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(54) TRI-RANGE POWER SUPPLY SYSTEM

(76) Inventor: **Michael Hoffman**, Amery, WI (US)

Correspondence Address:
SKINNER & ASSOCIATES
619 SECOND STREET
SUITE 201
HUDSON, WI 54016 (US)

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(57) **ABSTRACT**

A power supply system is disclosed. The power supply has tri range features. The power supply is particularly useful in pulse plating apparatus and methods.

TRI-RANGE POWER SUPPLY SYSTEM

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates, generally, to power supply apparatus and methods. More particularly, the invention relates to a tri-range variable power supply. The invention has particular utility in pulse plating power supplies.

[0003] 2. Background Information

[0004] The state of the art includes various power supply devices and methods.

[0005] Prior art devices and methods are believed to have significant limitations and shortcomings.

[0006] The present invention provides a tri range power supply which is believed to constitute an improvement over the prior art.

BRIEF SUMMARY OF THE INVENTION

[0007] The present invention provides a tri range power supply system.

[0008] The features, benefits and objects of this invention will become clear to those skilled in the art by reference to the following description, claims, and schematic drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0009] The invention is shown and described in the attached appendix information.

DETAILED DESCRIPTION

[0010] The invention is described and shown in the attached appendix information which is hereby incorporated by reference as part of the specification.

[0011] The descriptions above and the accompanying drawings should be interpreted in the illustrative and not the limited sense. While the invention has been disclosed in connection with the preferred embodiment or embodiments thereof, it should be understood that there may be other embodiments which fall within the scope of the invention as defined by the following claims. Where a claim, if any, is expressed as a means or step for performing a specified function it is intended that such claim be construed to cover the corresponding structure, material, or acts described in the specification and equivalents thereof, including both structural equivalents and equivalent structures, material-based equivalents and equivalent materials, and act-based equivalents and equivalent acts.

Joel

From: Mike Hoffman[SMTP:mHoffman@dynatronix.com]
Reply To: mHoffman@dynatronix.com
Sent: Thursday, September 28, 2000 2:42 PM
To: Joel Skinner
Cc: Norm Osero
Subject: Provisional patenet application data

131-0636-641.pdf xr_patent.pdf 131-0630-46.pdf 138-0300-00.pdf 138-0300-01.pdf 138-0300-02.pdf

231-0300-01.pdf 231-0304-01.pdf 990-0270-641.pdf 131-0630-45.pdf ATT00003.txt

Joel,

I have attached several "PDF" format files containing data on the invention we discussed. The attached file XR_patent gives a brief description of the circuitry and prior art. The attached files with a 990 prefix are top level assembly files. The files with a 138 prefix are the assemblies associated with the extended range invention. The 231 prefixes are the schematics associated with the invention and the 131 prefixes are schematics for the top level assemblies. Please let me know if you need any additional information or any clarification of this data.

Extended Range(XR)

Current Regulation system for pulse and pulse reversing power supplies

Field of Invention:
This invention is intended for use in the electroplating/surface finishing industry. Applications include but are not limited to semiconductor processing, electroplating, electroforming and electroetching.

Background Technology:
Historically, performance of pulse and pulse reversing power supplies for electroplating has been limited by the need to satisfy a wide spectrum of load conditions while maintaining output stability. This has limited the operational range in which these power supplies can deliver optimal performance in current or voltage regulation mode. In the past, the optimal operating range has been from 5% to100% of the peak rated current output capability of the power supply.

Purpose of Invention;
The goal of this invention is to enable a pulse or pulse reversing power supply to deliver optimal performance throughout a broad current regulated operating range. The ability to obtain optimal performance, from this type of power supply, through a output range from 0.1% to 100% of the peak rated output current is desired.

Description;
This has been achieved by changing the current sensing circuitry to switch between multiple current sensing elements instead of a single sensing element. The current sensing elements are sized to allow larger feedback signals when a lower output setting is required from the supply. In addition, the control loop compensation components are switched depending on the output current required. This allows performance of the power supply to be optimized depending on what output setting is desired.

Reference schematic 231-0300-01.
Three current sensing elements (SH1,SH2 & SH3) sense current flowing through the output connections of the power supply. Selection of the active current sensing element is controlled by Q1-Q3. Q3 is selected for the "high" operating range, Q2 is selected for the "mid" operating range and Q1 is selected for the "low" operating range. Selection of the active control loop compensation components is accomplished through U2:A-U2:C in a similar manner.

The feedback signal from the current sensing element is then processed (properly scaled) through the embedded control circuitry and firmware located on the associated digital control board (schematic 231-0304-01).

The values of SH1-SH3, Q1-Q3 and R1,R2 will vary depending on the peak output current rating of the power supply. The gain of amplifiers U7, U8 and U10 will also vary depending on the peak output current rating of the power supply. The embedded firmware allows the supply to be configured for different peak output current ratings based on the values of SH1-SH3 and the gain of the associated amplifiers (U7,U8 and U10).

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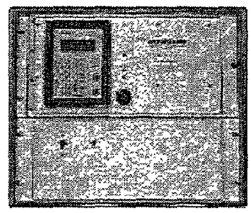
Methods of Control Computer Controllable Manual & PLC Controllable



Methods of Control

Methods of Control for Pulse Power Supplies

Methods of Control for D.C. Compact

Computer Controllable

Programmable Overview

Pro Series

Programmable Pair

Programmable Multi-Channel Power Supply

DynaComm™

DynaComm II™ (Windows version)

Custom

Manual & PLC Controllable

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Manual Overview

Pulse Pair DP/DPR Series

MDP Multiple Channel System

Micropulse Units (DuP/DuPR)

ATCs

DC Compact

DC 10KW

DC 10 Series

Custom

Users of Dynatronix Supplies

DYNATRONIX

E-mail: sales@dynatronix.com

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462 Griffin Blvd.
Amery, Wisconsin 54001 USA

Telephone: (715) 268-8118
FAX: (715) 268-8183
Toll-Free USA: (800) 826-7172

David Yamada
Dynatronix Western Regional Office
P.O. Box 11538
Pleasanton, CA 94588-1538
Phone: (925) 462-0344
Fax (925) 462-7233
E-mail dynatronixwro@mindspring.com

Pat Mentone
Ph.D, Plating Consultant
Mentone Component Technology
1653 Pinehurst
St. Paul, MN 55116
Phone: (651) 699-3119
Fax: (651) 699-3129
E-mail: pmentone@mn.mediaone.net

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Methods of Control for Pulse Power Supplies

Manual Control Computer Control - Analog Computer Control - Digital DynaNetTM

Manual Control: Front panel controls on supply

Remote output front panel controls mounted up to 25 feet from supply, typically, used to set and monitor output only with timing set at supply front panel. Pulse timing can be remoted also.

Remote via 4/20mA or 0 - 5V levels using manual controls. Used to set and monitor output only. Timing is usually set at supply front panel. Typically used for distances over 50 feet. Requires isolated analog interface board, installed in supply.

"Computer" Control - Analog Levels

Programmable Logic Controller (PLC) using individual analog I/O modules
Personal computer using analog I/O card.

Output settings typically via 4/20mA or 0 - 5 volt
Output monitor typically via 4/20mA or 0 - 5 volt
(Voltage is sometimes monitored directly)

> Note: As in manual only, the output can be set and monitored. Timing is set at supply front panel. All analog signals must be isolated between controlling device ground and power supply ground.

Additional functions such as operate/standby (inhibit) can be performed with digital I/O modules from PLC or digital I/O card from PC. All signals must be ground isolated between controlling device and power supply.

"Computer" Control - Digital Options:

Plater Control Terminal (PCT) - Allows front panel or remote control of one single output programmable pulse power supply with all applicable set and monitor conditions. Maximum distance 50 feet.

DOS based PC with RS232 for one power supply or RS485 port, for more than one power supply on a network.

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> Note: If PC has RS232 port, DynaCommTM Conversion Interface (DCI) box can be added for RS485.

DynaNet^{TM} is the internal software program that provides:

All applicable set conditions via RS232 for individual supply or RS485 for multiple supplies.

All applicable monitor conditions via RS232 for individual supply or RS485 for multiple supplies.

Under DynaNet^{TM} , additional conditions to set and monitor are available. Macro programs, ampere time cycles, real time cycles, tolerance parameters, multi-channel supplies and software control limits can be part of the instructions to the supply.

E-mail: sales@dynatronix.com

462 Griffin Blvd.
Amery, Wisconsin 54001 USA

Telephone: (715) 268-8118
FAX: (715) 268-8183
Toll-Free USA: (800) 826-7172

David Yamada
Dynatronix Western Regional Office
P.O. Box 11538
Pleasanton, CA 94588-1538
Phone: (925) 462-0344
Fax (925) 462-7233
E-mail dynatronixwro@mindspring.com

Pat Mentone
Ph.D, Plating Consultant
Mentone Component Technology
1653 Pinehurst
St. Paul, MN 55116
Phone: (651) 699-3119
Fax: (651) 699-3129
E-mail: pmentone@mn.mediaone.net

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Methods of Control for D.C. Compact

Computer Control - Analog   Computer Control - Digital   DynaNet™

Manual Front panel controls
Manual Remote front panel controls. Typically used for distances under 20 feet.
Manual Manual Remote via 4/20mA or 0 - 5v levels using manual controls. Typically used for distances over 50 feet. Requires isolated analog interface board, installed in supply.

"Computer" Control - Analog Options:

Programmable Logic Controller (PLC) using individual analog I/O modules
Personal Computer using analog I/O card

Output settings typically via 4/20mA or 0 - 5 volt
Output monitor typically via 4/20mA or 0 - 5 volt
(Voltage is sometimes monitored directly)

Note: All analog signals must be isolated between controlling device ground and power supply ground.

Additional functions such as operate/standby (inhibit) can be performed with digital I/O modules from PLC or digital I/O card from PC. All signals must be ground isolated between controlling device and power supply.

"Computer" Control - Digital Options:

DOS based PC with RS232 or RS485 port, or with a conversion box for RS485.

DynaNet™

All applicable set conditions via RS232 for individual supply or RS485 for multiple supplies.

All applicable monitor conditions via RS232 for individual supply or RS485 for multiple supplies.

Under DynaNetTM , additional conditions to set and monitor are available. Macro programs, ampere time cycles, real time cycles, tolerance parameters, multi-channel supplies and software control limits can be part of the instructions to the supply.

Top

DYNATRONIX
E-mail: sales@dynatronix.com
462 Griffin Blvd.
Amery, Wisconsin 54001 USA
Telephone: (715) 268-8118
FAX: (715) 268-8183
Toll-Free USA: (800) 826-7172

David Yamada
Dynatronix Western Regional Office
P.O. Box 11538
Pleasanton, CA 94588-1538
Phone: (925) 462-0344
Fax (925) 462-7233
E-mail dynatronixwro@mindspring.com

Pat Mentone
Ph.D, Plating Consultant
Mentone Component Technology
1653 Pinehurst
St. Paul, MN 55116
Phone: (651) 699-3119
Fax: (651) 699-3129
E-mail: pmentone@mn.mediaone.net

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An Overview of Pulse Plating

By Norman M. Osero

Applications in electronics continue to dominate but other industries are beginning to benefit.

Pulse plating is a method of depositing metal on a substrate using interrupted direct current (dc). These pulses are often employed at a rate of 500 to 10,000 times per second. They favor the initiation of grain nuclei and greatly increase the number of grains per unit area. The intended result is a finer grained deposit with better characteristics and properties than conventionally plated coatings.

The electronics industry has been and continues to be the major user of pulse plating. In fact, pulse plating has become a requirement in many cases where the process and/or product specifications are highly restrictive and sophisticated.

We will discuss some of the principles, practices, and applications of pulse plating, then conclude with a forecast of what the technique might hold for the future. We will begin with a discussion of equipment and wave shapes.

Pulsing Equipment

Early equipment for pulse plating consisted of a dc rectifier and chopper circuit, which provided low-frequency pulses with little regard for pulse frequency, rise-and-fall times, and regulation. Semiconductor regulators were added to the dc rectifier, resulting in a pulse power supply that offered switching frequencies up to 10 Hz with fast rise-and-fall times. In recent years, pulse power supplies have been changed to offer complex waveform capabilities (e.g., pulse reversing, pulse-on-pulse, and duplex pulses).

Single direction pulse power supplies are referred to as unipolar types. They have been the workhorse of pulse platers and represent about 90 to 95 percent of those in the market. They are available as add-on switches (converters) to be used with a separate dc rectifier or as an integrated supply with the dc portion and the switching circuits contained in one unit. The latter type is the most common arrangement.

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Converter pulse systems usually feature saturated or low-voltage-loss switches. They depend on the dc rectifier to provide current or voltage regulation. One disadvantage of this approach is that any ripple on the dc output is passed through the switch to the plating bath. When a current regulated dc rectifier is used, its output voltage will rise during the pulse off-time, charging the rectifier filter capacitors and yielding high-current spikes at the start of the on-time of the pulse.

SCR or thyristor-controlled dc power supplies often will not operate well with switching applications. At low output voltage or current, the SCRs are operating at a very low phase angle and the ac ripple component is very high.

Integrated pulse power supplies consist of a dc rectifiers and pulse switch circuits in one unit. They are more commonly used than those with an add-on switch to the dc rectifier. Integrated supplies offer the advantage of being able to better control the amplitude and ripple of the output current. Also, the dc portion of the supply is designed to be compatible with pulse switching techniques. These systems offer current or voltage regulation and are usually more readily applied to plating because of their ease of operation.

Wave Shapes

Pulse power supplies are offered with two basic wave shapes: sine and square wave. The modified sine-wave system uses the power-line frequency of 50 to 60 Hz half wave or 100 to 120 Hz full wave as its time base. The output pulse usually has a fast turn-on time and a slow sinusoidal turn-off time. Its advantage is lower cost by comparison with square-wave systems. However, because lower frequencies have not shown the benefits of higher ones, the modified sine-wave system has not found wide acceptance for pulse applications.

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Square-wave pulse power supplies feature a time base that is independent of the power-line frequency. They operate over a wide frequency range up to and often exceeding 10 kHz. These systems are successfully applied to both precious and base metals for electronic, microelectronic, and decorative applications. The wide operating parameters allow the user the most flexibility in determining the optimum operating parameters for a specific application.

Power supplies that deliver complex pulse wave shapes are also being applied to many processes. Pulse-reversing units feature a train of pulses in the cathodic direction followed by a train in the anodic direction. Some manufacturers offer equipment that allows independent control of forward and reverse pulse timing and amplitude. Converter systems for pulse reversing usually offer the same pulse amplitude in both directions and independent timing to allow the user to vary the average current.

Pulse-on-pulse systems offer complex wave shapes that have pulses at one amplitude riding on top of those of a lower amplitude riding on top of those of a lower amplitude. Duplex systems feature a burst of pulses at one level followed by a burst at another, all in one direction. Pulse-on-pulse and duplex systems are used mainly for research.

Because of the vast variety of plating processes and products, manufacturers of pulse power supplies have had to offer a great deal of flexibility in their equipment. Some companies offer custom-designed systems or standard equipment that can be adapted to the user's requirement.

These custom-designed products usually command a higher price than standard equipment. However, customized products offer the customer a piece of equipment that is often a better answer for his needs. Also, these

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custom-made units sometimes evolve into new standard products that can be offered at a more attractive price. Multiple-output pulse platers are an excellent example of this. They allow precision control of the current to each cathode for improved part-to-part thickness uniformity.

Application Overview

Now let's outline some of the current and prospective uses of pulse plating:

Connectors: Pulse plating is being used to a large degree for plating nickel and gold on electronic connectors and switch contacts. Some contacts are barrel plated with gold over the entire surface. But the cost of gold and concerns for minimizing its use have led manufacturer to develop selective plating methods for applying the gold only on the contact areas. Stripe plating of nickel and gold has been very successful with pulse deposition.

A reduction in stress of the pulse-plated deposits has allowed manufacturers to stamp and form contacts after plating. The economic gains have far surpassed the relatively high cost of pulse power supplies. A pulse cycle of 1.0 millisecond on and off is typical for depositing cobalt-and nickel-hardened gold.

Lead frames: manufacturers of semiconductor lead frames are using pulse plating to increase the reliability of wire bonds and to enhance deposition speed. This has been accomplished through the use of proprietary high-speed gold and silver plating solutions specially formulated for pulse deposition. Peak voltages in the range of 40 V are required to deliver the high peak amperes that are necessary.

Fine patterns: The microelectronics industry has recognized the advantage of pulse plating for high-density circuitry. A report of Missel et al on the square profile of pulse-plated circuit paths describes the process and advantages.

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Typically, dc plating results in mushroom-shaped deposits, which limit the proximity of one line trace to another in fine pattern plating. With the use of pulse technology, circuit traces can be positioned closer together without shorting one another. Companies that manufacture high-density circuits have been able to increase the number of circuits on a given surface dimension. Increased circuit density in thin-film magnetic heads for computer disc drives allows for greater magnetic strength of the head.

SAW Technology: Pulse plating is being studied for use in Surface Acoustic Wave (SAW) technology, which is employed in the manufacture of high-frequency (10 MHz to 1 Ghz) oscillators, filters and resonators for cable television, satellite communications, modems and radar applications.

Electroforming: This is a very important application for pulse power supplies. Nakamura reported that pulse deposition could be used to produce stronger electroformed copper and nickel parts with thinner walls and lighter weight. Also, companies are using pulse deposition to electroform nickel venturi valves for cryogenic applications, where it is very important to maintain exact replication of the machined aluminum mandrel.

Moreover, pulse power is being used in the electroforming of diamond cutoff wheels for the semiconductor industry. Improved properties of the pulsed nickel deposit result in better wear characteristics and heat transfer away from the cutting edge. Optics manufacturers are using pulsing techniques to electroform exacting molds for contact lenses,. The nickel deposits exhibit little or no stress. Molds for light-reflecting products (e.g., reflectors for cars and bicycles) are also being pulse electroformed. Reflectivity is said to be uniform over the full surface of the reflector.

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Finally, pulse electroformed nickel for large machined parts has improved machine ability. Pulsed current has reduced hydrogen embrittlement and treeing of the deposit. Reduced pitting has resulted in less scrap being generated during the machining operation.

Etching: Most applications of pulse power supplies are those where metal is being deposited. However, they are also being used to etch fine patterns in high-temperature metal alloys. Pulse etching has proven to be far superior to alternative methods in some cases. The capability to etch very sharp corners and straight walls in deep crevices by comparison with conventional etching methods has yielded products that meet exacting design requirements.

Waveguides: A smooth surface topography in high-frequency waveguides is important for the reduction of radio-frequency losses in transmission. Pulse-plated gold deposits exhibit reduced surface roughness for improved waveguide performance.

Decorative Work: Many high technology jewelry manufacturers are using pulse techniques to apply gold, rhodium and silver. Some decorative platers report that pulse plating allows better deposition into recessed areas of complex shapes while minimizing overplating at high-current-density areas.

Circuit Boards: Some PC board companies have been using pulse plating for tin-lead alloys and copper for a number of years. They report being able to maintain a very consistent tin-lead alloy content over the entire surface of a panel (4 to 5 ft). The resulting deposits are said to exhibit excellent characteristics with regard to infrared solder reflow.

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Copper deposition using pulse-reversing techniques was shown by Hall et al. To offer significant improvements in through-hole plating and elongation and thermal properties of the deposit. Ratios of up to 10:1 in board thickness to hole diameter are said to be possible.

With the increased demands on circuit board makers to produce boards with smaller holes and closer line widths and spaces, it would appear that pulse plating will become an increasingly important method. The challenge for rectifier manufacturers is to offer the PC industry power supplies that can deliver the large currents required for copper plating, and at an economical price.

Electroless Nickel: The application of pulsed current to Electroless nickel has been shown by Mallory and Lloyd to increase the deposition rate by a factor of several times while yielding deposits with physical properties similar to those of conventionally applied EN. This is an unconventional application of pulse power supplies, though perhaps it may become a significant one. R&D in this field could result in pulse plating becoming a very large and important part of the "Electroless" process.

A Forecast

Many companies have been using pulse plating primarily to obtain an improvement in deposit properties as a result of grain refinement. Others claim improvements in throwing power and thickness distribution, but the superior metallurgical properties by comparison with conventional dc plating are the major benefit. Nonetheless, it should be pointed out that pulse plating is not a panacea and that it is still an evolving technology.

Finishing and manufacturing engineers are continually requesting plating solutions that offer specific deposition results for stated pulse operating parameters. Solution formulators are being called upon to answer these needs Contrary to the theory that pulse plating eliminates the need for solution additives, we feel that baths developed for pulse deposition will continue to use additives in order to achieve optimum and repeatable results.

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There is also the possibility that pulse power will become a commonly used tool for other electrochemical processes (e.g., electrodischarge machining, electro etching, and electro cleaning). Electrical current can be defined and controlled more easily than can the chemical makeup of the solutions employed for these operations. This marriage of chemistry and the highly predictable and controllable parameters of electrical current could will result in future electrochemical processes that are easier to use and maintain and that deliver improved results.

The electronics industry continually pushes process technology to new horizons. The dynamics of this industry results in manufacturing processes that often experience a very short life. The process that was good yesterday may not even be used today. In the extreme, processes are sometimes outdated before they are even put to use.

This technological change is evidenced by new manufacturing methods for circuit boards, CaAs wafers, and microelectronic components. Greater demands to place more and more electronic circuits on a given substrate may result in line widths and spacings between lines that cannot be achieved with dc plating or even by altering solution chemistry.

Pulse power supplies will be changing continually to take advantage of new electronics technology - e.g., microprocessor control, smaller components, and greater current-handling semiconductors. However, the real future of pulse power supplies lies not in the equipment technology but in the sophisticated processes that require the use of pulse power to achieve the desired results.

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Finally, it is worth noting that the AESF has become increasingly active in this area. Its Third International Pulse Plating Symposium is scheduled for October 28-29 in Washington, DC, and authors are nearing completion of a society-sponsored book on the subject.

Yes, the future of pulse plating is now!

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About the Author

Norman M. Osero is president of Dynatronix, Inc. Amery, WI 54001. He has been active in the development, manufacture, and marketing of pulse plating equipment since 1971. Mr. Osero is a member of the AESF Upper Midwest Branch and holds a degree in electronics from North-central Technical Institute, Wausau WI.

DYNATRONIX

E-mail: sales@dynatronix.com

462 Griffin Blvd.
Amery, Wisconsin 54001 USA

Telephone: (715) 268-8118
FAX: (715) 268-8183
Toll-Free USA: (800) 826-7172

David Yamada
Dynatronix Western Regional Office
P.O. Box 11538
Pleasanton, CA 94588-1538
Phone: (925) 462-0344
Fax (925) 462-7233
E-mail David@xytek.com

Pat Mentone
Ph.D, Plating Consultant
Mentone Component Technology
1653 Pinehurst
St. Paul, MN 55116
Phone: (651) 699-3119
Fax: (651) 699-3129
E-mail: pmentone@compuserve.com

Dynatronix

Pulse Plating

Chuck Van Horn

Manager
Semi/Microelectronics
Ethone-OMI Inc.
West Haven, CT

Glossary Bath Considerations Equipment Considerations

Conventional pulse plating can simply be defined as metal deposition by pulsed electrolysis. Explanation in the simplest form is using interrupted D.C. current to electroplate parts. This is accomplished with a series of pulses of D.C. current, of equal amplitude and duration in the same direction, separated by periods of zero current. The pulse rate (frequency) and ON and OFF times (duty cycle) are controllable to meet the needs of a given application. The shape of the pulsed current is generally thought of as shown in Fig. 1A. An oscilloscope should be used to reveal how well the equipment controls the output. (See Fig. 1B)

This method of plating has gained acceptance in a number of metal finishing industries, especially the electronics industry. With the advent of solid state pulse plating power supplies, the art has been taken out of the process. The amount of time the current is off and the amount of time the current is on are set directly on the digital thumb wheel switches or on units with the software, programmed directly prior. There are two different modes of operation possible; constant current or constant voltage pulses. Figure 2 illustrates the constant current mode of operation. The tops of the current pulses are kept flat by allowing the voltage to vary during the pulses ON time. The situation is different in the constant voltage mode illustrated in Figure 3. The tops of the voltage pulses are kept flat by varying the current.

Because of the shape of the current pulse in this mode, the peak current is not useful to control the plating rate. An ampere-minute controller is needed to accurately control the plating thickness.

The advantages of pulse plating vary from one user to another. However, the most common are:

- Pulsing the current produces dense fine-grained deposits and in some cases such as gold plating, less gold is needed to meet an end-use specification.
- The variation in thickness from one part to the next is reduced considerably.
- Plating speeds can normally be increased. The current efficiency in most instances is better than conventional D.C. plating.
- The need for organic additives in most cases is reduced by 50 to 60%.
- The properties from the pulsed coating is summarized as follows:

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a. The coating is free from dendritic growth even if devoid of additives.
b. The coating has fine crystalline structures.
c. The coating is smooth.
d. The coating is nearly free of pinholes.
e. The current efficiency, in most instances, is better than D.C. plating.

The disadvantages, although minimal are:

1. In most cases the cost of a pulse rectifier are much greater than a D.C. unit. It is a highly regulated and sophisticated design that costs more to manufacture.
2. The technology requires one to think and plan ahead with a series of various procedures to follow to obtain the best results.
3. For the chemical manufacturer., the requirement for additives is reduced.
4. To take best advantage of the pulse capabilities, one must optimize the mechanics of the plating equipment design before applying the pulse unit. Areas of use for the pulse rectifiers are:

a. Reel to reel plating for speeds, distribution, and reasons mentioned prior.
b. Rack plating for the prior statements.
c. Gold (both pure and alloy), nickel, silver, copper, chrome, tin/lead, palladium and anodizing are all areas of use.
d. In some select cases pulse is being used in etching, cleaning, and electroforming.

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The theory behind pulse plating is simple. The cathode film is kept as rich in metal ions as possible and as low in impurities as possible. During the period when the current is ON, the metal ions next to the cathode are depleted and a layer which is rich in water molecules is left.

During the portion of the cycle when the current is OFF, the metal ions from the bulk of the plating solution diffuse into the layer next to the cathode. Then the process is repeated again. Also during the time the current is OFF, gas bubbles, and impurities which have been absorbed on the cathode have a change to desorb.

Typical ON times are from 0.1 to 9.9 milliseconds and typical OFF times from 1 to 99 milliseconds. If an ammeter is inserted into a plating circuit which uses pulsed current it would respond to the average current. In order to have the same plating rate using pulsed current as with D.C., the average current must be the same. Either the peak current, ON time or OFF time can be adjusted. By carefully picking the plating parameters the physical and chemical properties of the deposit can be very precisely controlled.

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One of the most dramatic advances in modern electroplating has been the recent use of microprocessor-controlled modulation of applied direct current to improve the electrodeposition process. The method has found application across a broad spectrum of the industry for both precious and non-precious metal plating. It is being used in real-to-reel selective plating, in automatic tab platers, on barrel lines, in still plating, electroforming, anodizing, electrocleaning, electro-polishing and machining and, most recently, has been adapted by the semiconductor bump and wafer plating technologies.

Results obtained with this sophisticated power control include (in addition to greatly increased plating speeds) improved distribution, lower deposit stress, finer grain structure, increased ductility, improved adhesion, increased micro-throwing power, reduced hydrogen embrittlement, and a markedly decreased need for additives.

A careful selection of a select few marketed series of modulated D.C. power supplies embodies the most advanced electronic circuitry to control output patterns with extreme precision.

Simply speaking, a high quality unit will superimpose periodic reverse on high frequency pulse. The power pattern that results, however, is quite complex with a wide range of profiles. The output, a series of pulses with controllable amplitude, frequency, duration and polarity, has an influence on the deposition characteristics of any solution which is far different from that of conventional pulse or periodic reverse. By "tuning" or shaping the output power pattern to a given plating application, the rate of deposition and the character of the deposit can be enhanced dramatically.

In periodic reverse plating, the polarity of a constant D.C. output is switched back and forth in a regular pattern. Figure 4A depicts the ideal output; Figure 4B shows the actual output from a slow-response control unit.

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The sharpens of the output current pattern as revealed by a scope depends upon the degree of ripple in the rectifier output and the quickness of response in the internal switching circuitry of the controller. Quality units produce extremely sharp square wave patterns when seen on a scope as shown in Figures 3 and 4.

Figure 5 illustrates the wave form of the Forward (cathodic) and Reverse (anodic) output of a quality unit.

The duration of the current in each direction, called the Forward and Reverse envelopes, can be individually controlled from 0.1 millisecond to 99.99 seconds. (The zero current delay of less than 0.1 millisecond indicated in the diagram between Forward and Reverse is a design feature of high quality units to prevent transistor failure due to "shoot through".)

The simple, square-wave in Figure 3 is a precisely controlled periodic reverse output upon which pulse frequencies are then superimposed. Within each envelope a square-wave pulse is generated as depicted in Figure 6. The frequency and the duration of the pulses are set independently for the forward and reverse envelopes. Frequency range is from 10 to 9,999 Hertz. Duty cycle settings in percentages determine ON and OFF for each pulse.

On some quality models, forward and reverse amplitude can be controlled individually as illustrated in Figure 7. This permits, for example, a higher current density in the reverse (deplating) state than in the forward (plating) stage - highly desirable for some applications. For a more complete explanation of output control with specific manufactured units, refer to the operational manuals supplied by the manufacturer.

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In order to avoid confusion, a very condensed "Glossary of Terms" follows:

Cathodic, Anodic

Used to describe current direction - i.e., Cathodic indicates flow is in normal (plating) direction; Anodic indicates flow is in reverse (deplating) direction.

Forward, Reverse

Used interchangeably with Cathodic and Anodic to indicate direction of current. In normal operation of a reversing pulse unit, current direction alternates in a controllable forward and reverse pattern.

Envelope

The time span during which current may flow in only one direction. The time spans of the Forward Envelope and the Reverse Envelope are set individually.

Pulse Train

A regularly interrupted current flow in either cathodic or anodic direction. A pulse Train exits within the envelope.

Pulse

The individual interval in a pulse train, consisting of an "ON and OFF" period.

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Pulse Rate

The number of times the current is switched on in a given period of time, usually a second.

Duty Cycle

The ratio of time an individual pulse is ON compared to the total pulse time (ON and OFF). For an example: 5 m/sec ON and 5 m/sec OFF is a 50% duty cycle; 4 ON and 1 OFF is an 80% duty cycle, etc. (Note that if the duty cycle is set for 100%, there is no OFF time. The current will be on for the duration of the envelope and there will be no pulse or frequency.)

Frequency

The pulse rate expressed as Hertz units, e.g., 100 Hertz = 100 pulses per second.

Pulse Width

The time span of the ON portion of a pulse. Pulse width is a function of both frequency and duty cycle. For example: a 1,000 Hertz pulse with a duty cycle of 50% has a pulse width of 0.5 milliseconds.

Bath Considerations

With the changes that take place in the tank when a modulated periodic reverse pulse is impressed on the electrolyte, changes in the other operating conditions or even in the formulation may be required. Generally speaking, better results are obtained with simpler, rather than sophisticated, formulations.

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The polarization imposed by the power pattern on the bath reduces, or even eliminates, the need for some addition agents. Typical formulations used in pulse plating:

NICKEL:	reel-to-reel with insoluble anodes, Watts type
Nickel Sulfate	650 g/L
Boric Acid	50 g/L
Temperature	60° C
pH	3 to 4
Anodes	Platinized Niobium
Organic Additives	None

Note: When using soluble nickel anodes and reversing pulse modes, the need for an anode activator such as chloride is not required as the reversing current keeps the anode active and soluble.

PURE GOLD

Potassium Citrate	150 g/L
Citric Acid	15 g/L
Potassium Phosphate	26 g/L
Boric Acid	72 g/1
Gold Metal	8.2 g/1
Temperature	140° F
pH	3.5 to 4.0
Anodes	Platinized titanium

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HARD GOLD

Citric Acid	65 g/L
Potassium Citrate	50 g/L
Cobalt	0.5 to 0.6 g/L
Gold	8.2 g/L
pH	3.8 to 4.0
Temperature	90 to 100° F

With pulse, you have a higher voltage than with D.C. plating. As voltage favors the deposition of the alloying agent, one must analyze the deposit to determine if an adjustment to the amount of cobalt in solution must be made. In most cases, the reduction of available cobalt or any alloying agent must be reduced to obtain the desired hardness etc.

In many cases, additives can actually inhibit the effectiveness of the power pattern. Large molecule additives do not respond as they do under conventional power. In a high frequency pulse field, their molecular size is a disadvantage. Small molecule organic or inorganic will generally function well as additives. In many cases, brighteners can be reduced as much as 90% without diminishing the brightness of the deposit because of the improved grain structures. (If brightener level is not reduced, longer pulses - i.e., lower frequency and/or higher duty cycle, may be required.)

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It is vital that the conductivity of the electrolyte be maintained at a high level to allow the peak pulse current to be completely effective. If the conductivity is not high enough, an excess in voltage will be required to attain the desired peak current. Such peaks are power-inefficient and less effective.

Note that anode-to-cathode ratios are rarely the same as for conventional power applications. Generally speaking, in acid or alkaline non-chelating formulations, the anode area should be reduced. In a cyanide or other chelating formulations, the reverse is generally the case, and a greater anode area is required.

Temperature and agitation conditions may also have to be altered from normal for modulated power pattern plating. Unfortunately, no general rule applies; each application has its own requirements.

Equipment Considerations

One factor which should always be checked when planning a change in power is the tank electrical contact system. Although perfectly suitable for conventional plating, some anode an/or cathode contacts may present unwanted resistance to high frequency peak currents. Overlooking this factor may prevent the realization of the true benefits of a modulated power supply.

The major consideration, of course, is the power system itself. Existing rectifiers may or may not be suitable for use with modulated periodic reverse or direct pulse units. A high voltage, quick response rectifier is required, and the lower the ripple the more precise and predictable the output.

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Although pulse units are available for use with existing power supplies, the models with self-contained rectifiers specifically designed for this function give greater assurance that full benefit of the control system will be realized.

Quality pulse units with self contained power may be operated in either a constant average current or constant voltage mode. The significance of this option is illustrated graphically in Figure 8.

Figure 8A is a depiction of a pulse train with a 50% duty cycle. The average current delivered is 50% of the peak value, represented by the dotted line.

Figure 8B illustrates the effect of reducing the duty cycle to 25% when in a constant voltage mode. The peak current remains the same, but the average current changes directly with the duty cycle, in this case dropping to half its former value. Note that the current density of the pulsed current will remain the same, but twice as much real time will be required to deliver the same ampere-minutes of current.

Figure 8C shows the effect of reducing the duty cycle from 50% to 25% when operating in constant average current mode. In this case, the peak current changes inversely to the duty cycle, increasing in value to maintain the same average current delivered as before but in shorter pulses.

Figure 9 illustrates what should be apparent; that a change in frequency, although it, too, changes the pulse width, does not effect either peak or average current regardless of output mode.

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There is one other consideration that must be made, and which, unfortunately, is occasionally overlooked in "sizing up" the unit required. Unlike conventional plating rectifiers which are rated by average current capacity (ignoring the ripple), modulated periodic reverse pulse units are normally rated by their peak current capacity. Since both peak and average current values are intrinsic to modulated power pattern plating, both output capacities must be considered. Depending upon the internal circuitry of the unit, the average current output capacity of some makes may be as low as 25% or 30% of the peak capacity.

With that low value for average current, the rated peak current output would be attained even at average current capacity only if a duty cycle as low as 25% or 30% was used. Attempting to push average current up would drastically shorten the life of the unit. Since experience has shown that effective duty cycles are rarely less than 50% most units are designed to deliver an average current capacity of 50 to 60% of the peak current capacity rating. However, any desired duty cycle may be used or specified, keeping in mind that the average current is the percentage (duty cycle) of the peak rating.

References

1. H.Y. Chen, J. Electrochem Society., 11W 551 (1971)
2. R.J. Tedeschi, Metal Finishing, Nov.49 (1971)
3. J. Padden, Pwr, Inc., J. Lochet, C. Vanhorn, Vanguard West, Inc. - "Improvement of electrodeposition through modulated D.C. power patterns" (1981)

For further information, Contact Chuck VanHorn c/o
Enthone-OMI, Inc.
P.O. Box 1900
New Haven, CT 06508

Marketing Services Dept
Tel: (203) 799-4907
Fax: (203) 799-1513

Top

DYNATRONIX

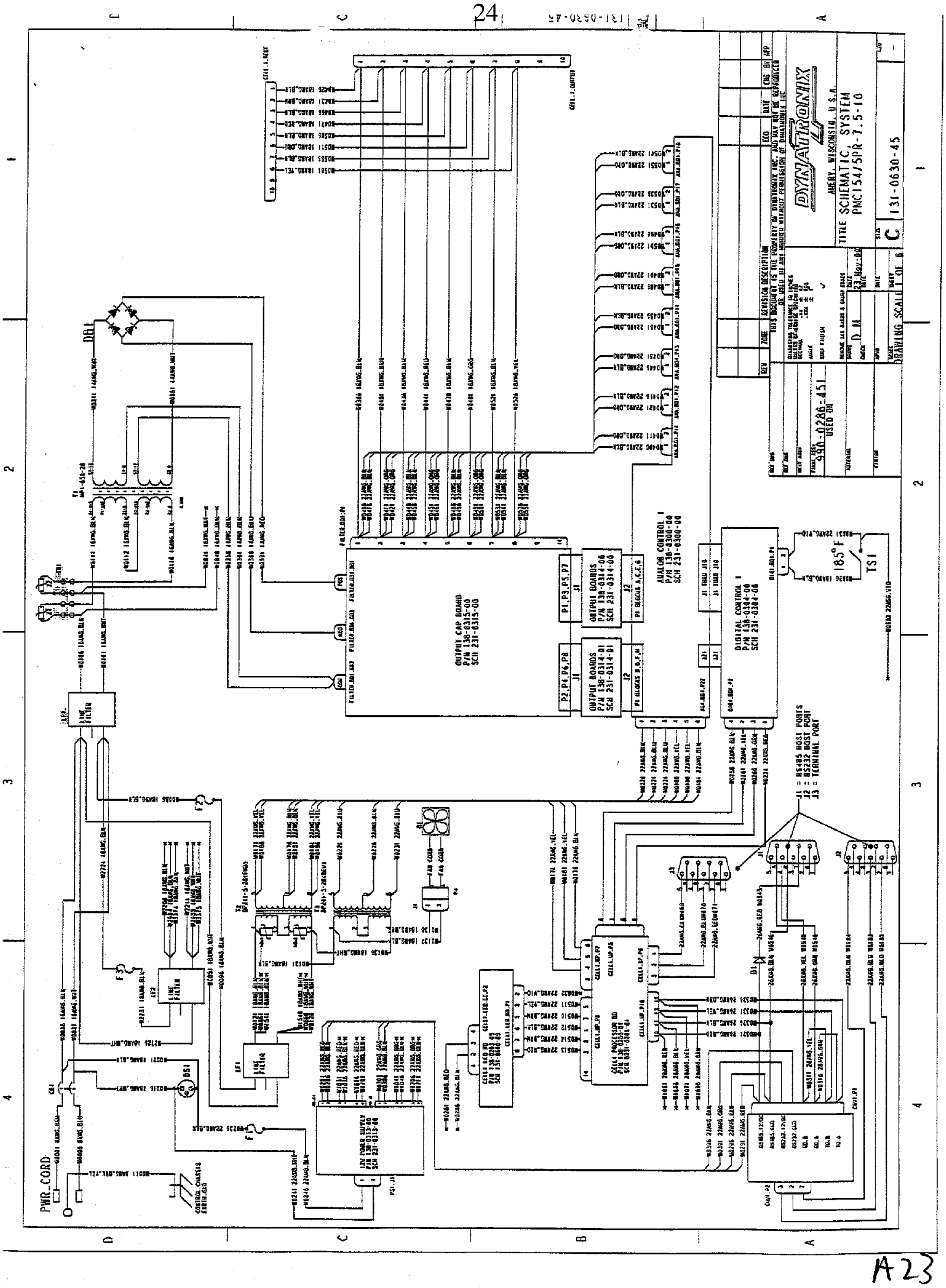
E-mail: sales@dynatronix.com

462 Griffin Blvd.
Amery, Wisconsin 54001 USA

Telephone: (715) 268-8118
FAX: (715) 268-8183
Toll-Free USA: (800) 826-7172

David Yamada
Dynatronix Western Regional Office
P.O. Box 11538
Pleasanton, CA 94588-1538
Phone: (925) 462-0344
Fax (925) 462-7233
E-mail David@xytek.com

Pat Mentone
Ph.D, Plating Consultant
Mentone Component Technology
1653 Pinehurst
St. Paul, MN 55116
Phone: (651) 699-3119
Fax: (651) 699-3129
E-mail: pmentone@compuserve.com



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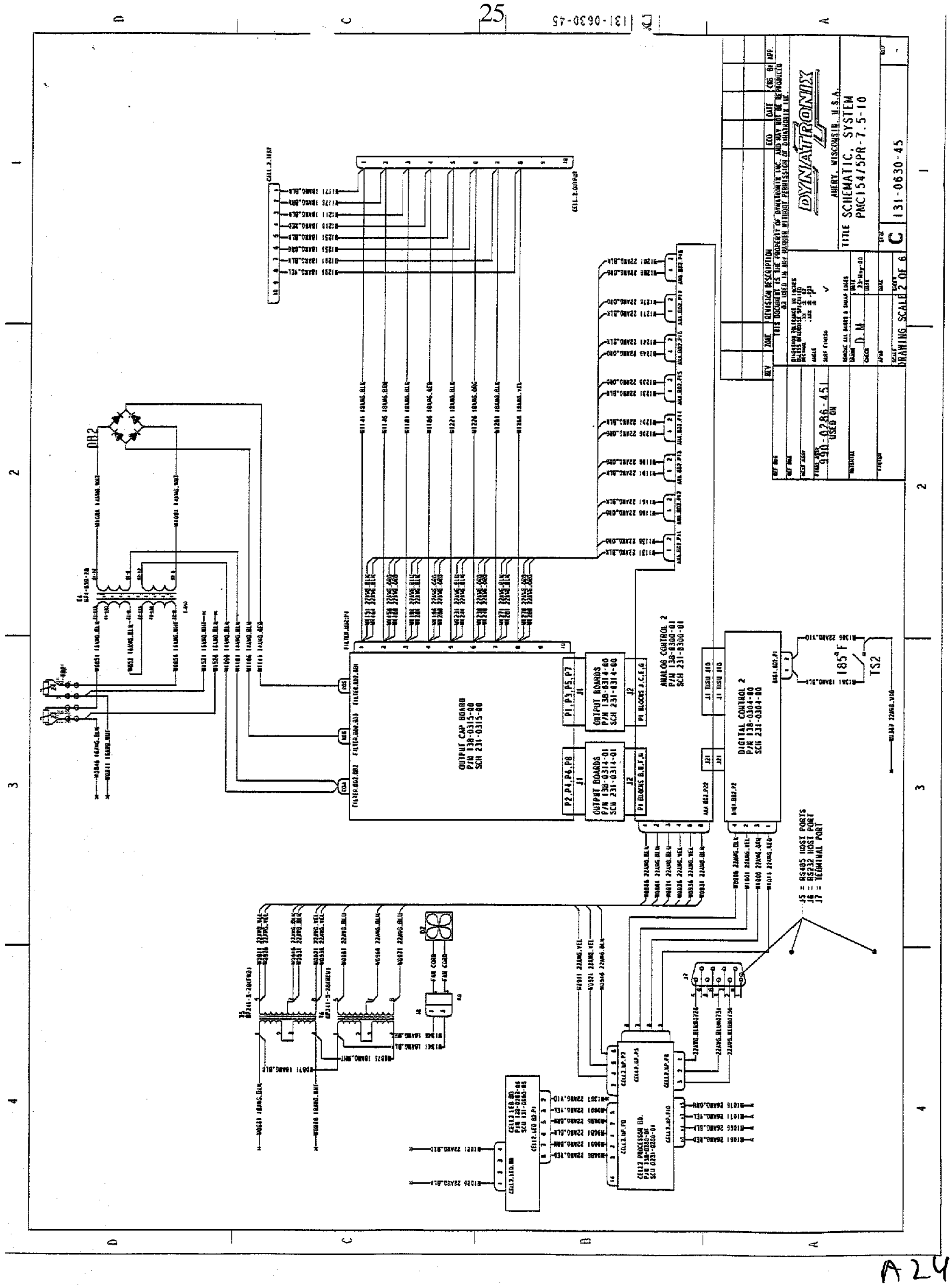
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PMC154/5PR-7.5-10
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OUTPUT BOARDS
ANALOG CONTROL 2
DIGITAL CONTROL 2
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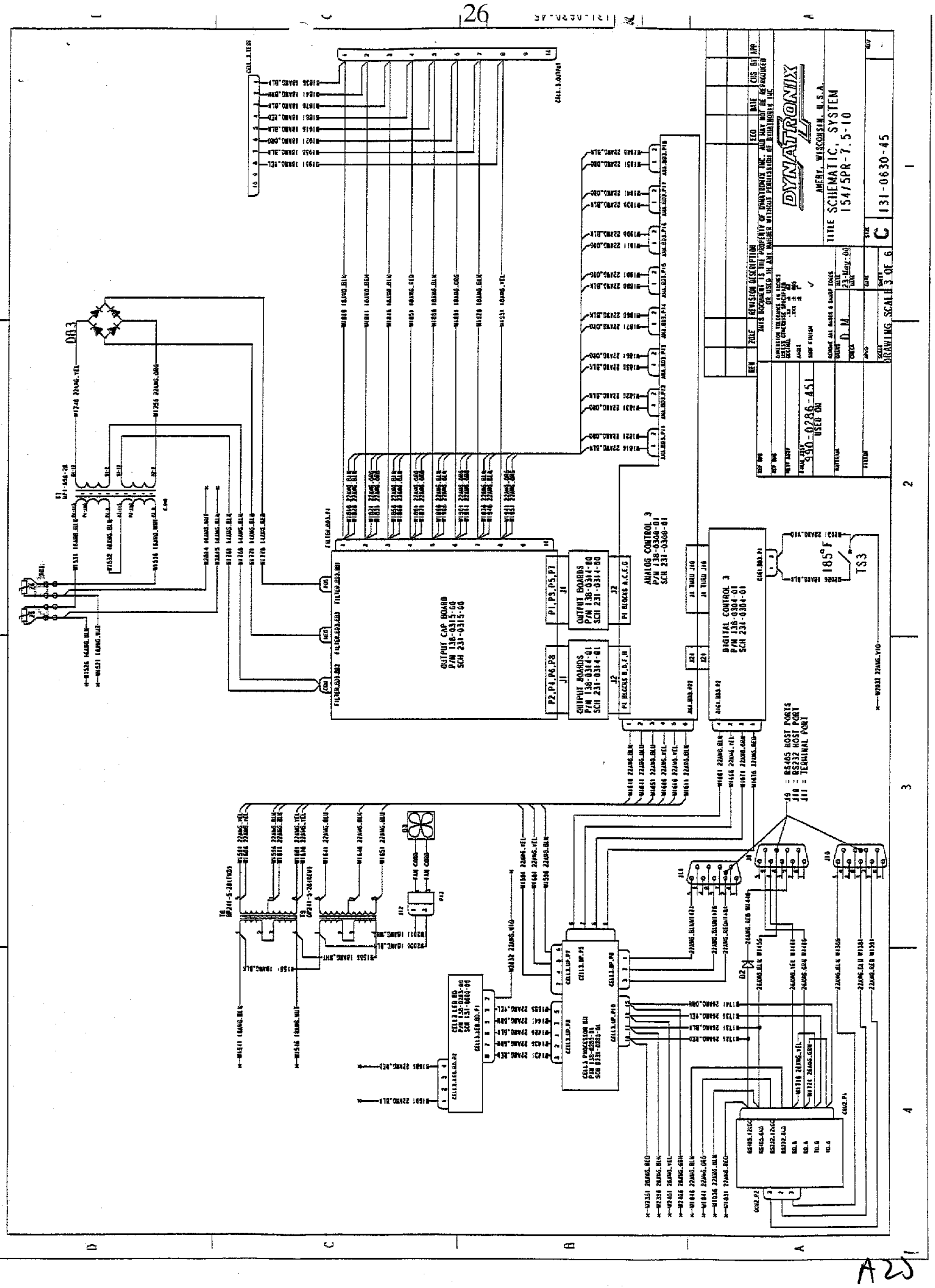
TS2
DB2

A24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131-0630-45
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SCH 231-0315-00
ANALOG CONTROL 3
P/N 138-0300-01
SCH 231-0300-01
DIGITAL CONTROL 3
P/N 138-0304-01
SCH 231-0304-01
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DB3
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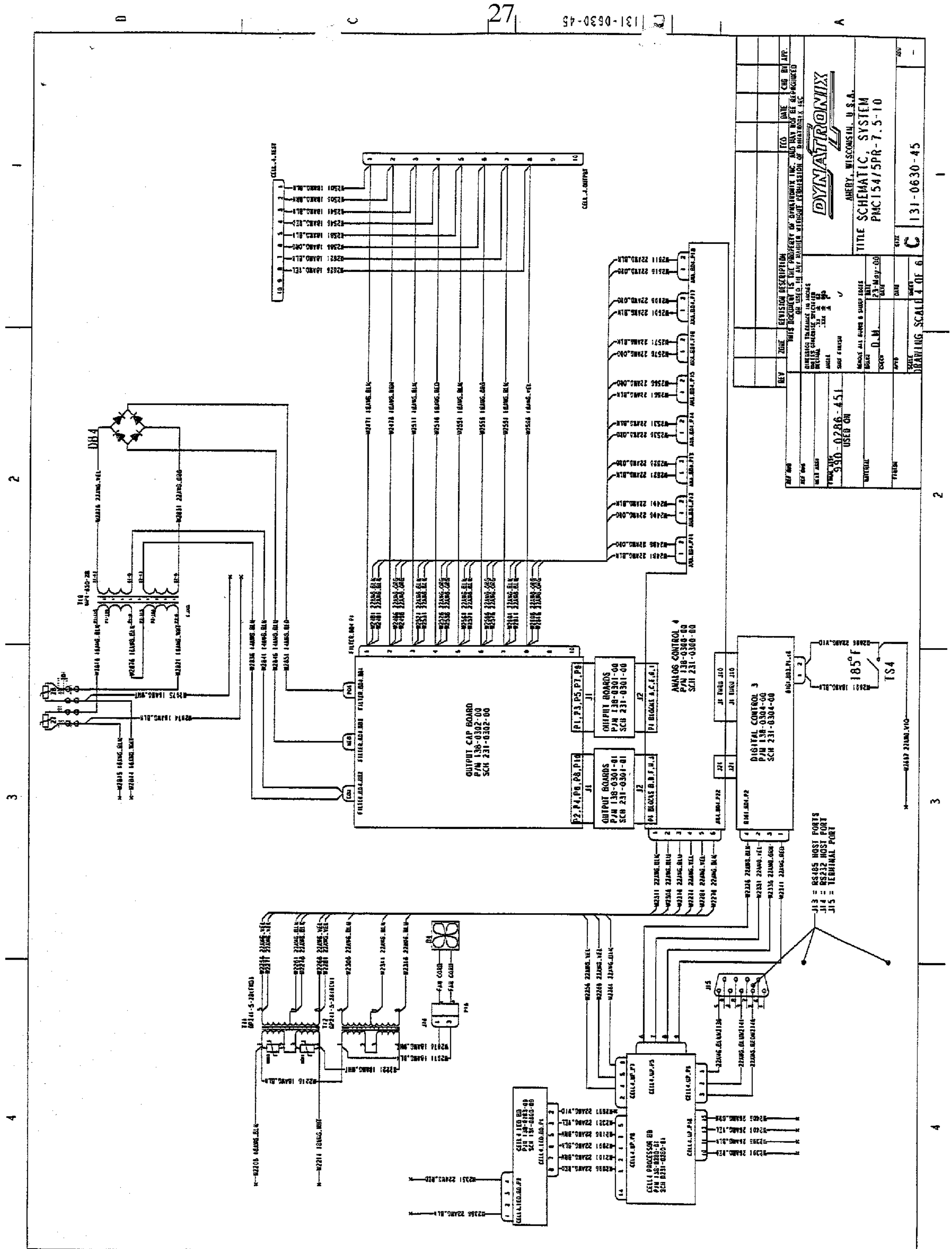
J10 = RS232 HOST PORT
J11 = TERMINAL PORT

A25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990-0286-451
USED ON
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SCH 231-0302-00
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P/N 138-0300-00
SCH 231-0300-00
DIGITAL CONTROL 3
P/N 138-0304-00
SCH 231-0304-00
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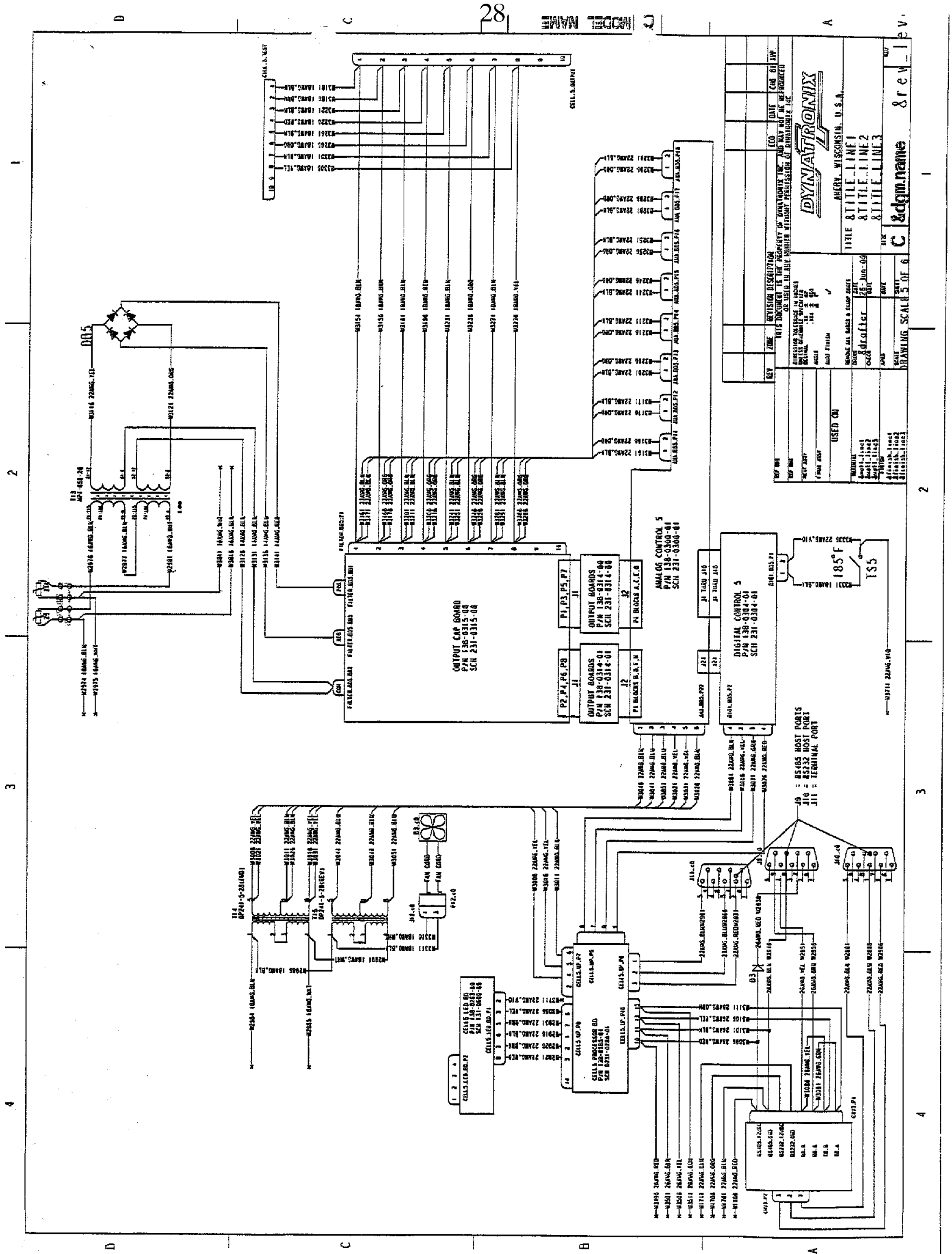
J14 = RS232 HOST PORT
J15 = TERMINAL PORT
185°F
TS4
DB4

A26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AMERY, WISCONSIN, U.S.A.
OUTPUT CAP BOARD
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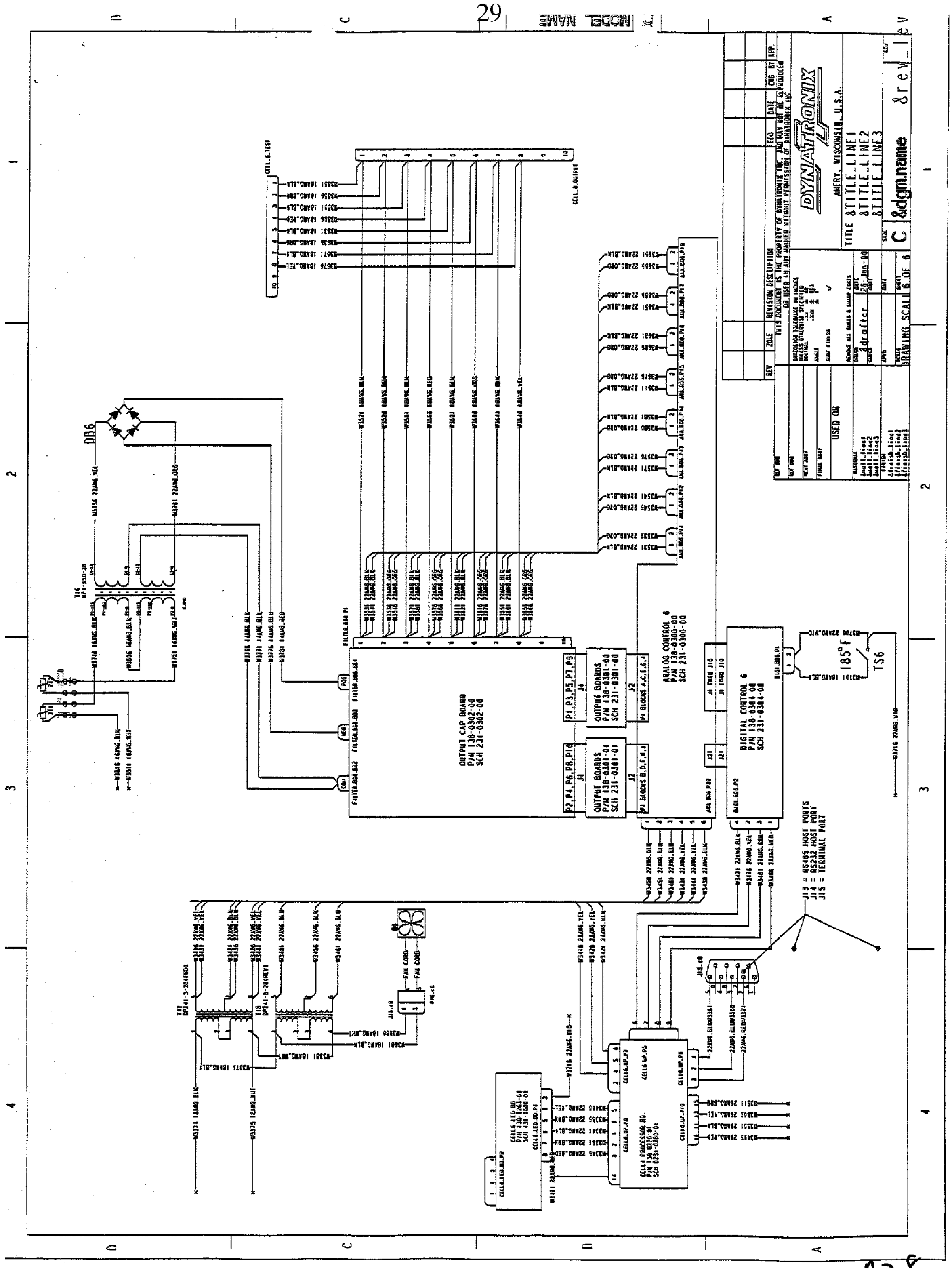
ANALOG CONTROL 5
DIGITAL CONTROL 5
185°F
TS5

A27



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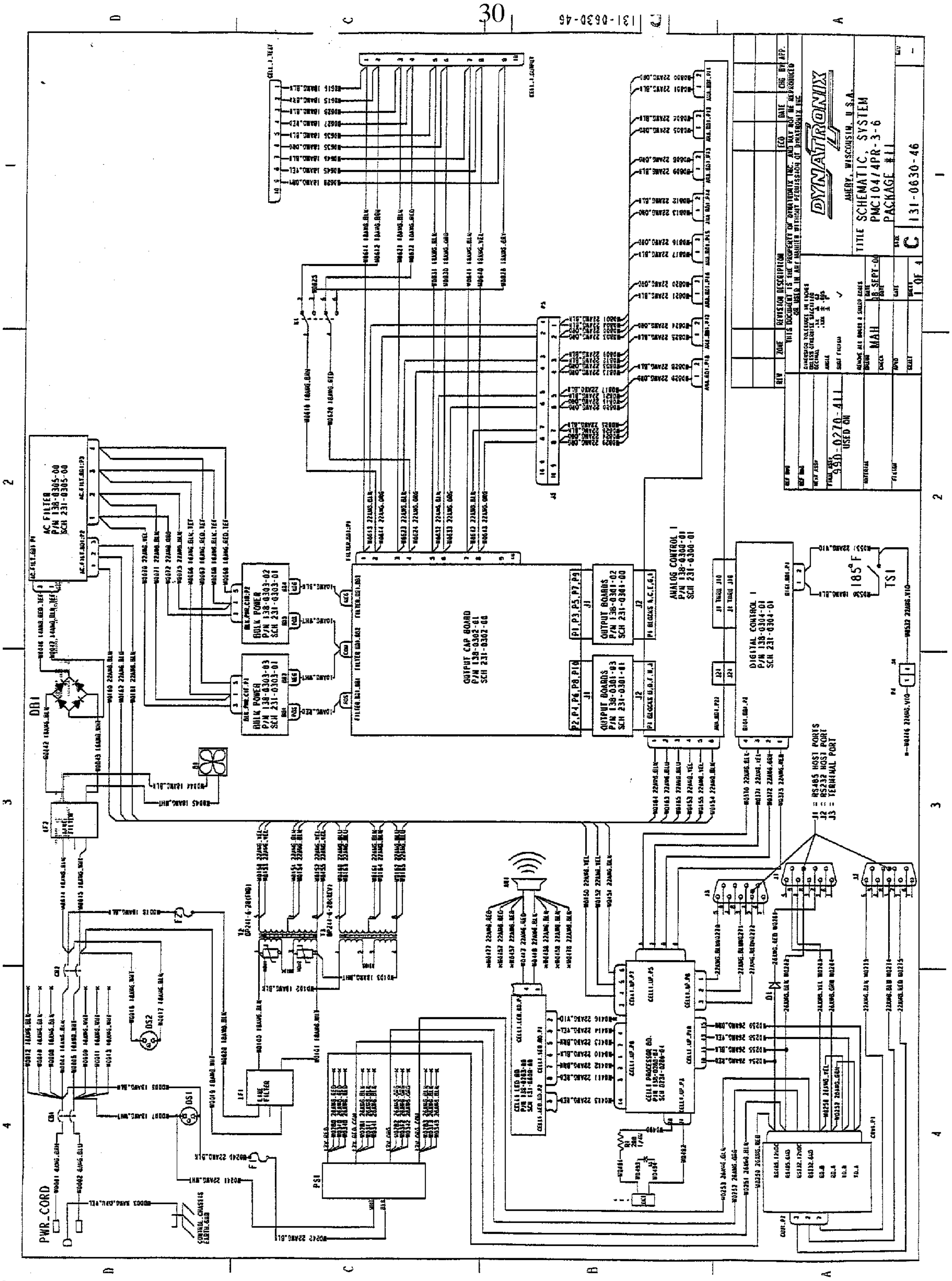

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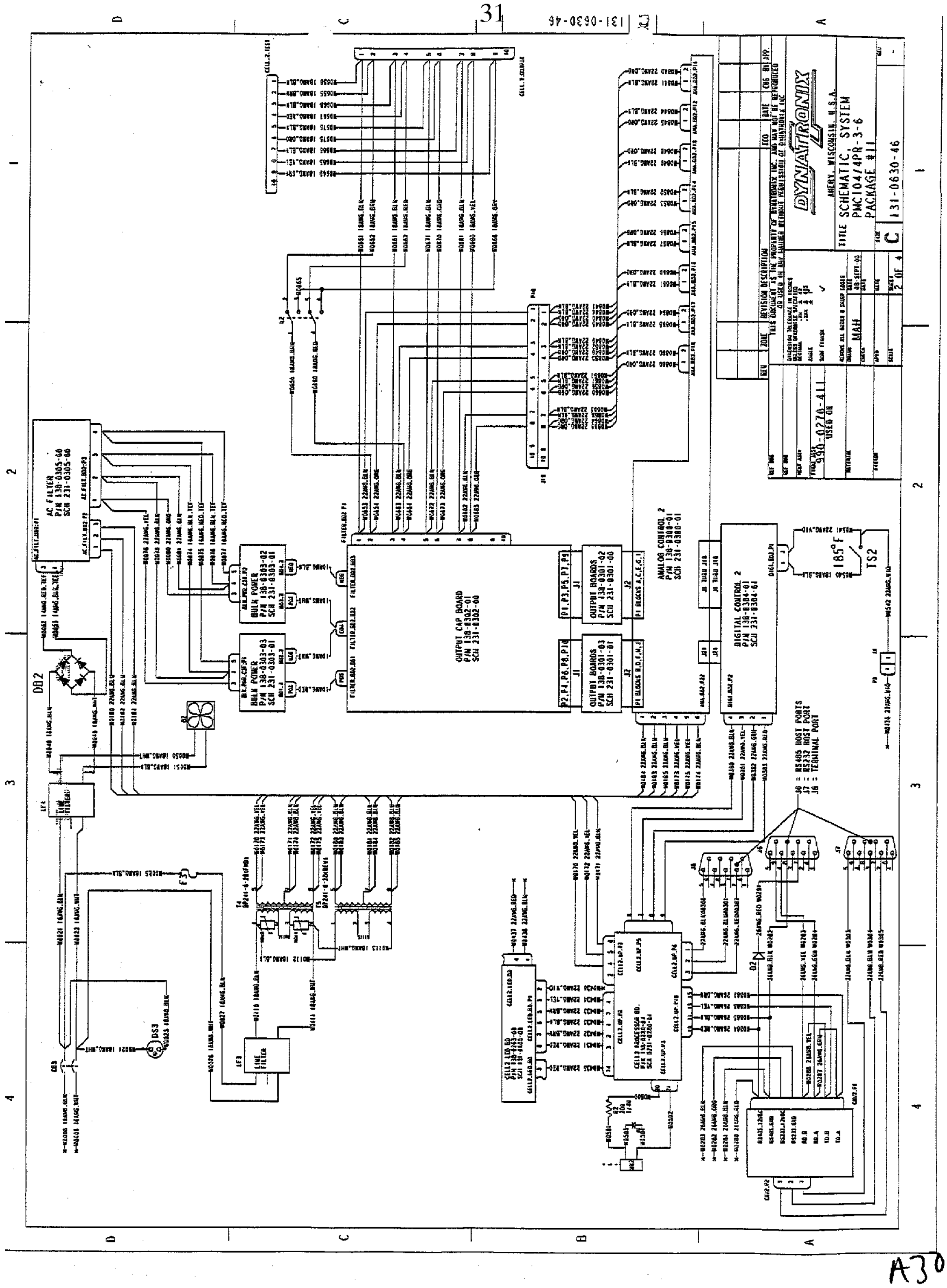

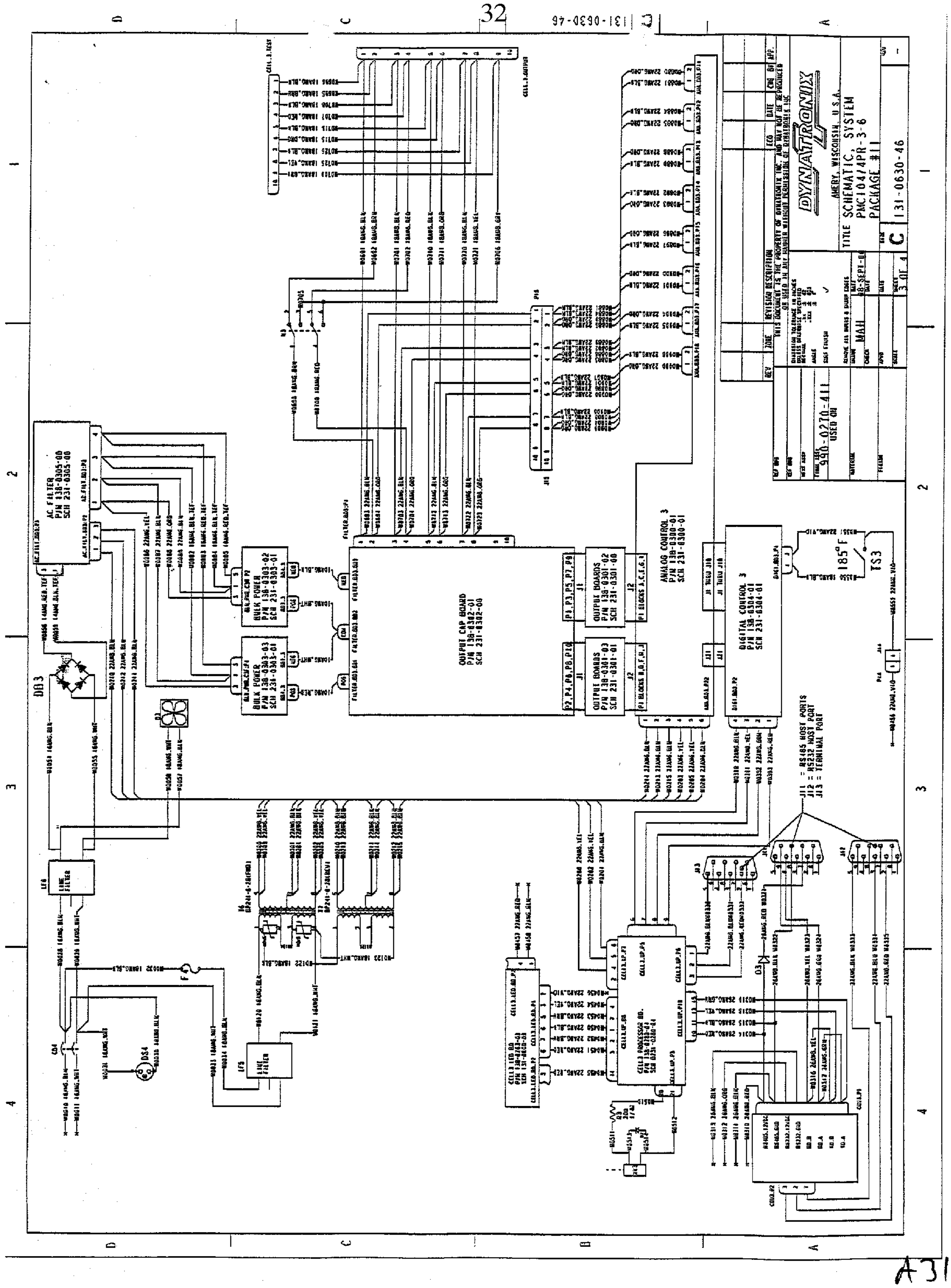

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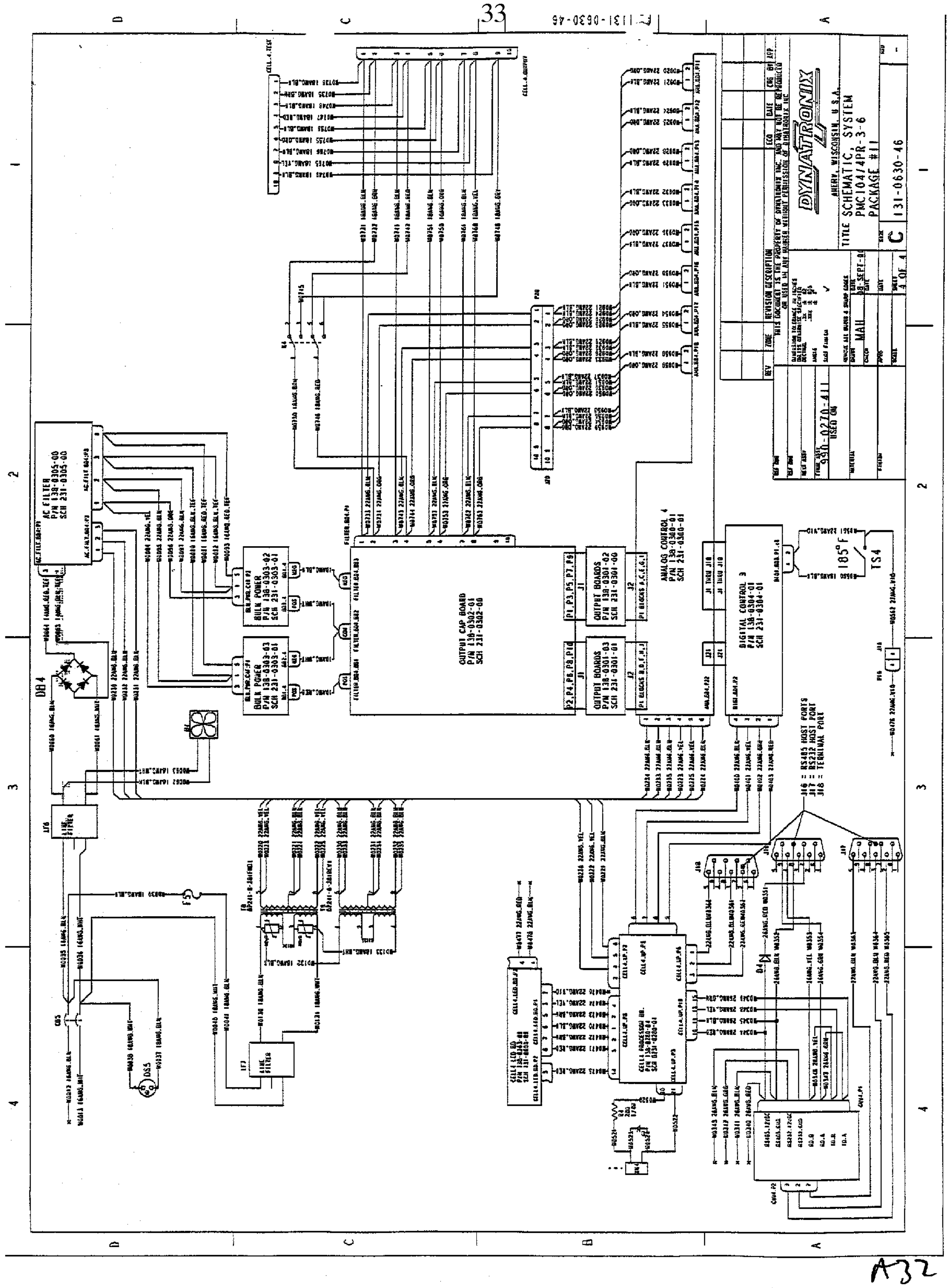

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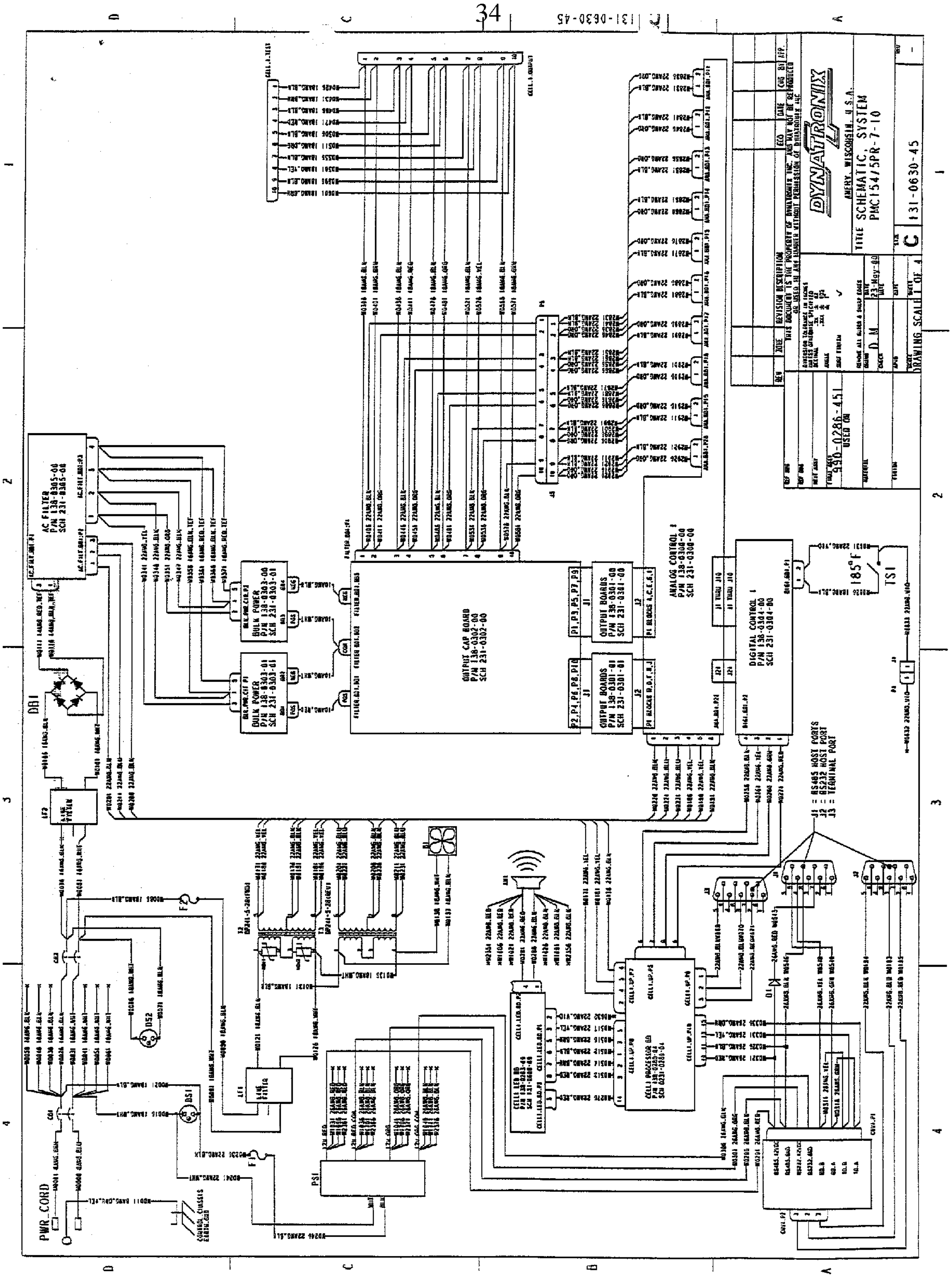
DYNATRONIX
AMERY, WISCONSIN, U.S.A.
SCHEMATIC, SYSTEM
PMC154/5PR-7-10
131-0630-45
OUTPUT CAP BOARD
DIGITAL CONTROL I
ANALOG CONTROL I
AC FILTER
BULK POWER
OUTPUT BOARDS
PWR_CORD
185° F
TS1

A33

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:

Exclusions: None

View Options: Normal

Parent: 990-0270-641 Desc: PMC106/4PR-3-6 PROG. M-ICHNL,PKG#13

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
001	131-0636-641 SCH,SYS,PMC106/4PR-3-6,SEMITOOL	0	X	EA		
001	155-0696-641 WIRETAB,PMC106/4PR-3-6,SEMITOOL	1	X	EA		
001	198-0361-06 MANUAL,PMC106/4PR-3-6,XR	1	N	EA	MANUAL	
010	130-0740-05 ASSY,CHASS,PMC106/4PR-3-6,XT RNG.	1	N	EA	CHASSIS	
020	123-0679-07 ASSY,PANEL,FRONT,PMC106/4PR-3-6 XR	1	N	EA	FRPNLASSY	
020	130-0741-06 ASSY,CHASSIS,PWR CTRL,PMC106/4PR-3-	1	N	EA	PROC_XFMR	CHASSIS
030	003-0712-06 PANEL,RIGHTSIDE,PMC106/4PR-3-6	1	N	EA	PNL_RGHT	
030	003-0712-05 PANEL,LEFTSIDE,PMC106/4PR-3-6	1	N	EA	PNL_LEFT	
030	114-0013-00 LINE FILTER; 20 AMP 250 VOLT SWITCH	1	N	EA	LF1	
030	010-0262-02 BRACKET, A/I BOARD MTG; MOD FOR FUS	1	N	EA	BRKT_FUSE	
030	010-0291-01 BRACKET; TERM&CELL SEL. PMCPR105/1-	1	N	EA	BRKT_TERM	
030	070-0090-00 FUSE HOLDER;ROUND;20A; STRAIGHT SOL	3	N	EA	XF1 - XF3	
030	025-0349-12 SWITCH; ROTARY;3D;1P;12POS;.25A;W/3	1	N	EA	SW1	
030	045-0010-00 KNOB;ROUND 5/8 DIA 1/4 SHAFT BLK CH	1	N	EA	XSW1	
030	024-0395-09 CONN;9-P D-TYPE;MALE HOUSING;FEM.SL	1	N	EA	J7	
030	024-0412-00 JACKSCREW; 4-40 FEM; .125 IN. PNL;	2	N	EA	XJ7	
030	011-0080-03 COVER,PMC106/4PR-3-6,	1	N	EA		
030	003-0713-07 PANEL, REAR, PMC106/4PR-3-6	1	N	EA	PNL_REAR	

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
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View Options: Normal

Parent: 990-0270-641 Desc: PMC106/4PR-3-6 PROG. M-ICHNL,PKG#13

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
030	018-0083-02 LABEL,CELL SELECT;TERM PORT;.5A	1	N	EA	CMT30	TERMINAL PORT LABEL
030	070-0100-00 FUSE .75 AMP 1/4 X 1 1/4 SLO-BLO CE	3	N	EA		
030	018-0083-04 LABEL,FUSE,6CELL, .75AMP LOGIC	1	N	EA	LABEL, LOGIC_FUSE	
030	018-0085-03 LABEL,DYN.HOST PORTS,3 SEP.RS232/48	1	N	EA	LABEL_COMM, PORT	
030	018-0104-00 LABEL,OUTPUT,PMC 6CEL 2CH,.2SP,CAT	1	N	EA		
031	024-0325-00 CONN;RECEPTACLE 3 CIRCUIT W/LOCK (M	6	N	EA	J10, J13, J16, J19, J22, J25	
031	024-0326-00 CONN; PLUG 3 CIRCUIT W/MTG EARS (FE	6	N	EA	P10, P13, P16, P19, P22, P25	
032	024-0243-12 PLUG; 12 CKT FEMALE HSNG	6	N	EA	J11, J14, J17, J20, J23, J26	
032	024-0244-12 CONN; 12 CKT MALE HSNG	6	N	EA	P11, P14, P17, P20, P23, P26	
032	024-0256-00 CONN.; 6 CIRCUIT; MALE HOUSING	6	N	EA	P9, P12, P15, P18, P21, P24	
032	024-0257-00 CONN.; 6 CIRCUIT W/EARS; FEMALE HOU	6	N	EA	J9, J12, J15, J18, J21, J24	
032	024-0434-06 HSNG; IDC;CLSD;6 POS;22GA;SNGL.ROW;	6	N	EA	DIGI_BD_P2	
032	024-0436-06 STRAIN RLF;IDC;CLSD;6 POS;SNGL.ROW;	6	N	EA	DIGI_BD_XP	
032	024-0413-00 CONN. HSNG 4 CKT W/MTG EARS RECEPT	1	N	EA	P8	
032	024-0414-00 CONN. HOUSING 4 CKT W/ MTG EARS PLU	1	N	EA	J8	
032	024-0443-04 CONN;TERM.BLK;PLUG-IN;5MM CENTERS;4	1	N	EA	PS1_J3	
033	210-2003-00 ASSY; HOST SOFTWARE; UTILITIES; DYN	1	N	EA		
033	020-0005-01 CABLE;COMPUTER;RS-232;9 PIN FEM TO	1	N	EA		

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 990-0270-641 Desc: PMC106/4PR-3-6 PROG. M-ICHNL,PKG#13

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text

*** END OF REPORT ***

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 138-0300-00 Desc: CCA,SHUNT SEL./REG. CARD,PMC155PR-7

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
001	231-0300-01 SCH, RANGE SELECT/REG CIRCUITS 1	0	X	EA		
010	190-0300-01 PWB,PRECISION OUTPUT/SHUNT SELECT,	1	N	EA	PWB	
020	029-0360-04 IC,DG444DY,4X ANA SW,RDS=85OHM,LO C	30	N	EA	U2, U4, U6	BLOCK A-J
030	029-0361-01 IC,LTC1293BCS,A/D,6CH.12-BIT,SER.I/	10	N	EA	U11	BLOCK A-J
040	029-0391-01 IC,AD7249BR,12-BIT,2CH VO DAC,W/SER	10	N	EA	U5	BLOCK A-J
050	029-0281-00 IC;LM336Z-2.5; VLTG REF 2.5V .3 /10	10	N	EA	Q5	BLOCK A-J
060	029-0350-00 IC;LM336Z-5.0;PREC. 5V REF	10	N	EA	Q6	BLOCK A-J
070	021-0087-00 TRANSISTOR;MPF990;FET N-CH;90V;2A;T	10	N	EA	Q4	BLOCK A-J
080	021-0127-00 TRANS;N CH.(FET); 30A; 60V; RDS=.05	15	N	EA	(R)Q1 - (R)Q3	BLOCK B,D,F,H,J (REV)
090	021-0128-00 TRANS;P CH.(FET); 30A; 60V; RDS=.08	15	N	EA	(F)Q1 - (F)Q3	BLOCK A,C,E,G, I (FWD)
100	022-0138-01 DIODE,SWITCHING,1N4148W 150MA,75V,S	50	N	EA	D5 - D9	BLOCK A-J
120	022-0151-01 DIODE SD101AW,15MA IFWD,60 VREV,SCH	30	N	EA	D10 - D12	BLOCK A-J
130	022-0224-00 DIODE,ZENER,MMSZ5231B,5.1V,SOD-123	40	N	EA	D1 - D4	BLOCK A-J
140	022-0198-14 DIODE, ZENER, 1N5351B, 14V, 5W, AXI	2	N	EA	D100, D107	
150	022-0119-00 DIODE; GENERAL; 1N4004; 400V/1A; DO	6	N	EA	D101 - D106	
160	022-0163-00 DIODE;VM48;DUAL IN LINE BRIDGE ASSY	2	N	EA	BR1, BR2	
171	029-0373-01 IC,LT1220CS8,OP AMP HIGH-SPEED, 8-P	30	N	EA	U1, U8, U9	BLOCK A-J
172	029-0400-01 OPAMP,OPA27,SOIC	10	N	EA	U7	BLOCK A-J

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 138-0300-00 Desc: CCA,SHUNT SEL./REG. CARD,PMC155PR-7

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
180	029-0396-01 IC,OPAMP,LT1358,8-PIN SOIC,DUAL,25M	20	N	EA	U3, U10	BLOCK A-J
200	106-0211-1004 RESISTOR,SMT,1 MEG OHM,1/8WATT,1%,1	40	N	EA	R10, R12, R16, R56	BLOCK A-J
210	106-0214-1003 RESISTOR,SMT,100 K OHM,1/8WATT,0.1%	20	N	EA	R5, R6	BLOCK A-J
220	106-0211-4992 RESISTOR,SMT,49.9K OHM,1/8WATT,1%,1	10	N	EA	R22	BLOCK A-J
230	106-0211-4752 RESISTOR,SMT,47.5K OHM,1/8WATT,1%,1	20	N	EA	R50, R52	BLOCK A-J
240	106-0211-4532 RESISTOR,SMT,45.3K OHM,1/8WATT,1%,1	20	N	EA	R53, R54	BLOCK A-J
250	106-0211-3322 RESISTOR,SMT,33.2K OHM,1/8WATT,1%,1	40	N	EA	R45, R47 - R49	BLOCK A-J
280	106-0211-2872 RESISTOR,SMT,28.7K OHM,1/8WATT,1%,1	20	N	EA	R3, R51	BLOCK A-J
290	106-0211-2802 RESISTOR,SMT,28.0K OHM,1/8WATT,1%,1	20	N	EA	R38, R40	BLOCK A-J
300	106-0211-2552 RESISTOR,SMT,25.5K OHM,1/8WATT,1%,1	10	N	EA	R21	BLOCK A-J
310	106-0211-2492 RESISTOR,SMT,24.9K OHM,1/8WATT,1%,1	20	N	EA	R20, R69	BLOCK A-J
320	106-0211-1002 RESISTOR,SMT,10.0K OHM,1/8WATT,1%,1	110	N	EA	R17, R18, R24 - R26, R39, R41, R43, R46, R55, R66	BLOCK A-J
330	106-0211-1002 RESISTOR,SMT,10.0K OHM,1/8WATT,1%,1	5	N	EA	R44	BLOCK B,D,F,H,J
350	106-0211-4991 RESISTOR,SMT,4.99K OHM,1/8WATT,1%,1	20	N	EA	R32, R34	BLOCK A-J
360	106-0211-3011 RESISTOR,SMT,3.01K OHM,1/8WATT,1%,1	20	N	EA	R36, R37	BLOCK A-J
370	106-0211-2001 RESISTOR,SMT,2.00K OHM,1/8WATT,1%,1	70	N	EA	R11, R14, R15, R61 - R64	BLOCK A-J
380	106-0211-1001 RESISTOR,SMT,1.00K OHM,1/8WATT,1%,1	110	N	EA	R19, R27 - R31, R33, R57 - R60	BLOCK A-J
410	106-0211-7500 RESISTOR,SMT,750 OHM,1/8WATT,1%,100	10	N	EA	R67	BLOCK A-J

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 138-0300-00 Desc: CCA,SHUNT SEL./REG. CARD,PMC155PR-7

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
420	106-0211-6040 RESISTOR,SMT,604 OHM,1/8WATT,1%,100	20	N	EA	R23, R68	BLOCK A-J
430	106-0211-6819 RESISTOR,SMT,68.1 OHM,1/8WATT,1%,10	10	N	EA	R70	BLOCK A-J
440	106-0213-3008 RESISTOR,5W,3.0 OHM,1%,WW	10	N	EA	R2	BLOCK A-J
450	105-3309-00 RES.;33 OHM;2W;5%; CARB. CMP.	5	N	EA	R1[F]	BLOCK A,C,E,G,I [LOW RANGE FWD]
450	105-1509-00 RES.;15 OHM;2W;5%; CARB. CMP.	5	N	EA	R1[R]	BLOCK B,D,F,H,J [LOW RANGE REV]
500	036-0124-00 SHUNT; RES. TYPE; 4 LEAD; .1 OHM; .	10	N	EA	SH2	BLOCK A-J
510	036-0125-00 SHUNT; RES. TYPE; 4-LEAD; 1 OHM; .1	10	N	EA	SH1	BLOCK A-J
520	036-0151-01 SHUNT,RES.TYPE,4-LEAD,.01 OHM,.1%,2	10	N	EA	SH3	BLOCK A-J
600	023-0579-00 CAP,820UFD,35V,18MMDIAX15MM,RADIAL,	6	N	EA	C106, C111, C115, C118, C122, C127	
610	023-0553-00 *CAP, 1UFD, 50V, CERAMIC, X7R, 0.2L	18	N	EA	C100, C102, C105, C107, C109, C110, C113, C114, C116, C117, C119, C120, C123, C125, C126, C128, C131, C133	
620	023-0554-00 *CAP, 2.2UFD, 50V, CERAMIC, Z5U, 0.	6	N	EA	C101, C108, C112, C121, C124, C132	
642	023-0581-00 CAP,1.0UF,10%,35V,TANT,3528 SMT PKG	90	N	EA	C12, C13, C18, C19, C30, C32, C33, C37, C42	
660	023-0538-00 CAPACITOR; 4.7MFD 25V. TANT .196 DI	40	N	EA	C14 - C17	BLOCK A-J
670	023-0466-00 CAP;10MFD 25V TANTALUM .225 DIA X .	4	N	EA	C103, C104, C129, C130	
680	023-0580-104 CAP,0.1UF,50 V, 0805 SMT PKG.,Z5U	120	N	EA	C2, C20, C21, C23, C27, C29, C31, C35, C36, C38 - C40	BLOCK A-J
690	023-0580-050 CAP,5PF,50 V, 0805 SMT PKG.,NPO	10	N	EA	C1	BLOCK A-J
700	023-0510-00 CAP;560PF 50VOLTS (.15MAX.WDTH .15M	5	N	EA	C8[F]	BLOCK A,C,E,G,I [LOW RANGE CURRENT COMP]

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 138-0300-00 Desc: CCA,SHUNT SEL./REG. CARD,PMC155PR-7

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
710	023-0557-00 CAPACITOR; 330PF; 50V; NPO CERAMIC.	10	N	EA	C9	BLOCK A-J [MID-RANGE CURRENT COMP]
710	100-1001-00 RES.;1K OHM;1/4W;1% METAL FILM	10	N	EA	R9	BLOCK A-J [MID-RANGE CURRENT]
720	023-0585-271 CAP,CER.,50V,270PF,COG	5	N	EA	C3[F]	BLOCK A,C,E,G,I [HIGH RANGE FWD]
720	100-3321-00 RES.;3.32K OHM;1/4W 1% METAL FILM	5	N	EA	R7[F]	BLOCK A,C,E,G,I [HIGH RANGE FWD]
730	100-6041-00 RES.;6.04K OHM;1/4W 1% METAL FILM	5	N	EA	R13[F]	BLOCK A,C,E,G,I [VOLTAGE FWD]
730	023-0556-00 CAPACITOR; 220PF;50V;NPO CERAMIC	5	N	EA	C10[F]	BLOCK A,C,E,G,I [VOLTAGE FWD]
740	023-0585-681 CAP,CER.,50V,680PF,COG	5	N	EA	C8[R]	BLOCK B,D,F,H,J [LOW RANGE REV]
750	023-0499-00 CAP;470 PF;100V;COG/NPO;.15X.15 RAD	5	N	EA	C3[R]	BLOCK [B,D,F,H,J]
750	100-1101-00 RES.;1.10K OHM;1/4W; 1% METAL FILM	5	N	EA	R7[R]	BLOCK [B,D,F,H,J]
760	023-0585-391 CAP,CER.,50V,390PF,COG	5	N	EA	C10[R]	BLOCK B,D,F,H,J [VOLTAGE REVERSE]
760	100-2321-00 RES.;2.32K OHM;1/4W 1% METAL FILM	5	N	EA	R13[R]	BLOCK B,D,F,H,J [VOLTAGE REVERSE]
800	029-0367-05 IC,78SR105HC,REG,SW,1.5AOUT,30VIN,H	2	N	EA	VR14, VR15	
810	029-0367-13 IC,78SR112HC,REG,SW,+12V,1.5AOUT,30	2	N	EA	VR13, VR16	
820	029-0367-14 IC,PT79SR112H,REG,SW,-12V,1.5AOUT,3	2	N	EA	VR12, VR17	
830	029-0110-00 IC; LM340T-5; 5V REG; 3 LEAD POWER-	2	N	EA	VR11, VR18	
900	024-0488-03 HEADER,INVERTED,5.08MM CENTERS,3-PO	10	N	EA	P1 - P10	

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 138-0300-00 Desc: CCA,SHUNT SEL./REG. CARD,PMC155PR-7

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
910	024-0498-16 CONN,HEADER,LOW PROFILE,16PIN(2X8)2	10	N	EA	J1 - J10	
920	024-0498-16 CONN,HEADER,LOW PROFILE,16PIN(2X8)2	1	N	EA	J21	
930	024-0438-06 HEADER;IDC;RT ANGLE;6 POS;FRCTN LOC	1	N	EA	J22	
940	024-0437-02 HEADER;IDC;STRAIGHT;2 POS;FRCTN LOC	10	N	EA	J11 - J20	
950	077-0002-00 JUMPER, FORMED INSUL, 22 GA. (.38)	0	N	EA	L2, L3, L5, L7, L9, L11	
950	031-0034-00 BEAD,LEADED,AXIAL,9.3MM X 3.8MM	6	N	EA	L1, L4, L6, L8, L10, L12	
960	029-0282-00 IC;LM320LZ5.O; REG;3 TERM;-5V;100 M	10	N	EA	VR1	BLOCK A-J
970	029-0206-00 IC;LM234Z-3; CURRENT SOURCE/TEMP. S	10	N	EA	Q7	BLOCK A-J

*** END OF REPORT ***

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 138-0300-01 Desc: CCA,SHUNT SEL/REG,PMC104PR-3-6

*Secn	*Component	*Quantity	CT	*UM	Reference	Reference Text
001	231-0300-01 SCH, RANGE SELECT/REG CIRCUITS 1	0	X	EA		
010	190-0300-01 PWB,PRECISION OUTPUT/SHUNT SELECT,	1	N	EA		
020	029-0360-04 IC,DG444DY,4X ANA SW,RDS=85OHM,LO C	24	N	EA	U2, U4, U6	BLOCK A-H
030	029-0361-01 IC,LTC1293BCS,A/D,6CH.12-BIT,SER.I/	8	N	EA	U11	BLOCK A-H
040	029-0391-01 IC,AD7249BR,12-BIT,2CH VO DAC,W/SER	8	N	EA	U5	BLOCK A-H
050	029-0281-00 IC;LM336Z-2.5; VLTG REF 2.5V .3 /10	8	N	EA	Q5	BLOCK A-H
060	029-0350-00 IC;LM336Z-5.0;PREC. 5V REF	8	N	EA	Q6	BLOCK A-H
070	021-0087-00 TRANSISTOR;MPF990;FET N-CH;90V;2A;T	8	N	EA	Q4	BLOCK A-H
080	021-0127-00 TRANS;N CH.(FET); 30A; 60V; RDS=.05	12	N	EA	(R)Q1 - (R)Q3	BLOCK B,D,F,H (REV)
090	021-0128-00 TRANS;P CH.(FET); 30A; 60V; RDS=.08	12	N	EA	(F)Q1 - (F)Q3	BLOCK A,C,E,G (FWD)
100	022-0138-01 DIODE,SWITCHING,1N4148W 150MA,75V,S	40	N	EA	D5 - D9	BLOCK A-H
120	022-0151-01 DIODE SD101AW,15MA IFWD,60 VREV,SCH	24	N	EA	D10 - D12	BLOCK A-H
130	022-0224-00 DIODE,ZENER,MMSZ5231B,5.1V,SOD-123	32	N	EA	D1 - D4	BLOCK A-H
140	022-0198-14 DIODE, ZENER, 1N5351B, 14V, 5W, AXI	2	N	EA	D100, D107	
150	022-0119-00 DIODE; GENERAL; 1N4004; 400V/1A; DO	6	N	EA	D101 - D106	
160	022-0163-00 DIODE;VM48;DUAL IN LINE BRIDGE ASSY	2	N	EA	BR1, BR2	
171	029-0373-01 IC,LT1220CS8,OP AMP HIGH-SPEED, 8-P	24	N	EA	U1, U8, U9	
172	029-0400-01 OPAMP,OPA27,SOIC	8	N	EA	U7	

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 138-0300-01 Desc: CCA,SHUNT SEL/REG,PMC104PR-3-6

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
180	029-0398-01 IC,OPAMP,LT1208,8-PIN,SOIC,DUAL	16	N	EA	U3, U10	BLOCK A-H
200	106-0211-1004 RESISTOR,SMT,1 MEG OHM,1/8WATT,1%,1	32	N	EA	R10, R12, R16, R56	BLOCK A-H
210	106-0214-1003 RESISTOR,SMT,100 K OHM,1/8WATT,0.1%	32	N	EA	R5, R6	BLOCK A-H
220	106-0211-4992 RESISTOR,SMT,49.9K OHM,1/8WATT,1%,1	8	N	EA	R22	BLOCK A-H
230	106-0211-4752 RESISTOR,SMT,47.5K OHM,1/8WATT,1%,1	16	N	EA	R50, R52	BLOCK A-H
240	106-0211-4532 RESISTOR,SMT,45.3K OHM,1/8WATT,1%,1	16	N	EA	R53, R54	BLOCK A-H
250	106-0211-3322 RESISTOR,SMT,33.2K OHM,1/8WATT,1%,1	40	N	EA	R45, R47 - R49	BLOCK A-H
280	106-0211-4422 RESISTOR,SMT,44.2K OHM,1/8WATT,1%,1	16	N	EA	R3, R51	BLOCK A-H
290	106-0211-4641 RESISTOR,SMT,4.64K OHM,1/8WATT,1%,1	16	N	EA	R38, R40	BLOCK A-H
300	106-0211-2552 RESISTOR,SMT,25.5K OHM,1/8WATT,1%,1	8	N	EA	R21	BLOCK A-H
310	106-0211-2492 RESISTOR,SMT,24.9K OHM,1/8WATT,1%,1	16	N	EA	R20, R69	BLOCK A-H
320	106-0211-1002 RESISTOR,SMT,10.0K OHM,1/8WATT,1%,1	88	N	EA	R17, R18, R24 - R26, R39, R41, R43, R46, R55, R66	BLOCK A-H
330	106-0211-1002 RESISTOR,SMT,10.0K OHM,1/8WATT,1%,1	4	N	EA	R44	BLOCK B,D,F,H
350	106-0211-4991 RESISTOR,SMT,4.99K OHM,1/8WATT,1%,1	16	N	EA	R32, R34	BLOCK A-H
360	106-0211-3011 RESISTOR,SMT,3.01K OHM,1/8WATT,1%,1	16	N	EA	R36, R37	BLOCK A-H
370	106-0211-2001 RESISTOR,SMT,2.00K OHM,1/8WATT,1%,1	56	N	EA	R11, R14, R15, R61 - R64	BLOCK A-H
380	106-0211-1001 RESISTOR,SMT,1.00K OHM,1/8WATT,1%,1	88	N	EA	R19, R27 - R31, R33, R57 - R60	BLOCK A-H
410	106-0211-7500 RESISTOR,SMT,750 OHM,1/8WATT,1%,100	8	N	EA	R67	BLOCK A-H

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 138-0300-01 Desc: CCA,SHUNT SEL/REG,PMC104PR-3-6

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
420	106-0211-6040 RESISTOR,SMT,604 OHM,1/8WATT,1%,100	16	N	EA	R23, R68	BLOCK A-H
430	106-0211-6819 RESISTOR,SMT,68.1 OHM,1/8WATT,1%,10	8	N	EA	R70	BLOCK A-H
440	106-0116-00 RES.;5 OHM;5W;5%; METAL OXIDE	8	N	EA	R2	BLOCK A-H
450	105-4709-00 RES.; 47 OHM; 2W; 5% METAL FILM.	8	N	EA	R1	BLOCK A-H
500	036-0125-00 SHUNT; RES. TYPE; 4-LEAD; 1 OHM; .1	8	N	EA	SH2	BLOCK A-H
510	036-0127-10 SHUNT RES. TYPE 4-LEAD 10 OHM .1	8	N	EA	SH1	BLOCK A-H
520	036-0124-00 SHUNT; RES. TYPE; 4 LEAD; .1 OHM; .	8	N	EA	SH3	BLOCK A-H
600	023-0579-00 CAP,820UFD,35V,18MMDIAX15MM,RADIAL,	6	N	EA	C106, C111, C115, C118, C122, C127	
610	023-0553-00 *CAP, 1UFD, 50V, CERAMIC, X7R, 0.2L	18	N	EA	C100, C102, C105, C107, C109, C110, C113, C114, C116, C117, C119, C120, C123, C125, C126, C128, C131, C133	
620	023-0554-00 *CAP, 2.2UFD, 50V, CERAMIC, Z5U, 0.	6	N	EA	C101, C108, C112, C121, C124, C132	
640	023-0581-00 CAP,1.0UF,10%,35V,TANT,3528 SMT PKG	72	N	EA	C12, C13, C18, C19, C30, C32, C33, C37, C42	BLOCK A-H
660	023-0538-00 CAPACITOR; 4.7MFD 25V. TANT .196 DI	32	N	EA	C14 - C17	BLOCK A-H
670	023-0466-00 CAP;10MFD 25V TANTALUM .225 DIA X .	4	N	EA	C103, C104, C129, C130	
680	023-0580-104 CAP,0.1UF,50 V, 0805 SMT PKG.,Z5U	96	N	EA	C2, C20, C21, C23, C27, C29, C31, C35, C36, C38 - C40	BLOCK A-H
690	023-0580-050 CAP,5PF,50 V, 0805 SMT PKG.,NPO	8	N	EA	C1	BLOCK A-H
700	023-0499-00 CAP;470 PF;100V;COG/NPO;.15X.15 RAD	4	N	EA	C8[F]	BLOCK A,C,E,G [LOW RANGE FWD]
710	023-0557-00 CAPACITOR; 330PF; 50V; NPO CERAMIC.	4	N	EA	C9[F]	BLOCK A,C,E,G [MID RANGE FWD]

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 138-0300-01 Desc: CCA,SHUNT SEL/REG,PMC104PR-3-6

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
710	100-8060-00 RES.;806 OHM;1/4W; 1% METAL FILM	4	N	EA	R9[F]	BLOCK A,C,E,G [MID RANGE FWD]
720	023-0585-271 CAP,CER.,50V,270PF,COG	4	N	EA	C3[F]	BLOCK A,C,E,G [HIGH RANGE FWD]
720	100-1212-00 RES.;12.1K OHM;1/4W 1% METAL FILM	4	N	EA	R7[F]	BLOCK A,C,E,G [HIGH RANGE FWD]
730	023-0556-00 CAPACITOR; 220PF;50V;NPO CERAMIC	4	N	EA	C10[F]	BLOCK A,C,E,G [VOLTAGE FWD]
730	100-5621-00 RES.;5.62K OHM;1/4W 1% METAL FILM	4	N	EA	R13[F]	BLOCK A,C,E,G [VOLTAGE FWD]
740	023-0585-391 CAP,CER.,50V,390PF,COG	4	N	EA	C8[R]	BLOCK B,D,F,H [LOW RANGE REV]
750	023-0585-271 CAP,CER.,50V,270PF,COG	4	N	EA	C9[R]	BLOCK B,D,F,H [MID RANGE REV]
750	100-3321-00 RES.;3.32K OHM;1/4W 1% METAL FILM	4	N	EA	R9[R]	BLOCK B,D,F,H [MID RANGE REV]
760	023-0557-00 CAPACITOR; 330PF; 50V; NPO CERAMIC.	4	N	EA	C3[R]	BLOCK B,D,F,H [HIGH RANGE REV]
760	100-5621-00 RES.;5.62K OHM;1/4W 1% METAL FILM	4	N	EA	R7[R]	BLOCK B,D,F,H [HIGH RANGE REV]
770	023-0557-00 CAPACITOR; 330PF; 50V; NPO CERAMIC.	4	N	EA	C10[R]	BLOCK B,D,F,H [VOLTAGE REV]
770	100-1501-00 RES.;1.5K OHM;1/4W; 1% METAL FILM	4	N	EA	R13[R]	BLOCK B,D,F,H [VOLTAGE REV]
800	029-0367-05 IC,78SR105HC,REG,SW,1.5AOUT,30VIN,H	2	N	EA	VR14, VR15	
810	029-0367-13 IC,78SR112HC,REG,SW,+12V,1.5AOUT,30	2	N	EA	VR13, VR16	
820	029-0367-14 IC,PT79SR112H,REG,SW,-12V,1.5AOUT,3	2	N	EA	VR12, VR17	
830	029-0110-00 IC; LM340T-5; 5V REG; 3 LEAD POWER-	2	N	EA	VR11, VR18	
900	024-0488-03 HEADER,INVERTED,5.08MM CENTERS,3-PO	8	N	EA	P1 - P8	

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 138-0300-01 Desc: CCA,SHUNT SEL/REG,PMC104PR-3-6

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
910	024-0498-16 CONN,HEADER,LOW PROFILE,16PIN(2X8)2	8	N	EA	J1 - J8	
920	024-0498-16 CONN,HEADER,LOW PROFILE,16PIN(2X8)2	1	N	EA	J21	
930	024-0437-06 HEADER;IDC;STRAIGHT;6 POS;FRCTN LOC	1	N	EA	J22	
940	024-0437-02 HEADER;IDC;STRAIGHT;2 POS;FRCTN LOC	8	N	EA	J11 - J18	
950	077-0002-00 JUMPER, FORMED INSUL, 22 GA. (.38)	0	N	EA	L2, L3, L5, L7, L9, L11	
950	031-0034-00 BEAD,LEADED,AXIAL,9.3MM X 3.8MM	6	N	EA	L1, L4, L6, L8, L10, L12	
960	029-0282-00 IC;LM320LZ5.O; REG;3 TERM;-5V;100 M	8	N	EA	VR1	BLOCK A-H
970	029-0206-00 IC;LM234Z-3; CURRENT SOURCE/TEMP. S	8	N	EA	Q7	BLOCK A-H

*** END OF REPORT ***

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 138-0300-02 Desc: CCA,SHUNT SEL/REG,PMC101PR-10-20

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
001	231-0300-00 SCH, RANGE SELECT / REG CIRCUITS, 1	0	X	EA		
010	190-0300-01 PWB,PRECISION OUTPUT/SHUNT SELECT,	1	N	EA	PWB	
020	029-0360-04 IC,DG444DY,4X ANA SW,RDS=85OHM,LO C	6	N	EA	U2, U4, U6	BLOCK A-B
030	029-0361-01 IC,LTC1293BCS,A/D,6CH.12-BIT,SER.I/	2	N	EA	U11	BLOCK A-B
040	029-0391-01 IC,AD7249BR,12-BIT,2CH VO DAC,W/SER	2	N	EA	U5	BLOCK A-B
050	029-0281-00 IC;LM336Z-2.5; VLTG REF 2.5V .3 /10	2	N	EA	Q5	BLOCK A-B
060	029-0350-00 IC;LM336Z-5.0;PREC. 5V REF	2	N	EA	Q6	BLOCK A-B
070	021-0087-00 TRANSISTOR;MPF990;FET N-CH;90V;2A;T	2	N	EA	Q4	BLOCK A-B
080	021-0127-00 TRANS;N CH.(FET); 30A; 60V; RDS=.05	3	N	EA	(R)Q1 - (R)Q3	BLOCK B (REV)
090	021-0128-00 TRANS;P CH.(FET); 30A; 60V; RDS=.08	3	N	EA	(F)Q1 - (F)Q3	BLOCK A (FWD)
100	022-0138-01 DIODE,SWITCHING,1N4148W 150MA,75V,S	10	N	EA	D5 - D9	BLOCK A-B
120	022-0151-01 DIODE SD101AW,15MA IFWD,60 VREV,SCH	6	N	EA	D10 - D12	BLOCK A-B
130	022-0224-00 DIODE,ZENER,MMSZ5231B,5.1V,SOD-123	8	N	EA	D1 - D4	BLOCK A-B
140	022-0198-14 DIODE, ZENER, 1N5351B, 14V, 5W, AXI	2	N	EA	D100, D107	
150	022-0119-00 DIODE; GENERAL; 1N4004; 400V/1A; DO	6	N	EA	D101 - D106	
160	022-0163-00 DIODE;VM48;DUAL IN LINE BRIDGE ASSY	2	N	EA	BR1, BR2	
171	029-0373-01 IC,LT1220CS8,OP AMP HIGH-SPEED, 8-P	2	N	EA	U9	BLOCK A,B
172	029-0400-01 OPAMP,OPA27,SOIC	6	N	EA	U1, U7, U8	BLOCK A-B

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent 138-0300-02 Desc: CCA,SHUNT SEL/REG,PMC101PR-10-20

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
180	029-0396-01 IC,OPAMP,LT1358,8-PIN SOIC,DUAL,25M	4	N	EA	U3, U10	BLOCK A-B
200	106-0211-1004 RESISTOR,SMT,1 MEG OHM,1/8WATT,1%,1	8	N	EA	R10, R12, R16, R56	BLOCK A-B
210	106-0214-1003 RESISTOR,SMT,100 K OHM,1/8WATT,0.1%	4	N	EA	R5, R6	BLOCK A-B
220	106-0211-4992 RESISTOR,SMT,49.9K OHM,1/8WATT,1%,1	2	N	EA	R22	BLOCK A-B
230	106-0211-4752 RESISTOR,SMT,47.5K OHM,1/8WATT,1%,1	4	N	EA	R50, R52	BLOCK A-B
240	106-0211-4532 RESISTOR,SMT,45.3K OHM,1/8WATT,1%,1	4	N	EA	R53, R54	BLOCK A-B
250	106-0211-3322 RESISTOR,SMT,33.2K OHM,1/8WATT,1%,1	8	N	EA	R45, R47 - R49	BLOCK A-B
280	106-0211-4422 RESISTOR,SMT,44.2K OHM,1/8WATT,1%,1	4	N	EA	R3, R51	BLOCK A-B
290	106-0211-1372 RESISTOR,SMT,13.7K OHM,1/8WATT,1%,1	4	N	EA	R38, R40	BLOCK A-B
300	106-0211-2552 RESISTOR,SMT,25.5K OHM,1/8WATT,1%,1	2	N	EA	R21	BLOCK A-B
310	106-0211-2492 RESISTOR,SMT,24.9K OHM,1/8WATT,1%,1	4	N	EA	R20, R69	BLOCK A-B
320	106-0211-1002 RESISTOR,SMT,10.0K OHM,1/8WATT,1%,1	22	N	EA	R17, R18, R24 - R26, R39, R41, R43, R46, R55, R66	BLOCK A-B
330	106-0211-1002 RESISTOR,SMT,10.0K OHM,1/8WATT,1%,1	1	N	EA	R44	BLOCK B
350	106-0211-4991 RESISTOR,SMT,4.99K OHM,1/8WATT,1%,1	4	N	EA	R32, R34	BLOCK A-B
360	106-0211-3011 RESISTOR,SMT,3.01K OHM,1/8WATT,1%,1	4	N	EA	R36, R37	BLOCK A-B
370	106-0211-2001 RESISTOR,SMT,2.00K OHM,1/8WATT,1%,1	14	N	EA	R11, R14, R15, R61 - R64	BLOCK A-B
380	106-0211-1001 RESISTOR,SMT,1.00K OHM,1/8WATT,1%,1	22	N	EA	R19, R27 - R31, R33, R57 - R60	BLOCK A-B
410	106-0211-7500 RESISTOR,SMT,750 OHM,1/8WATT,1%,100	2	N	EA	R67	BLOCK A-B

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 138-0300-02 Desc: CCA,SHUNT SEL/REG,PMC101PR-10-20

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
420	106-0211-6040 RESISTOR,SMT,604 OHM,1/8WATT,1%,100	4	N	EA	R23, R68	BLOCK A-B
430	106-0211-6819 RESISTOR,SMT,68.1 OHM,1/8WATT,1%,10	2	N	EA	R70	BLOCK A-B
440	106-0213-3008 RESISTOR,5W,3.0 OHM,1%,WW	2	N	EA	R2	BLOCK A-B
450	105-1509-00 RES.;15 OHM;2W;5%; CARB. CMP.	2	N	EA	R1[F], R1[R]	BLOCK A-B [LOW RANGE]
500	036-0124-00 SHUNT; RES. TYPE; 4 LEAD; .1 OHM; .	2	N	EA	SH2	BLOCK A-B
510	036-0125-00 SHUNT; RES. TYPE; 4-LEAD; 1 OHM; .1	2	N	EA	SH1	BLOCK A-B
520	036-0151-01 SHUNT,RES.TYPE,4-LEAD,.01 OHM,.1%,2	2	N	EA	SH3	BLOCK A-B
600	023-0579-00 CAP,820UFD,35V,18MMDIAX15MM,RADIAL,	6	N	EA	C106, C111, C115, C118, C122, C127	
610	023-0553-00 *CAP, 1UFD, 50V, CERAMIC, X7R, 0.2L	18	N	EA	C100, C102, C105, C107, C109, C110, C113, C114, C116, C117, C119, C120, C123, C125, C126, C128, C131, C133	
620	023-0554-00 *CAP, 2.2UFD, 50V, CERAMIC, Z5U, 0.	6	N	EA	C101, C108, C112, C121, C124, C132	
640	023-0581-00 CAP,1.0UF,10%,35V,TANT,3528 SMT PKG	16	N	EA	C13, C18, C19, C30, C32, C33, C37, C42	BLOCK A-B
641	023-0581-00 CAP,1.0UF,10%,35V,TANT,3528 SMT PKG	2	N	EA	C12	BLOCK A-B
660	023-0538-00 CAPACITOR; 4.7MFD 25V. TANT .196 DI	8	N	EA	C14 - C17	BLOCK A-B
670	023-0466-00 CAP;10MFD 25V TANTALUM .225 DIA X .	4	N	EA	C103, C104, C129, C130	
680	023-0580-104 CAP,0.1UF,50 V, 0805 SMT PKG.,Z5U	24	N	EA	C2, C20, C21, C23, C27, C29, C31, C35, C36, C38 - C40	BLOCK A-B
690	023-0580-050 CAP,5PF,50 V, 0805 SMT PKG.,NPO	2	N	EA	C1	BLOCK A-B
800	029-0367-05 IC,78SR105HC,REG,SW,1.5AOUT,30VIN,H	2	N	EA	VR14, VR15	

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 138-0300-02 Desc: CCA,SHUNT SEL/REG,PMC101PR-10-20

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
810	029-0130-00 IC; LM340T-12; 7812 REG 3-LEAD POWE	2	N	EA	VR13, VR16	SPECIAL INSTALLATION INSTRUCTIONS
820	029-0200-00 IC; UA7912UC; -12V REG. TO-220.	2	N	EA	VR12, VR17	SPECIAL INSTALLATION INSTRUCTIONS
830	029-0110-00 IC; LM340T-5; 5V REG; 3 LEAD POWER-	2	N	EA	VR11, VR18	
900	024-0488-03 HEADER,INVERTED,5.08MM CENTERS,3-PO	4	N	EA	P1 - P4	
910	024-0498-16 CONN,HEADER,LOW PROFILE,16PIN(2X8)2	2	N	EA	J1, J2	
920	024-0498-16 CONN,HEADER,LOW PROFILE,16PIN(2X8)2	1	N	EA	J21	
930	024-0438-06 HEADER;IDC;RT ANGLE;6 POS;FRCTN LOC	1	N	EA	J22	
940	024-0437-02 HEADER;IDC;STRAIGHT;2 POS;FRCTN LOC	2	N	EA	J11, J12	
950	077-0002-00 JUMPER, FORMED INSUL, 22 GA. (.38)	0	N	EA	L2, L3, L5, L7, L9, L11	
950	031-0034-00 BEAD,LEADED,AXIAL,9.3MM X 3.8MM	6	N	EA	L1, L4, L6, L8, L10, L12	
960	029-0282-00 IC;LM320LZ5.O; REG;3 TERM;-5V;100 M	2	N	EA	VR1	BLOCK A-B
970	029-0206-00 IC;LM234Z-3; CURRENT SOURCE/TEMP. S	2	N	EA	Q7	BLOCK A-B
980	JUMPER ENGINEERING INSTRUCTION	0	X	EA	CMT1	P1-3 TO P3-3 AND P2-3 TO P4-3 16AWG
990	JUMPER ENGINEERING INSTRUCTION	0	X	EA	CMT2	P1-2 TO P3-2 AND P2-2 TO P4-2 22AWG

*** * * END OF REPORT * * ***

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 990-0270-641 Desc: PMC106/4PR-3-6 PROG. M-ICHNL,PKG#13

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
001	131-0636-641 SCH,SYS,PMC106/4PR-3-6,SEMITOOL	0	X	EA		
001	155-0696-641 WIRETAB,PMC106/4PR-3-6,SEMITOOL	1	X	EA		
001	198-0361-06 MANUAL,PMC106/4PR-3-6,XR	1	N	EA	MANUAL	
010	130-0740-05 ASSY,CHASS,PMC106/4PR-3-6,XT RNG.	1	N	EA	CHASSIS	
020	123-0679-07 ASSY,PANEL,FRONT,PMC106/4PR-3-6 XR	1	N	EA	FRPNLASSY	
020	130-0741-06 ASSY,CHASSIS,PWR CTRL,PMC106/4PR-3-	1	N	EA	PROC_XFMR	CHASSIS
030	003-0712-06 PANEL,RIGHTSIDE,PMC106/4PR-3-6	1	N	EA	PNL_RGHT	
030	003-0712-05 PANEL,LEFTSIDE,PMC106/4PR-3-6	1	N	EA	PNL_LEFT	
030	114-0013-00 LINE FILTER; 20 AMP 250 VOLT SWITCH	1	N	EA	LF1	
030	010-0262-02 BRACKET, A/I BOARD MTG; MOD FOR FUS	1	N	EA	BRKT_FUSE	
030	010-0291-01 BRACKET; TERM&CELL SEL. PMCPR105/1-	1	N	EA	BRKT_TERM	
030	070-0090-00 FUSE HOLDER;ROUND;20A; STRAIGHT SOL	3	N	EA	XF1 - XF3	
030	025-0349-12 SWITCH; ROTARY;3D;1P;12POS;.25A;W/3	1	N	EA	SW1	
030	045-0010-00 KNOB;ROUND 5/8 DIA 1/4 SHAFT BLK CH	1	N	EA	XSW1	
030	024-0395-09 CONN;9-P D-TYPE;MALE HOUSING;FEM.SL	1	N	EA	J7	
030	024-0412-00 JACKSCREW; 4-40 FEM; .125 IN. PNL;	2	N	EA	XJ7	
030	011-0080-03 COVER,PMC106/4PR-3-6,	1	N	EA		
030	003-0713-07 PANEL, REAR, PMC106/4PR-3-6	1	N	EA	PNL_REAR	

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00 Effective Rev:
Exclusions: None
View Options: Normal

Parent: 990-0270-641 Desc: PMC106/4PR-3-6 PROG. M-ICHNL,PKG#13

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text
030	018-0083-02 LABEL,CELL SELECT;TERM PORT;.5A	1	N	EA	CMT30	TERMINAL PORT LABEL
030	070-0100-00 FUSE .75 AMP 1/4 X 1 1/4 SLO-BLO CE	3	N	EA		
030	018-0083-04 LABEL,FUSE,6CELL, .75AMP LOGIC	1	N	EA	LABEL, LOGIC_FUSE	
030	018-0085-03 LABEL,DYN.HOST PORTS,3 SEP.RS232/48	1	N	EA	LABEL_COMM, PORT	
030	018-0104-00 LABEL,OUTPUT,PMC 6CEL 2CH,.2SP,CAT	1	N	EA		
031	024-0325-00 CONN;RECEPTACLE 3 CIRCUIT W/LOCK (M	6	N	EA	J10, J13, J16, J19, J22, J25	
031	024-0326-00 CONN; PLUG 3 CIRCUIT W/MTG EARS (FE	6	N	EA	P10, P13, P16, P19, P22, P25	
032	024-0243-12 PLUG; 12 CKT FEMALE HSNG	6	N	EA	J11, J14, J17, J20, J23, J26	
032	024-0244-12 CONN; 12 CKT MALE HSNG	6	N	EA	P11, P14, P17, P20, P23, P26	
032	024-0256-00 CONN.; 6 CIRCUIT; MALE HOUSING	6	N	EA	P9, P12, P15, P18, P21, P24	
032	024-0257-00 CONN.; 6 CIRCUIT W/EARS; FEMALE HOU	6	N	EA	J9, J12, J15, J18, J21, J24	
032	024-0434-06 HSNG; IDC;CLSD;6 POS;22GA;SNGL.ROW;	6	N	EA	DIGI_BD_P2	
032	024-0436-06 STRAIN RLF;IDC;CLSD;6 POS;SNGL.ROW;	6	N	EA	DIGI_BD_XP	
032	024-0413-00 CONN. HSNG 4 CKT W/MTG EARS RECEPT	1	N	EA	P8	
032	024-0414-00 CONN. HOUSING 4 CKT W/ MTG EARS PLU	1	N	EA	J8	
032	024-0443-04 CONN;TERM.BLK;PLUG-IN;5MM CENTERS;4	1	N	EA	PS1_J3	
033	210-2003-00 ASSY; HOST SOFTWARE; UTILITIES; DYN	1	N	EA		
033	020-0005-01 CABLE;COMPUTER;RS-232;9 PIN FEM TO	1	N	EA		

DYNATRONIX, INC.

Production Bill of Materials

Component Effectivity Date: 9/28/00
Exclusions: None
View Options: Normal

Effective Rev:

Parent: 990-0270-641

Desc: PMC106/4PR-3-6 PROG. M-ICHNL,PKG#13

*Seqn	*Component	*Quantity	CT	*UM	Reference	Reference Text

*** * * END OF REPORT * * ***

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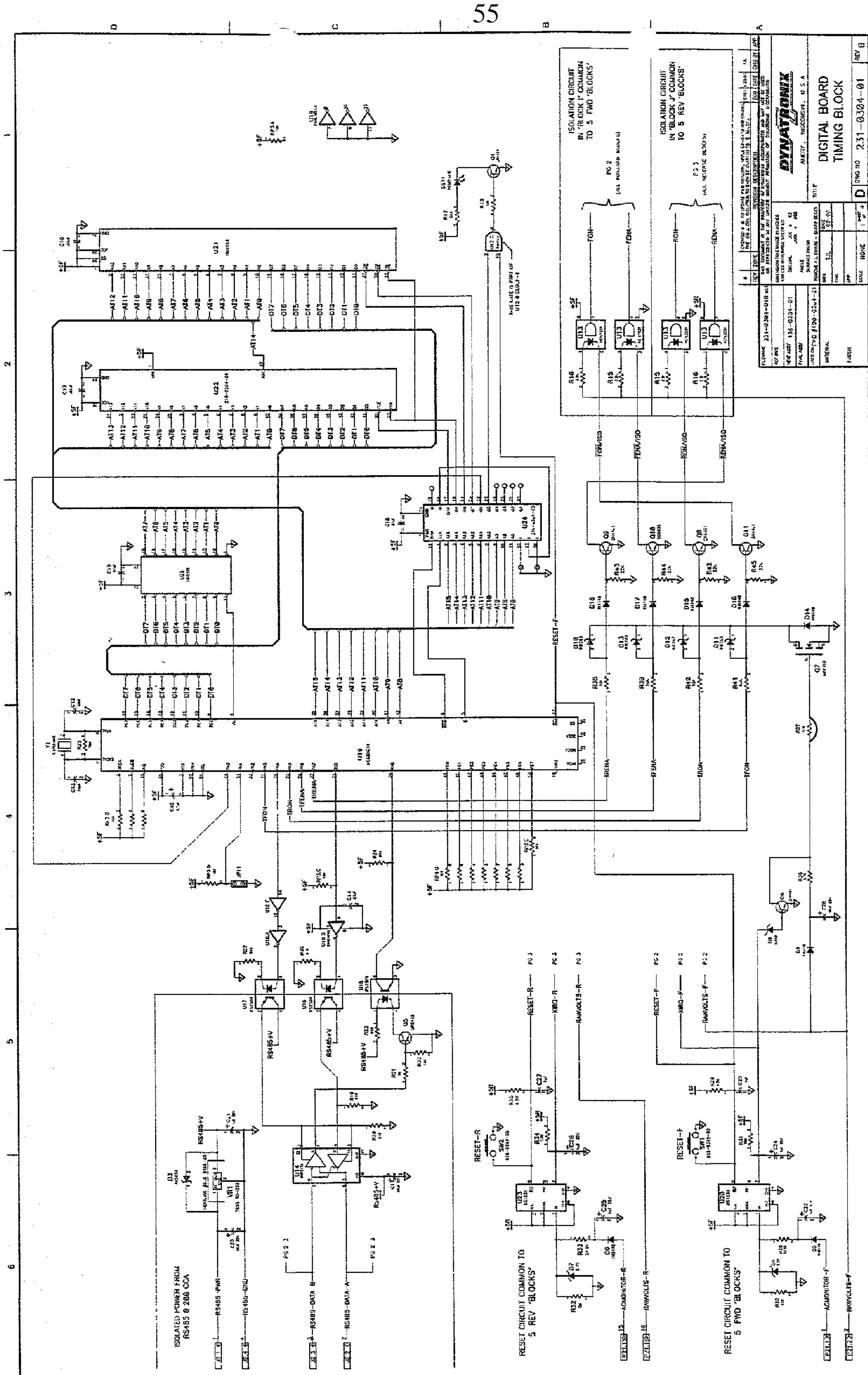
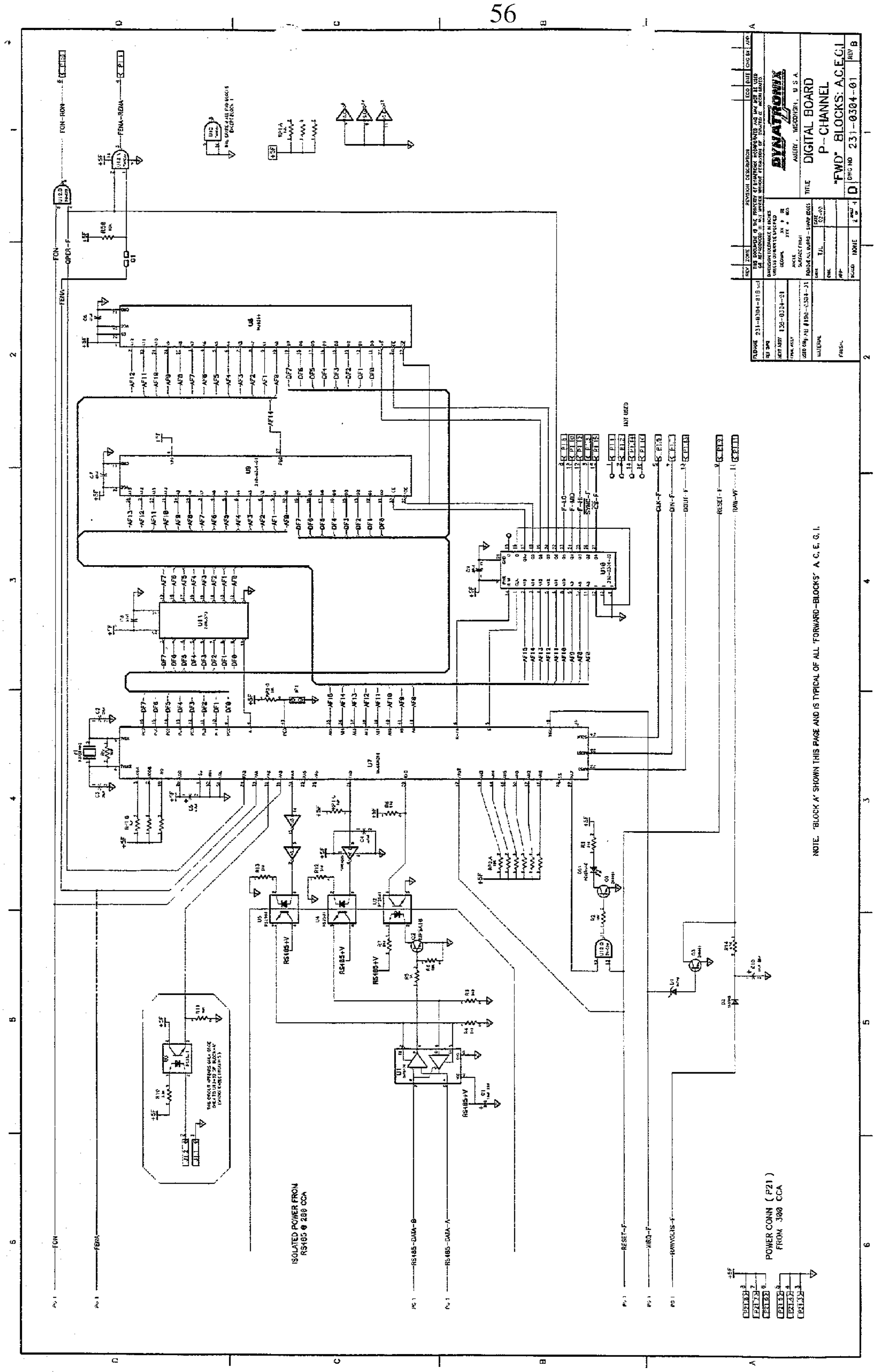
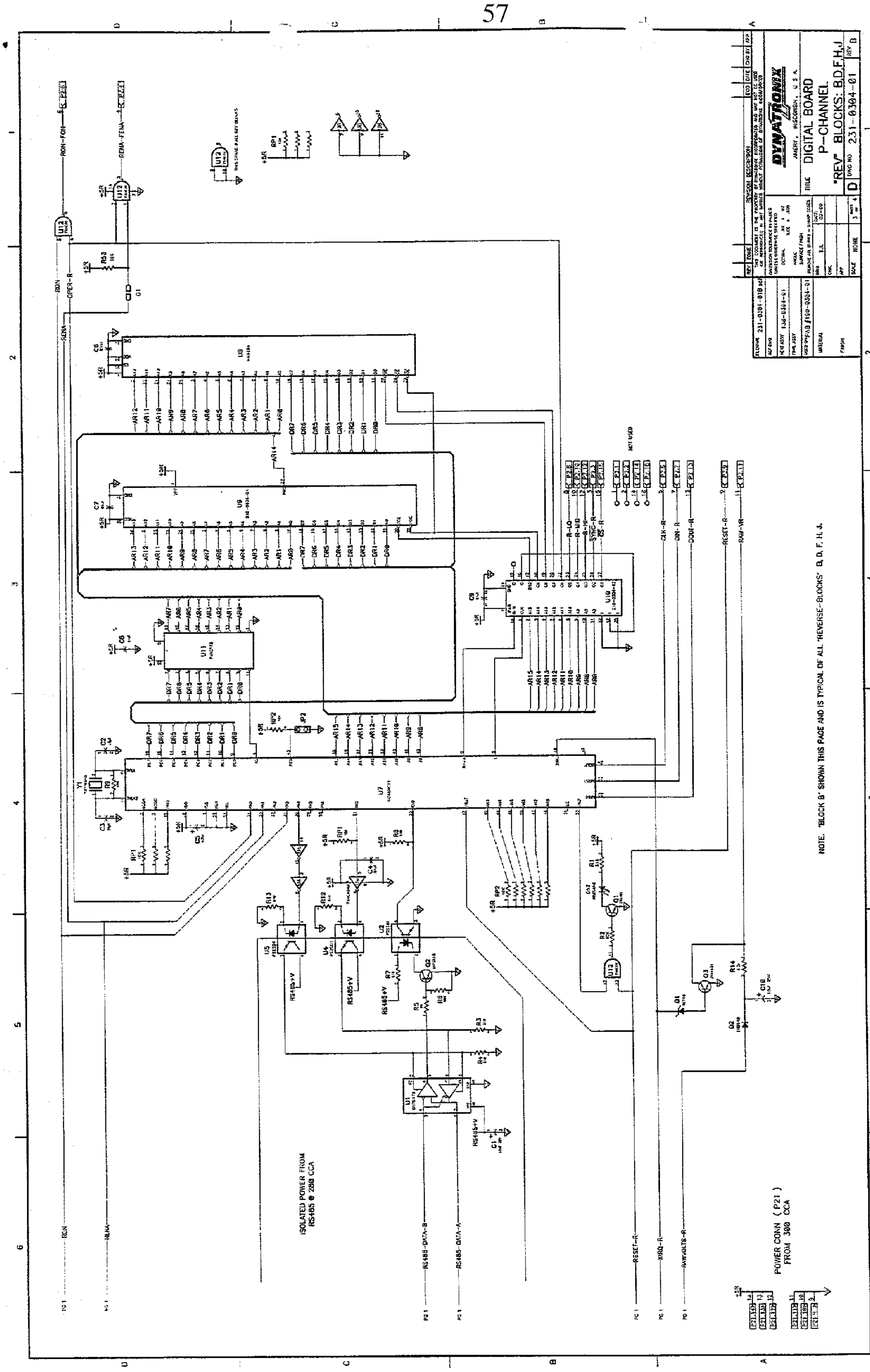


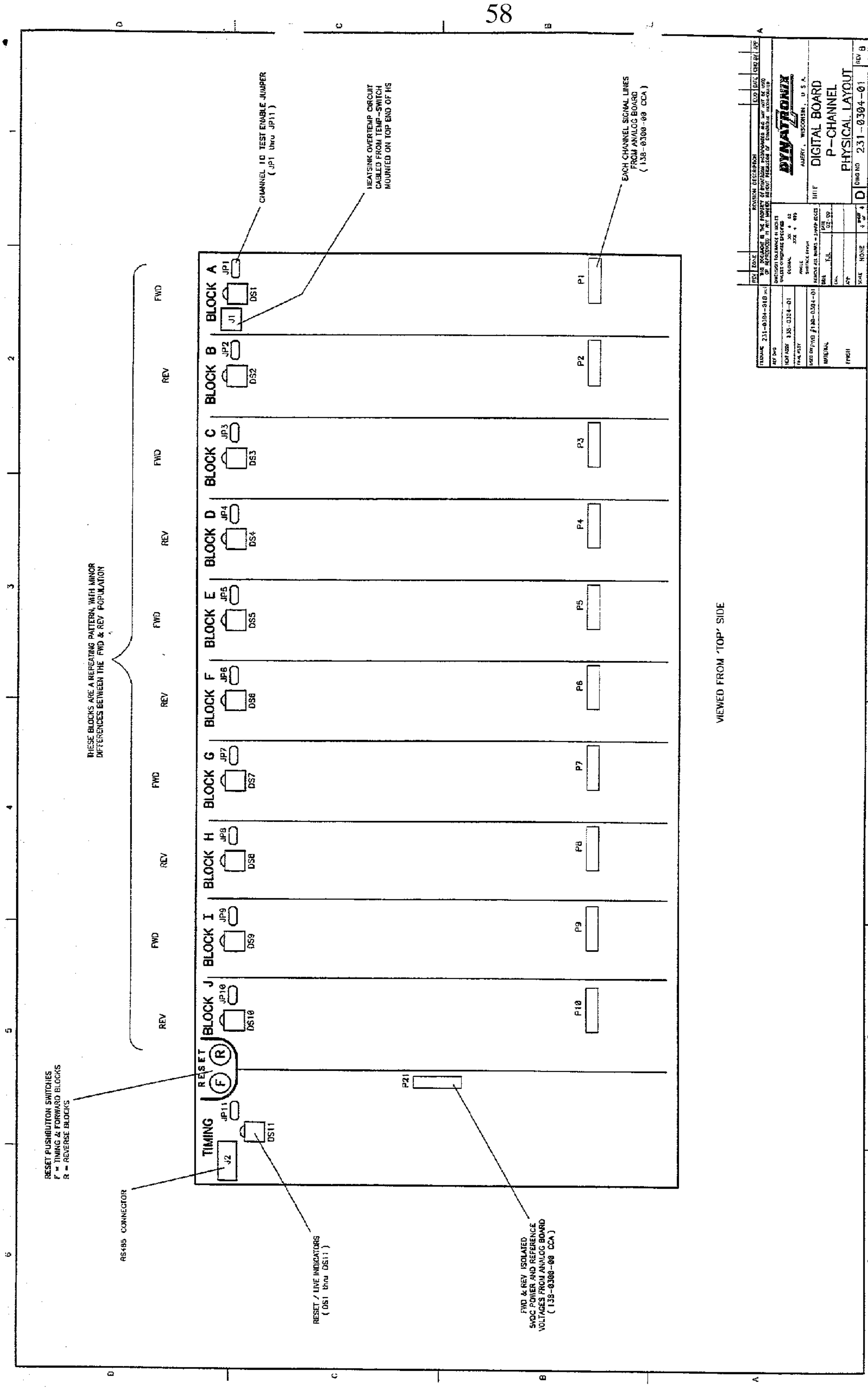
A54


DIGITAL BOARD
P-CHANNEL
"FWD" BLOCKS: A,C,E,G,I
231-0304-01
NOTE: "BLOCK A" SHOWN THIS PAGE AND IS TYPICAL OF ALL "FORWARD-BLOCKS" A, C, E, G, I.
ISOLATED POWER FROM RS485 @ 200 CCA
POWER CONN (P21) FROM 300 CCA

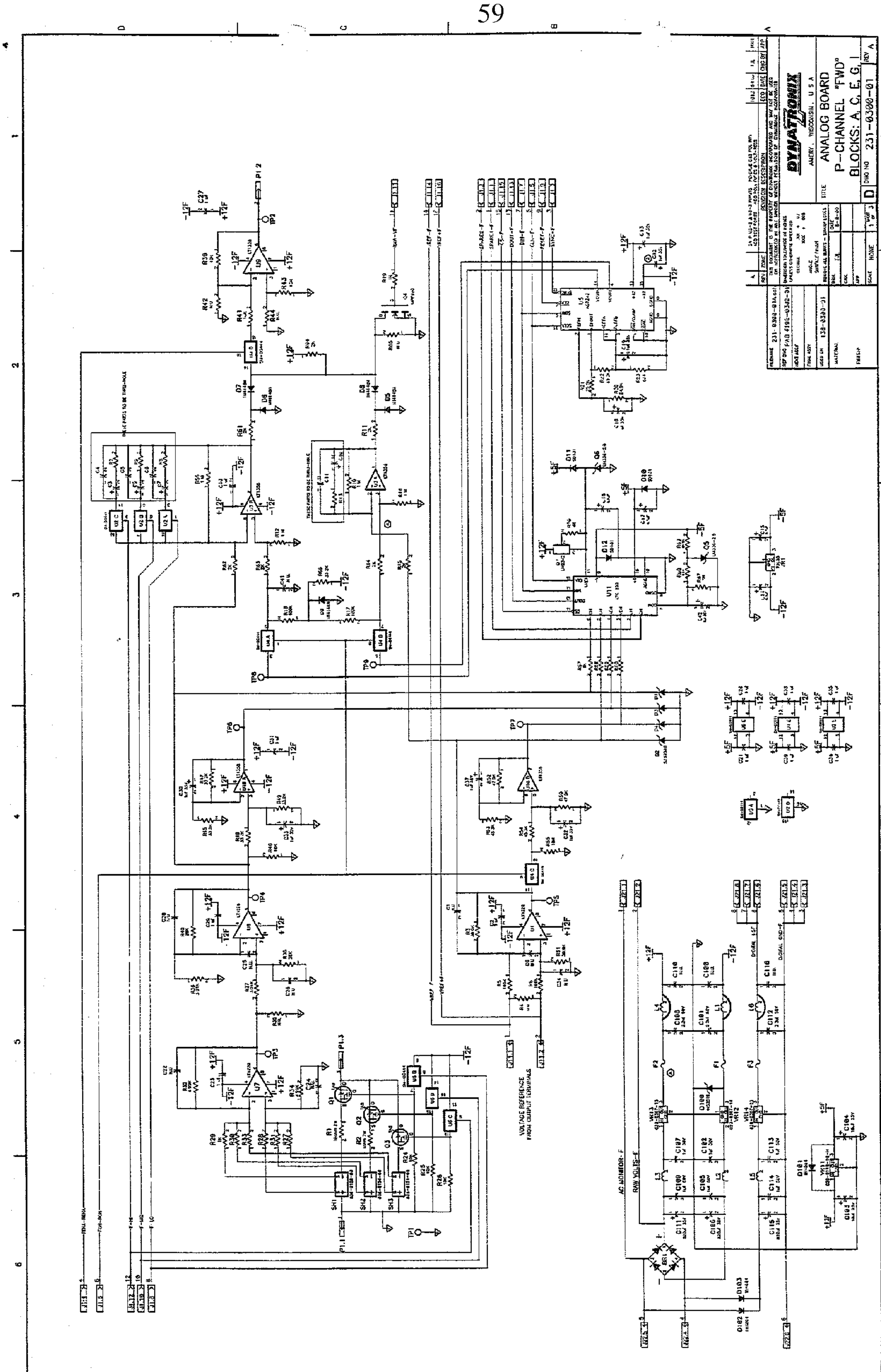
A55


DYNATRONIX
DIGITAL BOARD
P-CHANNEL
"REV" BLOCKS: B,D,F,H,J
231-0304-01
NOTE: 'BLOCK B' SHOWN THIS PAGE AND IS TYPICAL OF ALL 'REVERSE-BLOCKS' B, D, F, H, J.
ISOLATED POWER FROM RS485 @ 280 CCA
POWER CONN (P21) FROM 300 CCA

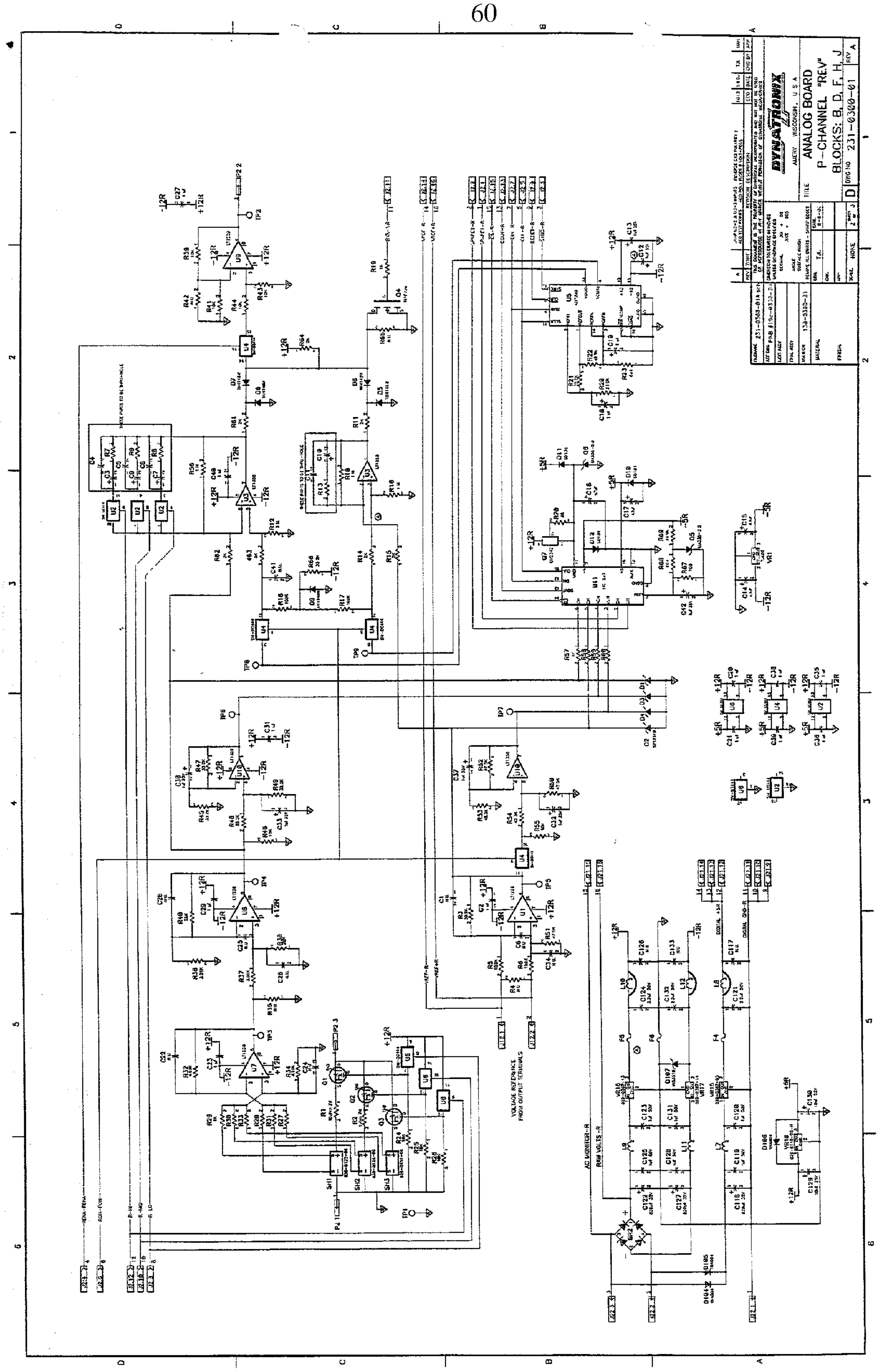
A56


DIGITAL BOARD
P-CHANNEL
PHYSICAL LAYOUT
231-0304-01
DYNATRONIX
VIEWED FROM 'TOP' SIDE
BLOCK A
BLOCK B
BLOCK C
BLOCK D
BLOCK E
BLOCK F
BLOCK G
BLOCK H
BLOCK I
BLOCK J
TIMING
RESET
FWD
REV
CHANNEL I.D. TEST ENABLE JUMPER (JP1 thru JP11)
HEATSINK OVERTEMP CIRCUIT CABLED FROM TEMP-SWITCH MOUNTED ON TOP END OF HS
EACH CHANNEL SIGNAL LINES FROM ANALOG BOARD (138-0300-00 CCA)
THESE BLOCKS ARE A REPEATING PATTERN, WITH MINOR DIFFERENCES BETWEEN THE FWD & REV POPULATION
RESET PUSHBUTTON SWITCHES F = TIMING & FORWARD BLOCKS R = REVERSE BLOCKS
RS485 CONNECTOR
RESET / LIVE INDICATORS (DS1 thru DS11)
FWD & REV ISOLATED 5VDC POWER AND REFERENCE VOLTAGES FROM ANALOG BOARD (138-0300-00 CCA)

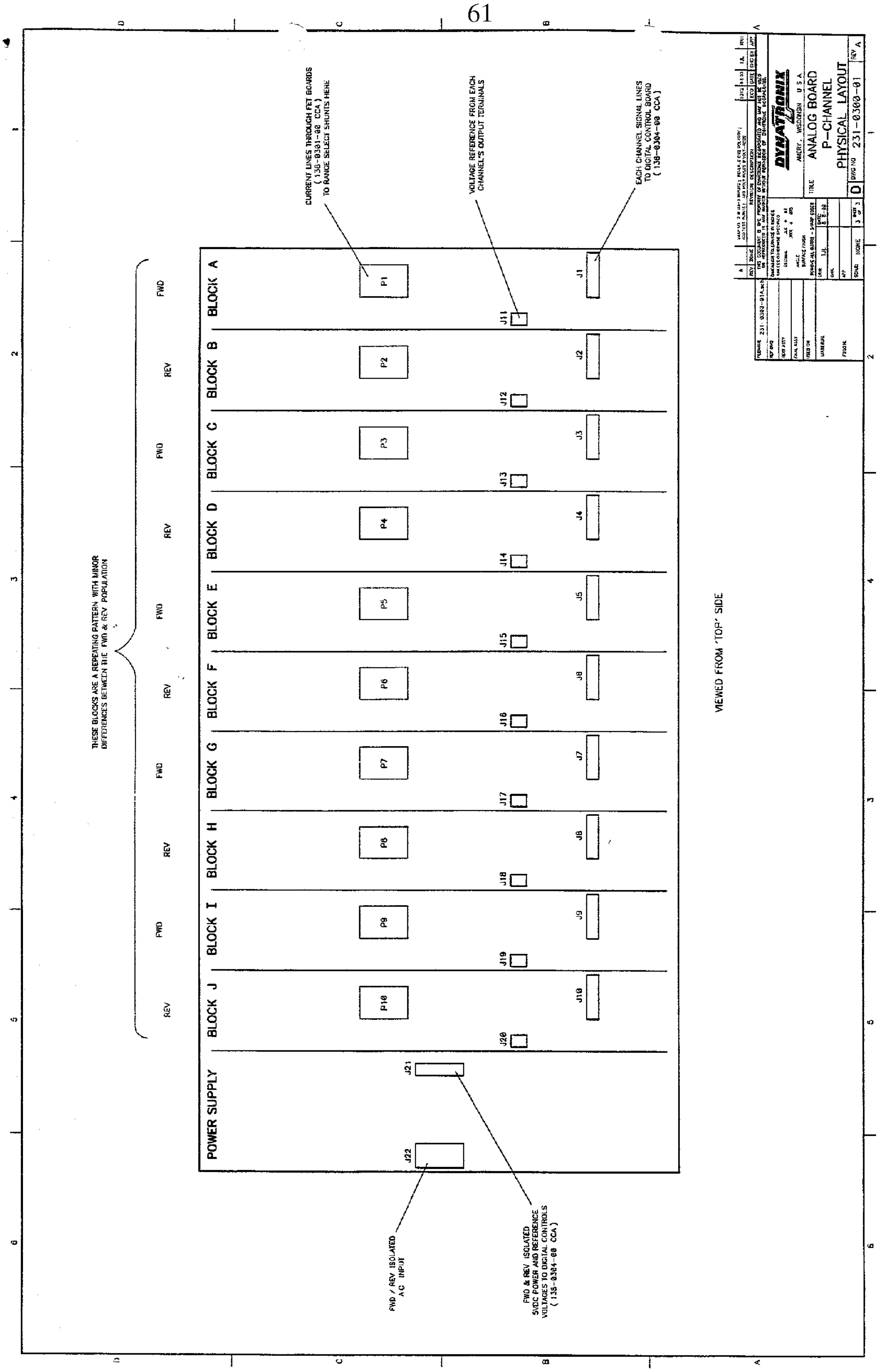
A57


DYNATRONIX
ANALOG BOARD
P-CHANNEL "FWD"
BLOCKS: A, C, E, G, I
231-0300-01

A58


DYNATRONIX
ANALOG BOARD
P-CHANNEL "REV"
BLOCKS: B, D, F, H, J
231-0300-01

A59


CURRENT LINES THROUGH FET BOARDS (138-0301-00 CCA) TO RANGE SELECT SHUNTS HERE
VOLTAGE REFERENCE FROM EACH CHANNEL'S OUTPUT TERMINALS
EACH CHANNEL SIGNAL LINES TO DIGITAL CONTROL BOARD (138-0304-00 CCA)
THESE BLOCKS ARE A REPEATING PATTERN WITH MINOR DIFFERENCES BETWEEN THE FWD & REV POPULATION
BLOCK A
BLOCK B
BLOCK C
BLOCK D
BLOCK E
BLOCK F
BLOCK G
BLOCK H
BLOCK I
BLOCK J
POWER SUPPLY
FWD
REV
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
J1
J2
J3
J4
J5
J7
J8
J9
J10
J11
J12
J13
J14
J15
J16
J17
J18
J19
J20
J21
J22
VIEWED FROM 'TOP' SIDE
FWD / REV ISOLATED AC INPUT
FWD & REV ISOLATED 5VDC POWER AND REFERENCE VOLTAGES TO DIGITAL CONTROLS (138-0304-00 CCA)
DYNATRONIX
AMERY, WISCONSIN U.S.A.
ANALOG BOARD
P-CHANNEL
PHYSICAL LAYOUT
231-0300-01

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The invention claimed is:

1. A power supply system.

2. A power supply system which comprises the structure and function disclosed in the attached appendix.

* * * * *