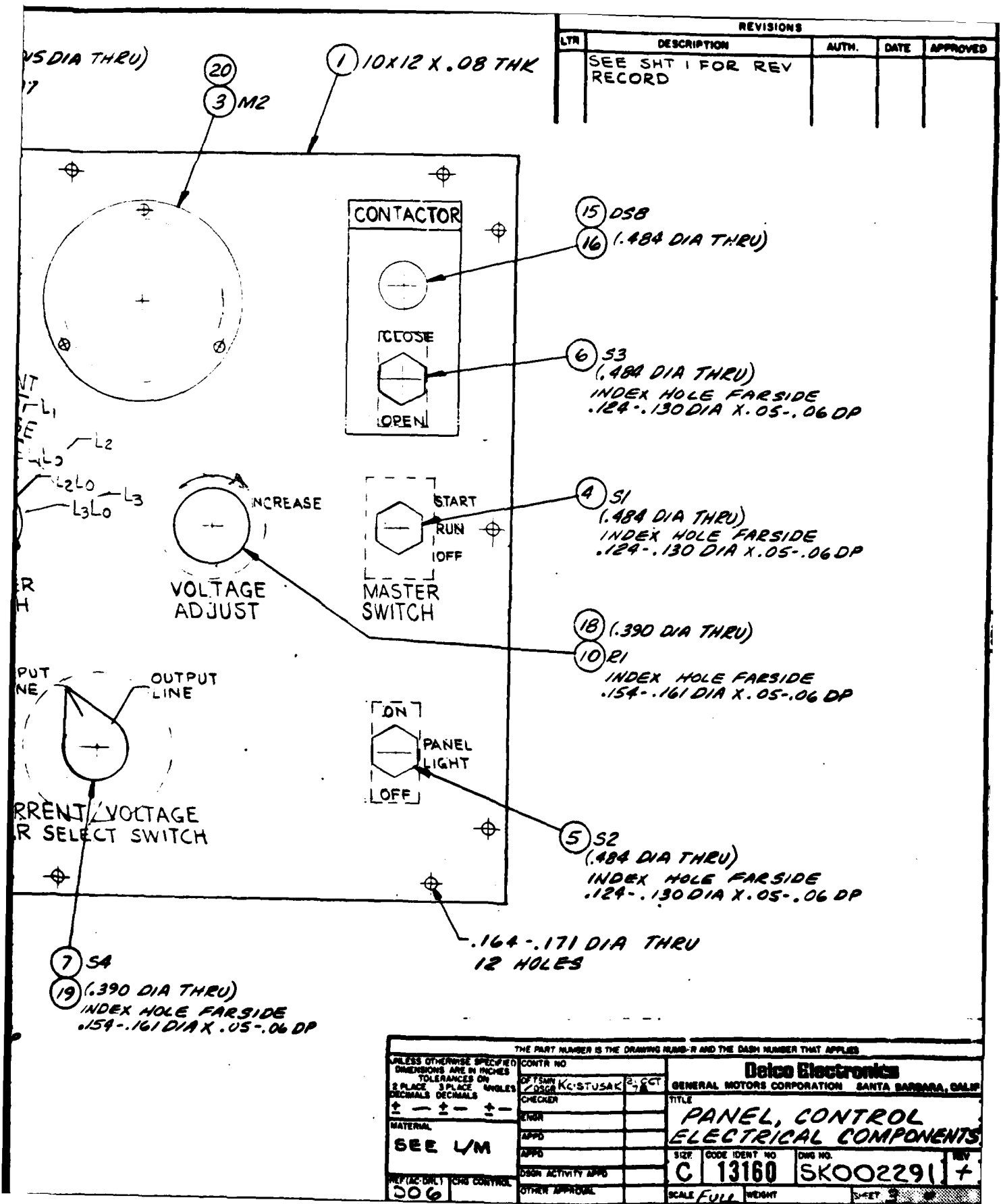


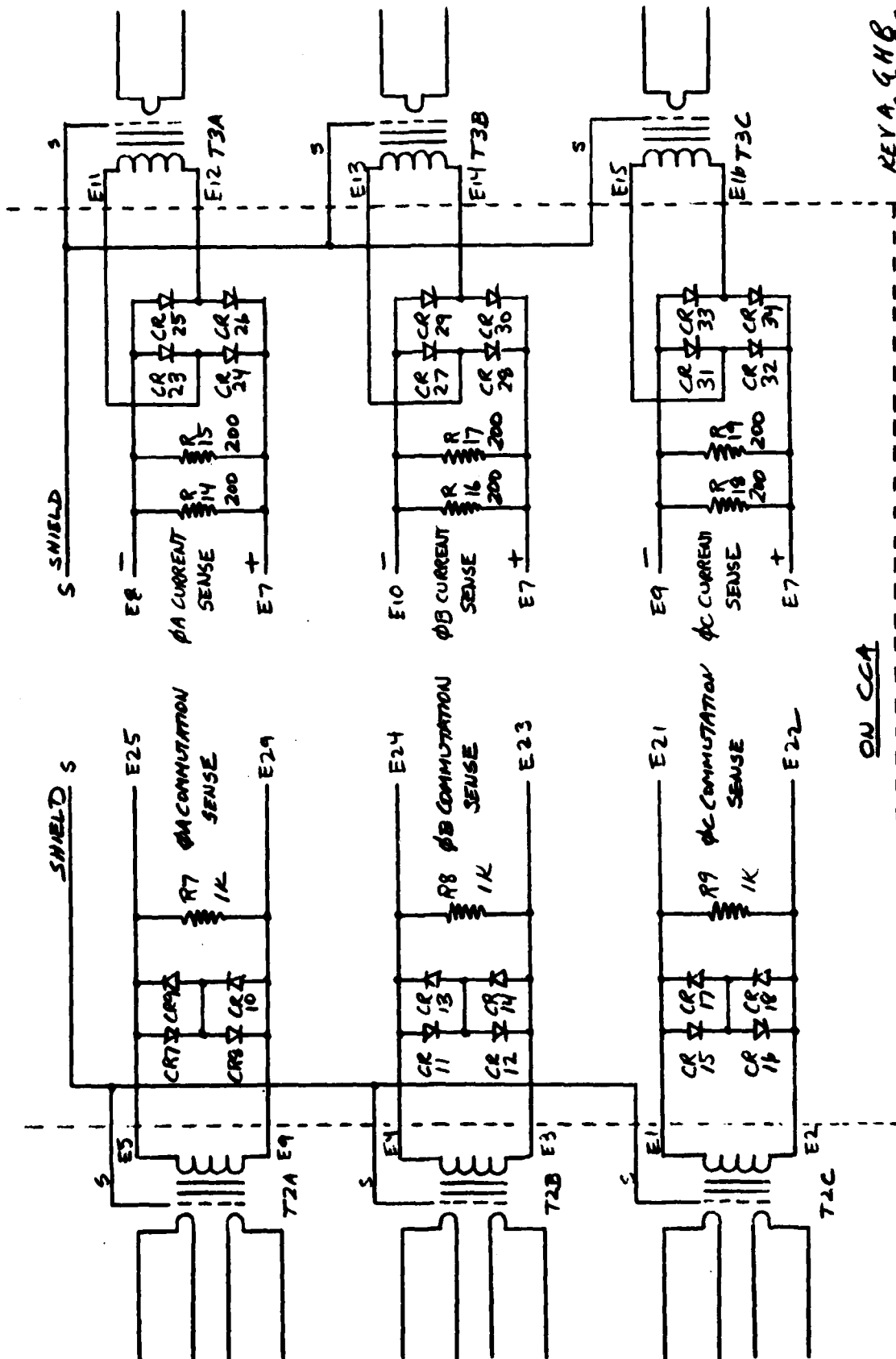


REV B JRC 8-31-92
REV A G & Barrett 9-2-00

DATE NO	Deice Electronics
NAME <i>W. B. Smith</i>	ORIGINAL SENT TO <i>Johnston</i> IN SAN JOSE, CALIFORNIA
TYPE <i>209</i>	R.C. CIRCUIT & POWER SUPPLY ASSYS
QTY	
PRICE ACTUAL \$	
OTHER CHARGE	
	13160 5.00







ON CCA

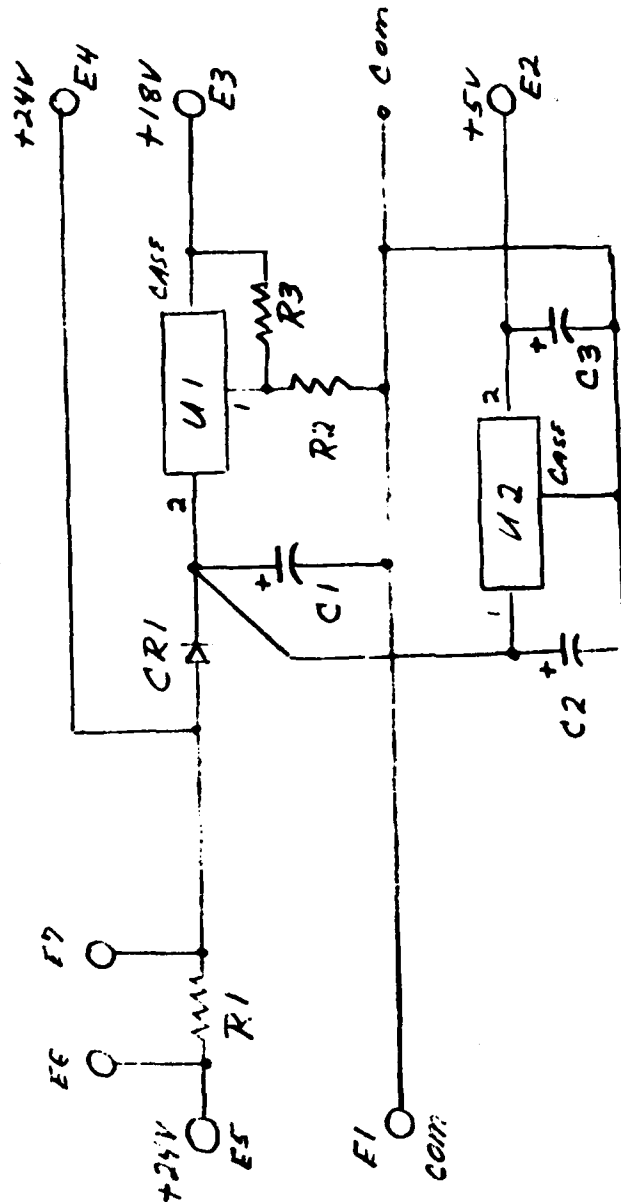
REV A 9-2-80

SIZE	CODE IDENT NO.	DWG NO.	REV
A	13160	SK 002405	A
SCALE			

Converter Sense CCA

Converter Sense CCA

To Start-up
& protect



SIZE	CODE IDENT NO.	DWG NO.	REV
A	13160	SK 002405	A
SCALE			

Datco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA TITLE			
VOLTAGE REGULATOR			
SIZE	CODE IDENT NO.	DWG NO.	REV
A	13160	SK 002406	A

N-12/13

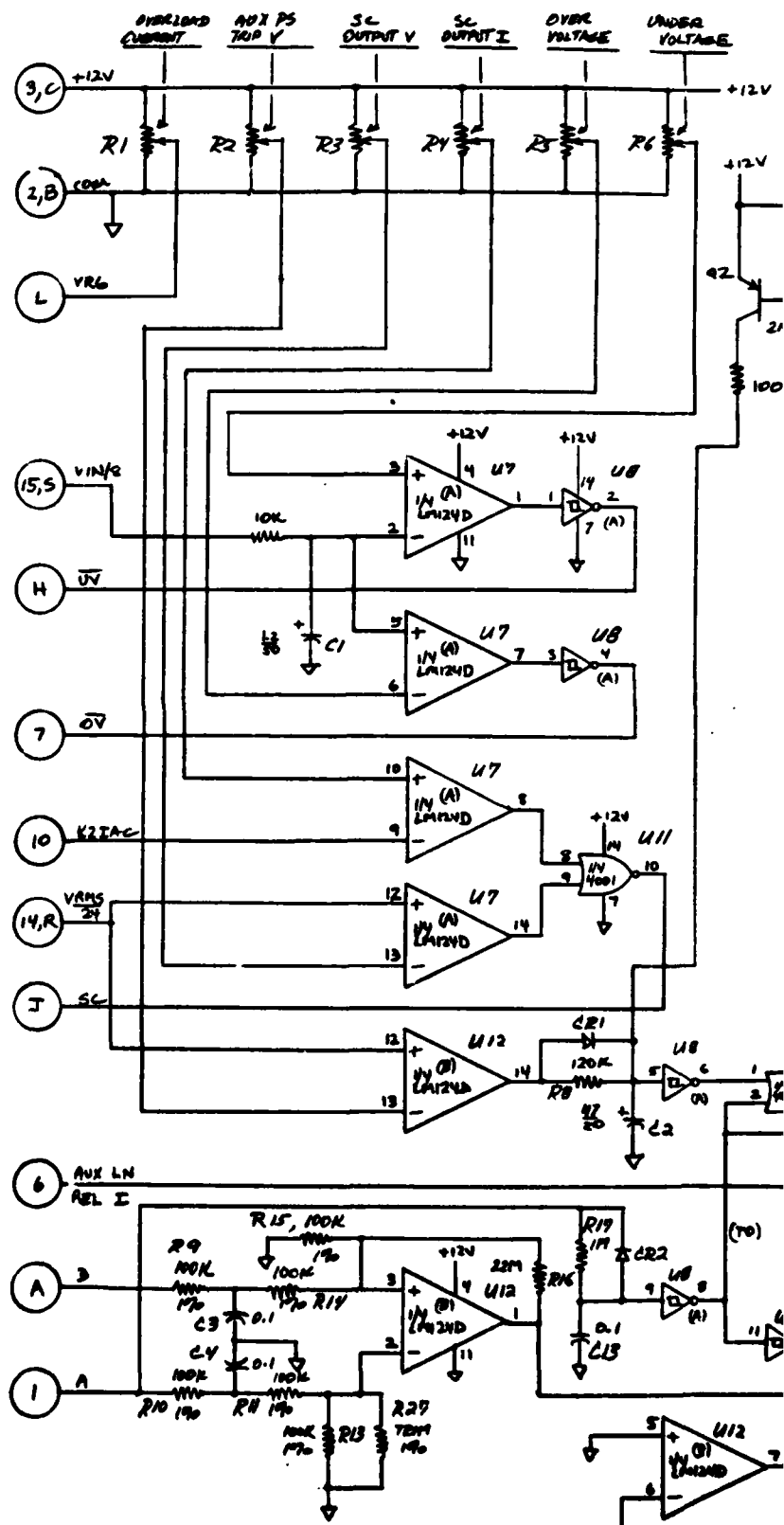
D

C



B

A

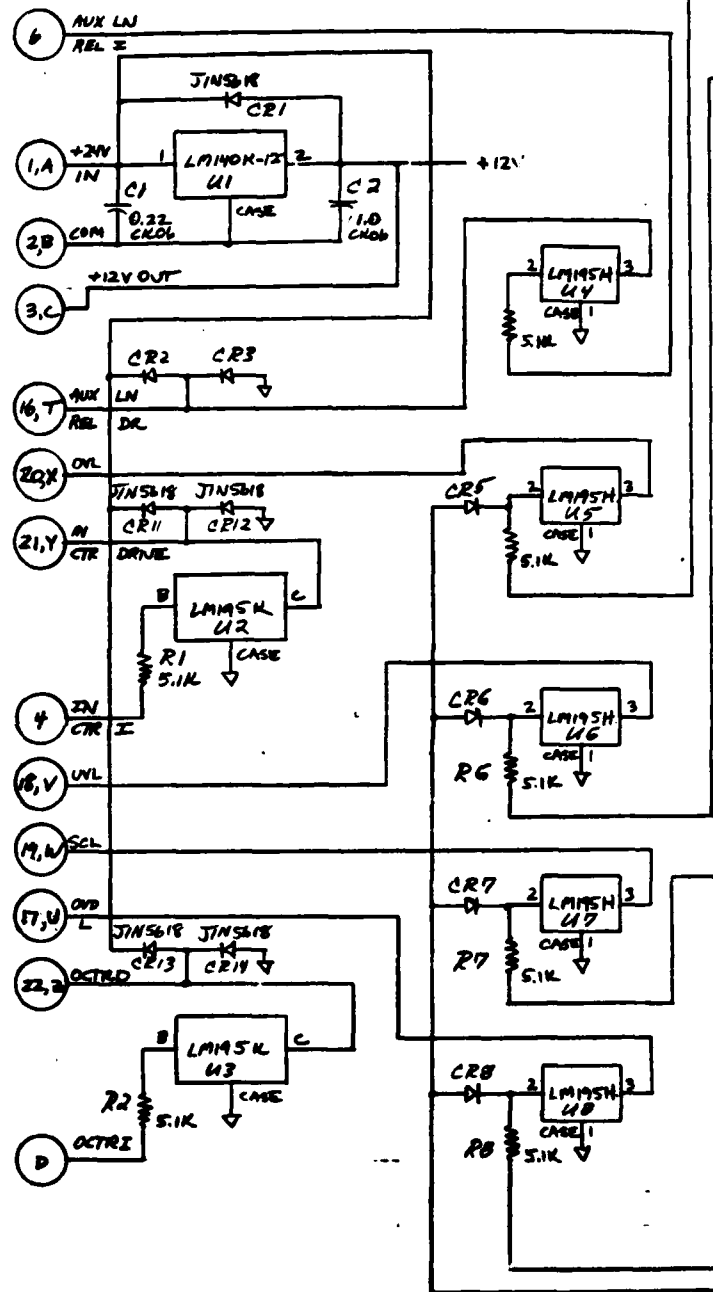


D

C

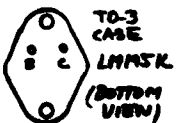
B

A

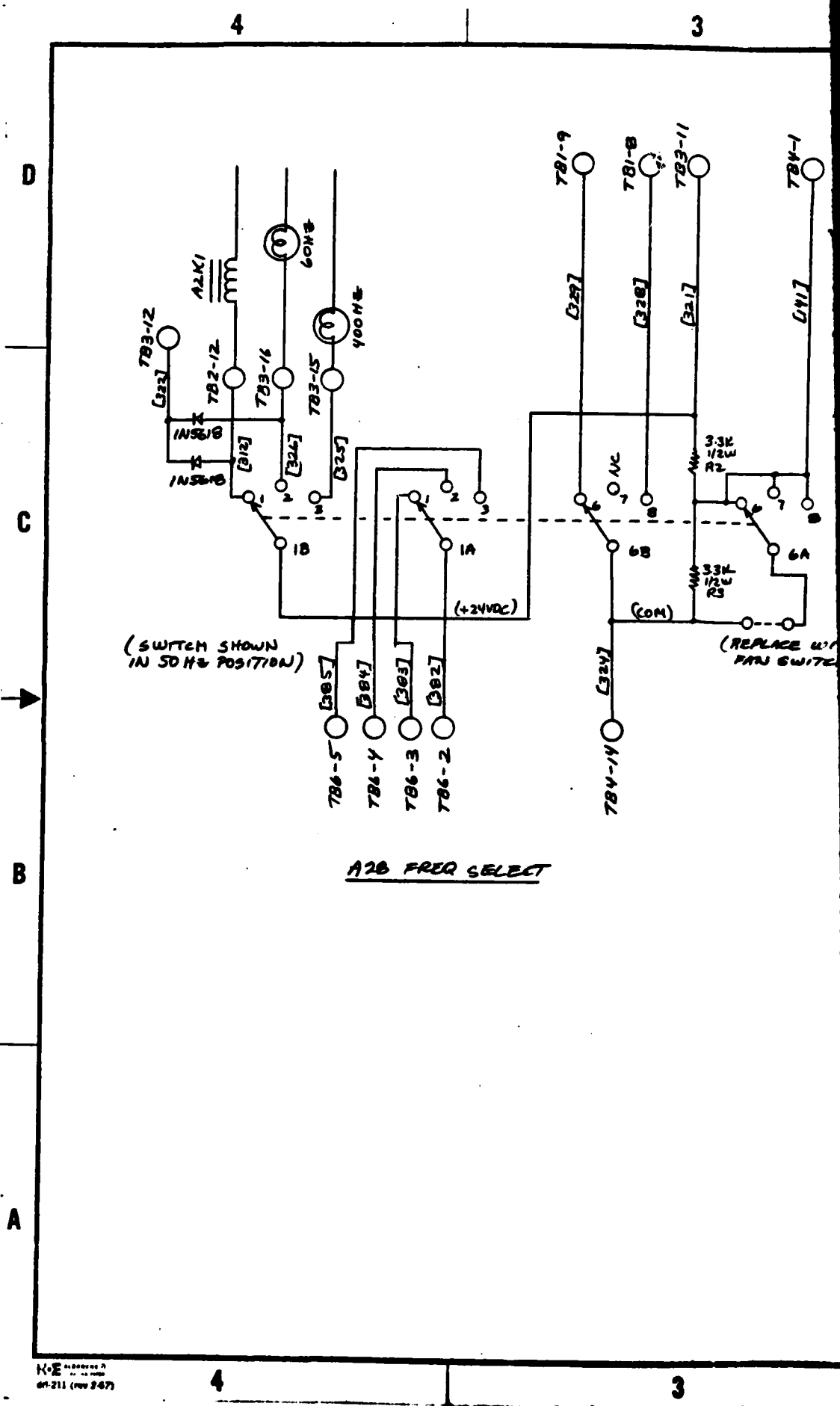


- NOTES: • ALL DIODES J1N4148-UNLESS INDICATED
 • ALL 2 DIGIT RESISTORS RC07, 1/4W, 25%
 • ALL 3 DIGIT RESISTORS RNC55H, 1/10W, ±1%
 •  DENOTES 7414 SCHMITT TRIGGER, EXT. INPUT VOLTAGE
 • ALL CAPACITOR VALUES IN µF

• UNUSED PINS







UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON		COST NO.		Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA CALIF.	
2 PLACE DECIMALS	3 PLACE DECIMALS	DEFINITION ENTER QWB.	189	TITLE A28 MOD AND A30 INTERCONNECT	
+	+	QWB TYPED			
MATERIAL		INCH			
		APPD			
		APPD			
		QWB ACTIVITY APPD		SIZE C	MODE IDENT NO. 13160
		OTHER APPROVAL		DWG NO. SK002747	REV A
REF (AC ONLY)	QWB CONTROL			SCALE —	WEIGHT —
				SHEET 1	OF 1

3

2

1

(BREAK
HERE)

CN36 (NO OTHER CONNECTION)

U36

NC 12 X0
 14 X1
 15 X2
 11 X3
 NC 1 Y0
 NC 5 Y1
 2 Y2
 4 Y3

U39A

+12V

R77 8.25K
 R76 470K

01-29-81 G.H.B. REV A

NOTE: THIS DRAWING SUPPLEMENTS
 SK002211

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE 3 PLACE ANGLES DECIMALS DECIMALS		CONTR NO G.H.B. 2748		Calco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA CALIF	
MATERIAL		CHECKER		TITLE A2M MODIFICATIONS FOR EXT. PREF. SOURCE	
APPD		TCCR		SIZE CODE IDENT NO	
APPD		APPD		DWG NO	
SIGN ACTIVITY APPD		OTHER APPROVAL		C 13160 SK002748 A	
REP (AC-DAILY) CHG CONTROL		SCALE		SHEET / OF /	

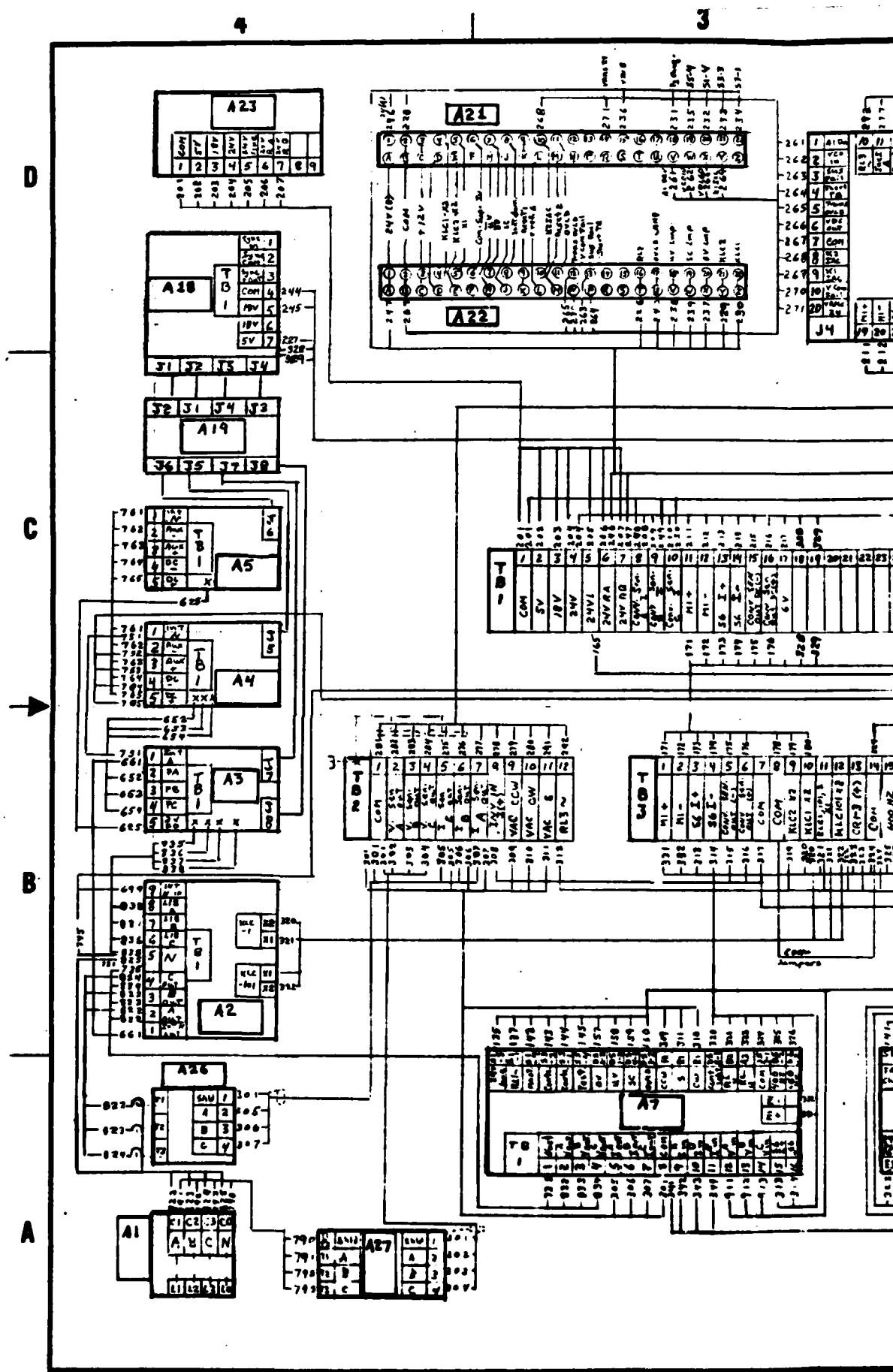
REV A

DWG NO.

B

A

N-18



DATE
FILMED
0-8