VLA Technical Report No. 31

# VLA ELECTRONICS DRAFTING MANUAL

D. Weber, R. Runyon
T. Cote, L. Carlisle

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## 1.0 INTRODUCTION

This manual describes the drafting practices recommended for VLA Electronics drawings and is addressed to the draftsmen, technicians and engineers who may be concerned with generating or using these drawings. The emphasis in this manual is to highlight or outline the more important aspects of good documentation procedures; detailed treatment of subjects like symbology, line widths, etc. are beyond the scope of this manual. The draftsmen who generate the drawings are expected to be knowledgeable as to the appropriate practices to be used.

The drafting practices and procedures set forth in this manual are not new to VLA but have been used by both CV and VLA site draftsmen for some time. This manual is written to formalize these procedures and to serve as a drafting reference for the engineers, technicians and draftsmen.

Drawings are a form of graphic communication and are generated by VLA drafting for three purposes:

1.1 Construction - by contractors and in-house at VLA and Charlottesville. When used for contract construction the drawings must adequately define the end product or we suffer the consequences in the form of poor quality and performance. Correcting contractors' fabrication deficiencies costs time, man-hours and materials at NRAO. It can be very difficult to convince a contractor to upgrade the quality of his work if he can show that he "built it to the print". Contract fabricators have a narrow profit margin and are primarily interested in doing the job within the contract funds so you can expect them to perform the work in the quickest way possible which may not be consistent with our fabrication expectations. Our principle leverage on the contractor is to insist on conformance to the drawings and specifications.

Drawings for in-house built equipment should be just as comprehensive as those for outside contractors' use; don't assume that since an item is being fabricated/built by NRAO "It'll be done right."

If any features of a design are important to fit, function or quality then they should be put on a drawing to explicitly communicate these requirements to the construction people; if you don't do this, you are delegating the implementation, quality and workmanship decisions to the judgement of the assembly workers. Obviously, verbal directions can be used as an alternate to graphic communication, but people quit, change jobs and forget the directions and special instructions after a little while. Make adequate drawings!

1.2 Maintenance - It is vitally important that the drawings also contain maintenance oriented information to assist maintenance people in testing, fault isolating and aligning equipment. The engineers and technicians are expected to suggest the appropriate information to the draftsmen as the drawings are generated.

1.3 Configuration and Construction Data Records - The potential for configuration confusion is apparent if we consider the numbers pertaining to the VLA modules which probably account for the major portion of VLA Electronics drawings. With our 28 antennas (hopefully identical) we use about 50 module types, each of which can have several model variations and revisions within the model. These modules will have been built over several years by a number of contractors and in-house people. If we don't establish and maintain good configuration control data in the form of drawings and wire lists, we will find that maintenance and future modifications will be difficult.

Even one of a kind items should have documentation adequate for maintenance or modification at some future date. For example, we have a Control Building and probably will never

discard it and replace it with another, but we have kept the construction drawings for use in making changes, running cables and pipes, etc.

This manual also includes a collection of specifications and useful drafting-related information such as drawing number practices, standard electrical and mechanical hardware items and the basic module metal and plastic part numbers.

## 2.0 CLASSES OF DRAWINGS AND USAGE

### 2.1 VLA Sketches

VLA sketches are usually informal and quickly drawn for in-house use but may be quite adequate for contract use. A sketch number (provided by drafting), title and designer's name are all the formal requirements. It is generally preferable to apply a transfer title block for uniformity of format. VLA sketches should always be drawn on reproducible paper and stored with the drawing files.

### 2.2 VLA Drawings

VLA drawings are used to define all the hardware features of the VLA system and consist of a wide variety of types. These types will be described in Section 4 of this manual.

### 2.3 Vendors' and Contractors' Drawings

We use a great many purchased items--both commercial and specially designed. Whenever possible, one or more sets of reproducible drawings for these items should be stored in the drafting files for general reference.

### 2.4 Specification Control Drawings

Specification control drawings are a powerful tool in controlling critical features of items purchased from contractors. A specification control drawing cites all features on a contractor's drawing which are critical in form, fit or function. Non-critical aspects are left to the contractor's design and change discretion. The specification control drawing should cite the contractor's name, drawing number, revision level and release/revision date.

## 2.5 Dummy Drawings

Dummy drawings are sometimes used as linkages or may be used to reserve some future drawing expansion.

## 2.6 Altered Item Drawings

Altered item drawings depict changes to purchased items to make them suitable for our use. Generally, they are based upon a contractor's drawing.

## 2.7 Make From Drawings

Make from drawings are drawings that depict changes to an item to adapt it for a particular function. In general, a make from drawing contains only the information required to implement the specific change to the basic unit. An example of a make from drawing is a VLA Data Set front panel which is "made from" the basic IUA module front panel. Make from drawings, when properly used, can save a lot of drafting time.

## 2.8 Process Drawings

Process drawings are a form of graphic specification which defines some aspect of fabrication, construction or assembly.

## 2.9 Test Specifications and Test Procedures

Test specifications and test procedures are analogous to drawings and should be subject to the same configuration control procedure as drawings. These are originated by technicians and engineers and are filed in the site technical files.

## 2.10 Specifications

Specifications are also analagous to drawings and are a written definition of a product. Specifications and the associated drawings should be cross-referenced. These are originated by engineers and technicians and are filed in the site technical files.

## 3.0 VLA DRAWING NUMBERING SYSTEMS

Two different drawing numbering systems are used in VLA drawings: Electronic and Antenna/Mechanical.

3.1 The following is an example of an Electronics Drawing Number and the associated coding scheme:

A13770M66-1

| | |
|---|---|
| A | - drawing size, single character |
| 13770 | - project number, 5 digits |
| M | - drawing type |
| 66 | - drawing number, unique ranging from 1 to 99 |
| -1 | - dash number (optional), usually used to define two or more varients of a basic item |

3.2 The VLA Antenna/Mechanical drawing numbering scheme is slightly different, as shown here:

9XC19XXX-XX

| | |
|---|---|
| 9X | - usage code |
| C | - drawing size |
| 19XXX | - antenna drawing number block |
| -XX | - dash number |

Parts lists are A size drawings, but A size drawings are not restricted to parts lists.

Usage codes are:

91 - Civil and concrete
92 - Transporter and heavy equipment
93 - Electrical, site
94 - Architectural
95 - Not used
96 - Antenna structural, E-Systems
97 - Fixtures and tooling
98 - Antenna mechanical and electrical, VLA generated drawings
99 - Railroad equipment

Specifications:

91SXXXXX - site, rail, the equipment telephone cable, communications systems, etc.

98SXXXXX - buildings and other site features

E Systems Generation Breakdown, Antenna Drawings - 96E20167

This generation breakdown is very comprehensive and covers the Electrospace Servo, ACU and NPL equipment.

## 4.0 VLA DRAWING TYPES

Nearly all VLA electronic drawings are one of the following types:

### 4.1 Assembly Drawings

Type symbol P -- These graphically illustrate the physical orientation, shape and mounting of the components which make up the assembly. Item numbers in balloons link the components to a Bill of Materials which contain the part number, value, reference designator and manufacturers' name. Note references in boxes convey general or specific instructions regarding assembly practices or instructions.

Assembly drawings are used for a wide variety of applications such as modules, PC boards, racks, bins, cables, antennas, subsystems, systems, etc.

### 4.2 Bill of Materials (BOM)

Type symbol Z -- The BOM lists all important data about the assembly drawing items such as part or drawing number, reference designator, value and tolerance, manufacturers' name, quantity required per assembly and so forth.

BOM's should be prepared for each assembly drawing and should reference that drawing and the next higher assembly drawing and BOM, as well as the top assembly drawing and BOM.

### 4.3 Schematic Diagrams

Type symbol S -- Schematics illustrate circuit design relationships, signal flow, component reference designators, location designators, values and tolerances, input and output connections, sheet to sheet references and any notes which may be useful for construction, testing or alignment. Phantom lines should enclose portions of a schematic which are contained on more than one subassembly. ANSI and IEEE symbology should be used.

## 4.4 Logic Diagrams

Type symbol L -- These drawings illustrate digital logic design relationships and are functionally similar to schematic diagrams. The logic diagram should show input/output connections, sheet to sheet references, reference designators, location designators, and any notes which may be useful for construction, testing or alignment. Again, phantom lines should enclose portions of circuitry which contain more than one assembly. ANSI and IEEE digital logic symbols should be used.

## 4.5 Printed Circuit Board Masters

Type symbol A -- These are precision-drawn tape or ink masters which depict single sided, double sided or multilayer circuit paths. An additional code letter A, B, C, etc. denotes the artwork scale of 1:1, 2:1, 3:1, respectively. Thus, B13720AB17 denotes a 2:1 scale master. Wherever possible, standard pre-cut commercial tape components shall be used in generating a master. The master contains scaling information and alignment targets for photo reduction and fabrication usage.

## 4.6 Printed Circuit Board Mechanical Drawings

Type symbol M -- These drawings define the requirements for drilling, plating, profiling and other mechanical fabrication processes. These drawings are sometime called Drill Drawings.

This type of drawing is distinguished from the Mechanical and Miscellaneous type (also M) by the different nature of the fabrication process so it is treated as a separate type by the Drawing Listing program discussed in Section 9.5.

## 4.7 Silkscreen Masters

Type symbol A -- Silkscreen masters may be drawn to mark panels and printed circuit cards.

## 4.8 Block Diagrams

Type symbol B -- Block diagrams depict signal flow through elements rendered as simple blocks whose detailed internal properties may not be vital for the emphasis of the drawing. Signal levels, frequencies, etc. and notes which are useful as maintenance information may be included on the block diagrams.

## 4.9 Wire Lists

Type symbol W -- Wire lists define wire paths, connections, wire size, color code, signal names, I/O connections, etc. and are used for rack, module and cable drawings. Special emphasis should be given to the preparation of wire lists so that both the construction and maintenance aspects of wire lists are clearly stated. Mnemonic signal names which are related to circuit function should be used wherever possible.

Wire lists are also generated by computer programs which analyze input data to produce wire lists and wiring machine drive data in several formats.

## 4.10 Mechanical or Miscellaneous Parts

Type symbol M -- This type encompasses all mechanical piece parts and miscellaneous items.

## 4.11 Tool Drawings

Type symbol T -- This drawing depicts any special tools, jigs, fixtures, etc. which may be used in building or maintaining VLA electronics.

## 4.12 Data Lists

Type symbol D -- This drawing contains any relevant physical or functional data.

## 5.0 DRAWING STRUCTURE

A set of drawings for an electronic assembly generally has a hierarchal structure as there are usually two or more levels of subassemblies in a module/rack/subsystem/system. To attain the quality of workmanship we require, it is necessary to control the assembly and wiring of this hardware. Therefore, the drawings should be prepared so that they clearly communicate the required assembly/subassembly relationships.

An important aspect of a hierarchal drawing structure is that it should be possible to trace out the upward and downward relationships of a drawing set by references on the drawings. The "Next Ass'y" and "Used On" references in the title block format provide upward visibility. "Next Ass'y" refers to the next higher assembly level in which the given assembly is referenced as a component part. When used, this scheme nicely links vertically adjacent assembly levels. The "Used On" is conveniently used to span several assembly levels to link a drawing to a major assembly. For example, a Dip Header assembly in the Data Set will cite the Data Set in the "Used On" blank which spans two assembly levels. This feature provides instant association with a major assembly.

A Generation Breakdown drawing provides a broad overview of a major assembly and is structured in a hierarchal manner. E-Systems has prepared a Generation Breakdown for the antenna drawings which provides good visibility for any antenna mechanical or electrical drawing. A Generation Breakdown has been partially developed for the equipment which is installed in the antennas by NRAO.

A drawing tree can also illustrate the hierarchal drawing relationships. Figure 5.1 depicts the Data Set drawing tree.

VLA electronic drawings for an assembly (typically a module) use a Top Assembly drawing and Top Bill of Material as a coupled pair. This pair of drawings is the primary reference for the assembly. The Top Assembly drawing graphically illustrates the physical relationships of the components which are described on the Top Bill of Materials by data such as manufacturers' part number, value, manufacturers' name, etc. The components are cross-referenced by item

numbers and reference designators. Subassemblies are referenced by item numbers which have the associated subassembly Bill of Materials number as a part number. Each assembly level in a drawing set has a coupled Bill of Materials (BOM) and an assembly drawing which define the components. Figures 5.2 and 5.3 depict the Data Set Top Assembly drawing and Top Bill of Materials.

In special cases other subordinate relationships may exist; for example, a PC artwork master and PC silkscreen drawing are subordinate to the PC drill drawing. These are usually treated as special cases in which the application dictates the approach.

TOP ASSEMBLY DRAWING - D13720P73
TOP BILL OF MATERIAL - A13720Z99

**IC MODULE PANEL**

Ass'y Dwg. - C13720P57
Ass'y BOM - A13720Z84

**DIP HEADER SUB ASS'YS.**

Ass'y Dwg. - Ass'y BOM
A13720P62 - A13720Z89
A13720P63 - A13720Z90
A13720P60 - A13720Z87
A13720P59 - A13720Z86
A13720P6 - A13720Z88
B13720P16 - A13720Z39
B13720P17 - A1372OZ9
A13720P69 - A13720Z95
B13720P14 - A13720Z10

**A/D CONVERTER SUB ASS'Y.**

Ass'd Dwg. - D13720P58
BOM - A13720Z85
Drill Dwg. - D13720M45
Artwork Dwg. - D13720AB11

**LED DISPLAY SUB ASS'Y.**

Ass'y Dwg. - C13720P38
BOM - A13720Z83
Drill Dwg. - C13720M33
Artwork Dwg. - B13720AB36

**MECHANICAL PARTS**

Front Panel, Engrvd. - B13720M22
Filter, Red Pol. - B13720M18-1
Filter, Clr - B13720M18-2
Rail Modified - C13720M15-1
Rail Modified - C13720M15-2
Rear Panel - B13450M32
Guide Blocks - B13050M4
Perf Cover - C13050M7
Side Plate - C13720M50
Bracket, Conn. - B13720M46
Spacer - B13720M47
Side Plate Insul. - B13720M49

**MASTER WIRE LIST A13720W61**

| HAND WIRE LIST | MACHINE WIRE LIST | CONNECTOR I/O LIST | POWER WIRING DIAGRAM |
|---|---|---|---|
| A13720W62 | A13720W63 | A13720W64 | D13720L44, SH7 |

**LOGIC DIAGRAMS D13720L44**

FIGURE 5.1 MODEL D DATA SET DOCUMENTATION TREE

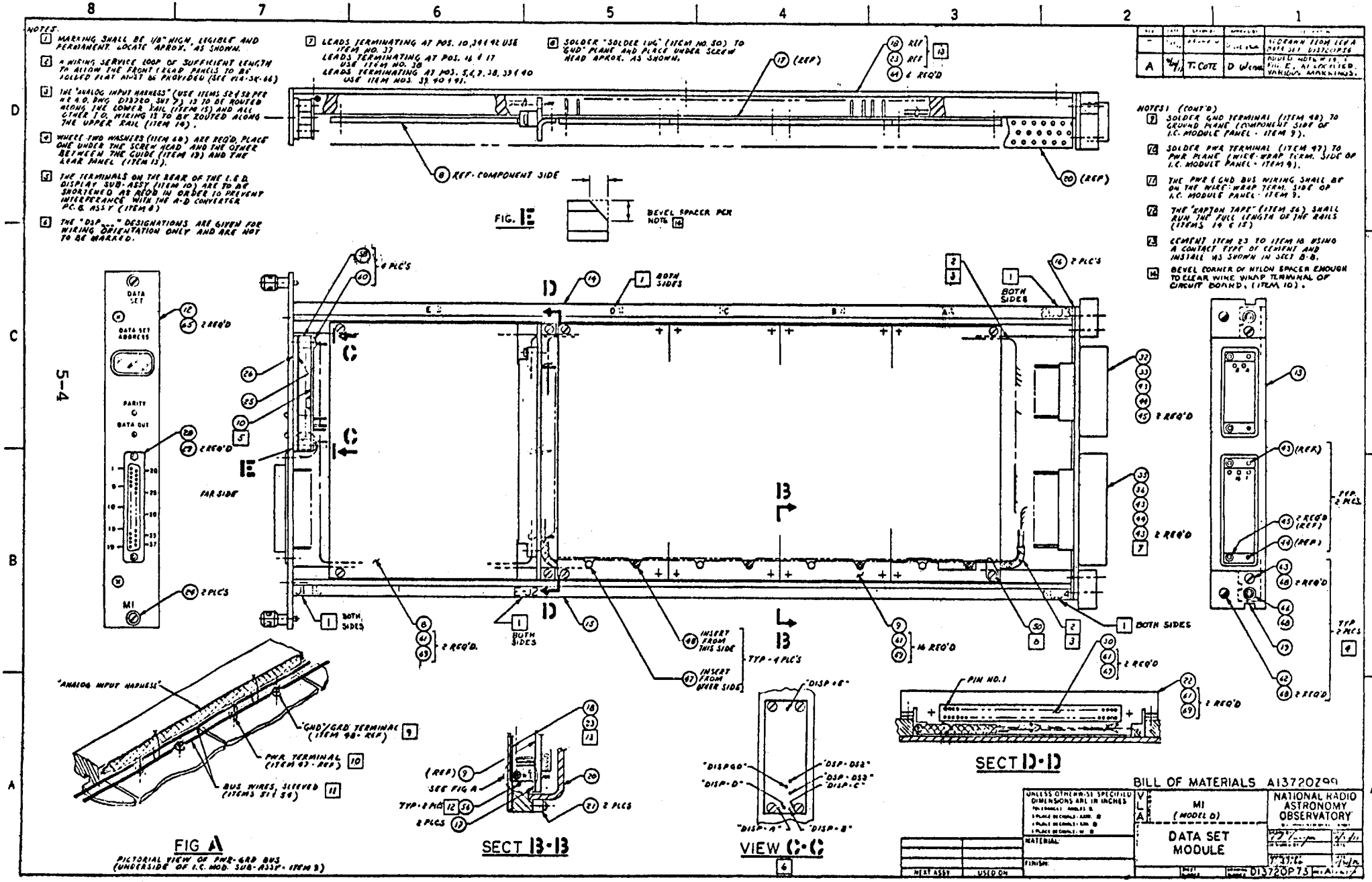
NOTES:
1 MARKING SHALL BE 1/8" HIGH, LEGIBLE AND PERMANENT. LOCATE APROX. AS SHOWN.
2 A WIRING SERVICE LOOP OF SUFFICIENT LENGTH TO ALLOW THE FRONT (READ PANELS TO BE SWUNG FLAT MUST BE PROVIDED (SEE H14-SK-66)
3 THE "ANALOG INPUT HARNESS" (USE ITEMS 52 & 53 PER H.R.A.O. DWG D13720, SHT 7) IS TO BE ROUTED ALONG THE LOWER RAIL (ITEM 15) AND ALL OTHER I.O. WIRING IS TO BE ROUTED ALONG THE UPPER RAIL (ITEM 14).
4 WHERE TWO WASHERS (ITEM 48) ARE REQ'D, PLACE ONE UNDER THE SCREW HEAD AND THE OTHER BETWEEN THE GUIDE (ITEM 19) AND THE REAR PANEL (ITEM 13).
5 THE TERMINALS ON THE REAR OF THE L.E.D. DISPLAY SUB-ASSY (ITEM 10) ARE TO BE SHORTENED AS REQ'D IN ORDER TO PREVENT INTERFERANCE WITH THE A-D CONVERTER P.C.B. ASS'Y (ITEM 8)
6 THE "DSP ..." DESIGNATIONS ARE GIVEN FOR WIRING ORIENTATION ONLY AND ARE NOT TO BE MARKED.
7 LEADS TERMINATING AT POS. 10, 39 & 42 USE ITEM NO. 33
LEADS TERMINATING AT POS. 16 & 17 USE ITEM NO. 38
LEADS TERMINATING AT POS. 5, 6, 7, 38, 39 & 40 USE ITEM NOS. 39, 40 & 41.
8 SOLDER "SOLDER LUG" (ITEM NO. 30) TO "GND" PLANE AND PLACE UNDER SCREW HEAD APROX. AS SHOWN.
NOTES: (CONT'D)
9 SOLDER GND TERMINAL (ITEM 98) TO GROUND PLANE (COMPONENT SIDE OF I.C. MODULE PANEL - ITEM 9).
10 SOLDER PWR TERMINAL (ITEM 97) TO PWR PLANE (WIRE-WRAP TERM. SIDE OF I.C. MODULE PANEL - ITEM 9).
11 THE PWR & GND BUS WIRING SHALL BE ON THE WIRE-WRAP TERM. SIDE OF I.C. MODULE PANEL - ITEM 9.
12 THE "KAPTON TAPE" (ITEM 54) SHALL RUN THE FULL LENGTH OF THE RAILS (ITEMS 14 & 15)
13 CEMENT ITEM 23 TO ITEM 18 USING A CONTACT TYPE OF CEMENT AND INSTALL AS SHOWN IN SECT B-B.
14 BEVEL CORNER OF NYLON SPACER ENOUGH TO CLEAR WIRE WRAP TERMINAL OF CIRCUIT BOARD. (ITEM 10).
A T. COTE D WEINE
DRAWN FROM LEVEL PAPER SET DISTRIBUTED
REVISED NOTE 14, FIG. E, AS SPECIFIED. VARIOUS MARKINGS.
FIG. E
BEVEL SPACER PER NOTE 14
8 REF - COMPONENT SIDE
17 (REF)
18 REF
23 REF
44 4 REQ'D
20 (REF)
4 PLC'S
1 BOTH SIDES
2 REQ'D
FAR SIDE
MI
2 PLCS
16 REQ'D
INSERT FROM THIS SIDE
INSERT FROM OTHER SIDE
TYP - 4 PLC'S
43 (REF)
TYP 2 PLCS
"ANALOG INPUT HARNESS"
"GND"/GRD TERMINAL (ITEM 98 - REF)
PWR TERMINAL (ITEM 97 - REF)
BUS WIRES, SLEEVED (ITEMS 51 & 54)
FIG A
PICTORIAL VIEW OF PWR-GRD BUS (UNDERSIDE OF I.C. MOD. SUB-ASSY - ITEM 9)
SEE FIG A
TYP - 2 PLCS
8 PLCS
SECT B-B
"DISP-A"
"DISP-B"
"DISP-C"
"DISP-D"
"DSP-DS2"
"DSP-DS3"
VIEW C-C
PIN NO. 1
SECT D-D
BILL OF MATERIALS A13720Z99
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
MATERIAL
FINISH
NEXT ASSY
USED ON
VLA
MI
(MODEL D)
NATIONAL RADIO ASTRONOMY OBSERVATORY
DATA SET MODULE
D13720P73
5-4

Figure 5.2

REVISIONS

| REV | DATE | DRAWN BY | APPRV'D BY | DESCRIPTION |
|---|---|---|---|---|
| - | 5/27/77 | | | REDRAWN FROM A13720283, REV E |
| A | 6/14/77 | | | ITEM 30 P/N WAS CINCH NO, 25F-43-30-410 |
| B | 9/28/77 | | | CANCELLED ITEM 38, CORRECTED P/N OF ITEMS 32, 35 & 37 |
| C | 1/16/78 | | | CORRECTED LENGTHS OF ITEMS 62, 65 & 66, QTY OF ITEM 37 AND P/N & QTY OF ITEM 38. |

| | | | | |
|---|---|---|---|---|
| DRAWN BY | DATE | | | |
| DESIGNED BY | DATE | | | |
| APPROVED BY | DATE | | | D13720P73 |
| | | | NEXT ASSY | USED ON |

NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO 87801

VLA

PROJECT: M1 (MODEL D)

TITLE: DATA SET MODULE

DWG NO. A13720299 SHEET OF

Figure 5.3

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☒ MECHANICAL BOM #A13720Z99 REV C DATE _____ PAGE 1 of 5 OF _____

MODULE # M1 NAME DATA SET MODULE DWG # D13720P73 SUB ASMB _____ DWG # _____

SCHEMATIC DWG # D13720L44 LOCATION _____ QUA/SYSTEM _____ PREPARED BY _____ APPROVED _____

| ITEM # | REF DESIG | MANUFACTURER | MFG PART # | DESCRIPTION | TOTAL QUA | |
|---|---|---|---|---|---|---|
| 1 | | N.R.A.O. | A13720Z99 | DATA SET MODULE | - | |
| 2 | | | | | | |
| 3 | | | A13720W61 | WIRE LIST - MASTER | - | |
| 4 | | | A13720W62 | WIRE LIST - HAND | - | |
| 5 | | | A13720W63 | WIRE LIST - MACHINE | - | |
| 6 | | | A13720W64 | WIRE LIST - CONNECTOR | - | |
| 7 | | | | | | |
| 8 | | | A13720Z85 | A.D. CONVERTER P.C.B. ASS'Y | 1 | |
| 9 | | | A13720Z84 | I.C. MODULE PANEL SUB-ASS'Y | 1 | |
| 10 | | | A13720Z23 | L.E.D. DISPLAY SUB-ASS'Y | 1 | |
| 11 | | | | | | |
| 12 | | | B13720M22 | ENGRAVED FRONT PANEL | 1 | |
| 13 | | | B13450M18 | PANEL, REAR | 1 | |
| 14 | | | C13720M15-1 | MODIFICATION, RAIL | 1 | |
| 15 | | N.R.A.O. | C13720M15-2 | MODIFICATION, RAIL | 1 | |

[redacted]

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☒ MECHANICAL BOM #A13720Z99 REV C DATE _____ PAGE 2 OF _____

| ITEM # | REF DESIG | MANUFACTURER | MFG PART # | DESCRIPTION | TOTAL QUA | |
|---|---|---|---|---|---|---|
| 16 | | N.R.A.O. | B13720M47 | SPACER | 2 | |
| 17 | | | C13720M17 | SPACER, RAIL | 2 | |
| 18 | | | C13720M50 | SIDE PLATE | 1 | |
| 19 | | | B13050M4 | GUIDE | 2 | |
| 20 | | | C13050M7 | PERFORATED COVER | 1 | |
| 21 | | | B13050M17 | FASTENER, PERF. COVER | 2 | |
| 22 | | N.R.A.O. | B13720M46 | BRACKET, CONN. | 1 | |
| 23 | | N.R.A.O. | B13720M49 | PANEL, SIDE, INSULATION | 1 | |
| 24 | | SOUTHCO | 47-10-204-10 | CAPTIVE SCREW | 2 | |
| 25 | | N.R.A.O. | B13720M18-1 | POLARIZED SCREEN | 1 | |
| 26 | | N.R.A.O. | B13720M18-2 | CLEAR FILTER | 1 | |
| 27 | | | | | | |
| 28 | | CINCH | DC-37S-F179 | CONNECTOR, D-SUBMIN. | 1 | |
| 29 | | CINCH | D20418-2 | SCREW LOCK ASS'Y. (FEMALE) | 2 | |
| 30 | | S.A.E | CPH7000-86ST | CONNECTOR, 43 POS. P.C.B. EDGE | 1 | |
| 31 | | | | | | |
| 32 | | AMP SPEC.INDUST. | 601488-2 | CONNECTOR, 34 PIN (PRE-ASSEM.) | 1 | |



FIGURE 5.3 (Cont'd)

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☒ MECHANICAL BOM #A13720Z99 REV C DATE _____ PAGE 3 OF _____

| ITEM # | REF DESIG | MANUFACTURER | MFG PART # | DESCRIPTION | TOTAL QUA | |
|---|---|---|---|---|---|---|
| 33 | | AMP SPEC. INDUST. | 202434-4 | SHIELD, 34 PIN CONN. | 1 | |
| 34 | | | | | | |
| 35 | | | 601488-4 | CONNECTOR, 42 PIN (PRE-ASSEM.) | 1 | |
| 36 | | | 202394-2 | SHIELD, 42 PIN CONN. | 1 | |
| 37 | | | 204219-1 | PIN, CRIMP (16 AWG) POS J4-10, 34 & 42 | 3 | |
| 38 | | | P76-0001-4142 | PIN, WW POS J4-16 & 17 | 2 | |
| 39 | | | 201143-5 | PIN, COAX. | 6 | |
| 40 | | | 328666 | FERRULE | 6 | |
| 41 | | | 201142-2 | SPRING, RETENTION | 6 | |
| 42 | | | | | | |
| 43 | | | 200833-4 | GUIDE PIN | 2 | |
| 44 | | | 202514-1 | GUIDE PIN (GND) | 2 | |
| 45 | | AMP SPEC. INDUST. | 203964-6 | GUIDE SOCKET | 4 | |
| 46 | | | | | | |
| 47 | | H. H. SMITH | 2010 | TERMINAL (SPLIT LUG) | 4 | |
| 48 | | H. H. SMITH | 2025 | TERMINAL (MIN. THROUGH) | 4 | |
| 49 | | | | | | |



FIGURE 5-3 (Cont'd)

[redacted] BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☒ MECHANICAL BOM # A1372099 REV C DATE _____ PAGE 4 OF _____

| ITEM # | REF DESIG | MANUFACTURER | MFG PART # | DESCRIPTION | TOTAL QUA | |
|---|---|---|---|---|---|---|
| 50 | | G.C. ELECTRONICS | 5706-C | LUG, SOLDER | 1 | |
| 51 | | ALPHA | 286 | BUS BAR TINNED COPPER (14 AWG) | A/R | |
| 52 | | BELDEN | 8654-50 | BRAID CABLE | A/R | |
| 53 | | ALPHA | PVC-105/6 | PLASTIC TUBING (TYPE PVC) .166 I.D. | A/R | |
| 54 | | ALPHA | TFT-200/13(NAT.) | TEFLON EXTRUDED TUBING | A/R | |
| 55 | | | ~~1.6" x 5-1/2" x .003THK MYLAR~~ | | ~~1~~ | |
| 56 | | CONN. HARD RUBBER CO. | TYPE K350 | KAPTON TEMP-R-TAPE (32/64"WIDE) | A/R | |
| 57 | | | | | | |
| 58 | | AMATOM | 8212-N-440 | THREADED STANDOFF (5/16" LG.) | 4 | |
| 59 | | | | | | |
| 60 | | | 4-40x1/4 LG. | SCREW, PAN HD., NYLON | 4 | |
| 61 | | | 4-40x3/8 LG. | SCREW, PAN HD., ST. ST'L. | 22 | |
| 62 | | | 6-32x.5/8 LG. | SCREW, PAN HD., ST. ST'L. | 2 | |
| 63 | | | 6-32x1-1/8 LG. | SCREW, PAN HD., ST. ST'L. | 2 | |
| 64 | | | 6-32x1/4 LG. | SCREW, FLAT HD., ST. ST'L. | 6 | |
| 65 | | | 6-32x 7/16 LG. | SCREW, FLAT HD., ST. ST'L. | 2 | |
| 66 | | | 6-32x 5/8 LG. | SCREW, SKT. HD. CAP, ST. ST'L. | 2 | |



FIGURE 5.3 (Cont'd)

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☒ MECHANICAL BOM #A13720299 REV C DATE _____ PAGE 5 of 5 OF _____

| ITEM # | REF DESIG | MANUFACTURER | MFG PART # | DESCRIPTION | TOTAL QUA | |
|---|---|---|---|---|---|---|
| 67 | | | | | | |
| 68 | | | NO. 6 | WASHER, EXT. TOOTH, ST. ST'L. | 10 | |
| 69 | | | NO. 4 | WASHER, SPLIT LOCK, ST. ST'L. | 22 | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
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| | | | | | | |



TABLE 5.3 (Cont'd)

## 6.0 FORMS AND FORMAT CONVENTIONS

Figure 6.1 depicts the VLA Electronic Drawing Title Block Format and the data entries.

Figure 6.2 depicts the Revision Block and entry conventions. The space below the Revision Block should be left blank so that many revision entries may be made. All sheets of a drawing should be kept at the same revision level as this is more straightforward than a multi-level treatment.

Figure 6.3 depicts the BOM format and the entry conventions.

Figure 6.4 is a table of the standard drawing form sizes. These should be used wherever possible.

Always use the smallest form size practical as this makes the drawings easier to handle on the lab bench. Large drawings may be easier to generate and entail fewer sheets, but are difficult to work with on the bench or in the field.

All sheets of the same drawing should use the same size form.

Figure 6.5 is the Change Order form which is a formal change control form, used principally to control major changes in equipment and drawings.

Figure 6.6 is the cover sheet for A size drawings such as wire lists and BOM's. The entries are identical to the Title Block entries of Figure 6.1.

Figures 6.7 and 6.8 are 16 and 14 pin Dip Header assembly drawing forms. These use the cover sheet of Figure 6.6 for Title Block and revision data.

Figure 6.9 is a general purpose A size form which may be used for applications like BOM notes, Spec Control Drawings, etc.

Figure 6.10 through 6.13 are module I/O connector pin/signal lists which define wiring on the module/bin interface connector.

Figure 6.14 is a rack wire list form which defines rack wiring. These forms are particularized to a particular connector and each pin is a nodal point in a to/from format.

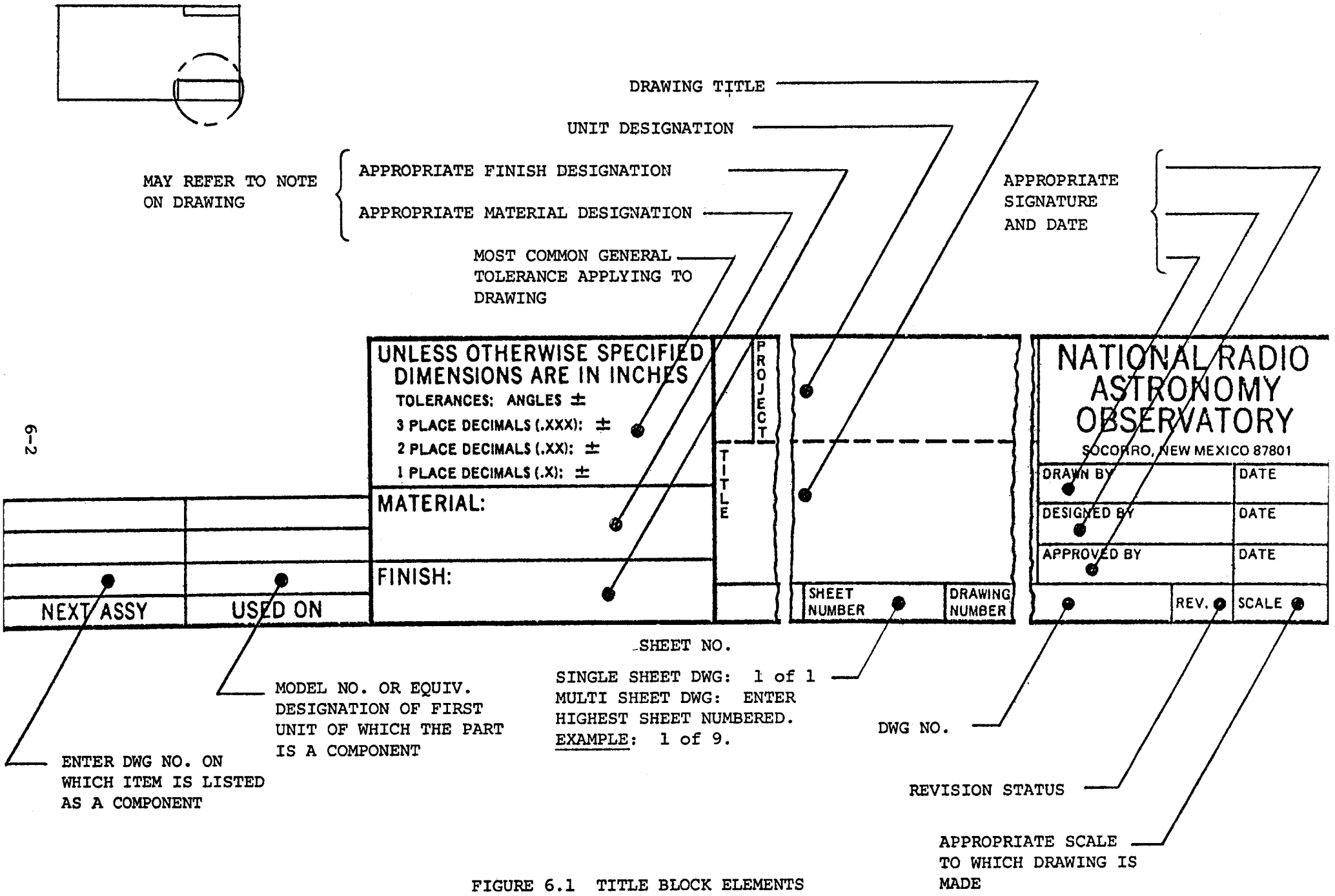
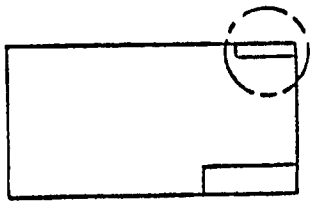



FIGURE 6.1 TITLE BLOCK ELEMENTS





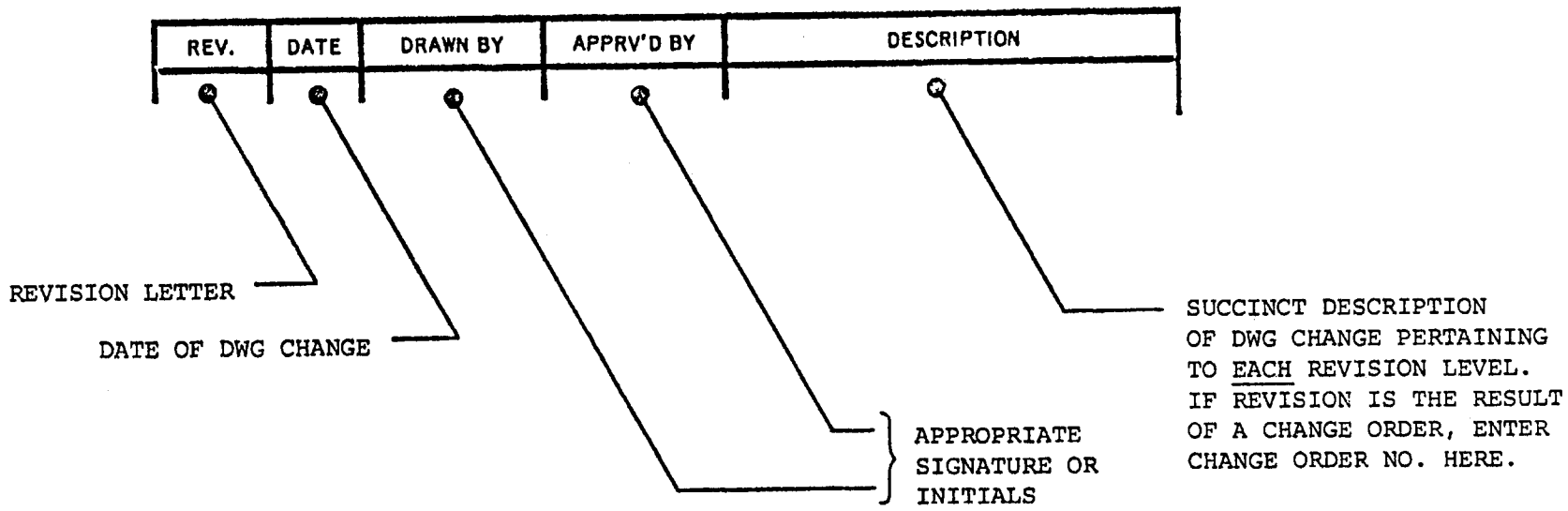



FIGURE 6.2 REVISION BLOCK ELEMENTS

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

[1] ☐ ELECTRICAL ☐ MECHANICAL BOM # [2] REV [3] DATE N/A PAGE ____ OF ____

MODULE # [4] NAME [5] DWG # [5] SUB ASMB [6] DWG # [6]

SCHEMATIC DWG # [7] LOCATION N/A QUA/SYSTEM N/A PREPARED BY N/A APPROVED N/A

| ITEM # | REF DESIG | MANUFACTURER | MFG PART # | DESCRIPTION | TOTAL QUA | |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |



[1] Check appropriate box based on contents of BOM (electrical components, mechanical parts or both).

[2] Drawing number of the BOM (this number and associated title shall also appear as item No. 1 in the body of the BOM).

[3] The revision level of the BOM.

[4] The module designation of the unit the BOM is associated with.

[5] The module name and its assembly and BOM numbers (this information is for reference only when "SUB ASMB" information is given).

[6] The subassembly name and its drawing number (if the BOM is being prepared for an assembly drawing, no information appears in this area. Otherwise, the information appearing here is the unit associated with the BOM).

[7] The schematic or logic diagram drawing number associated with the unit for which the BOM is being prepared.

Figure 6.3

| Form ID | Horiz. Dim. | Vert. Dim. | Recommended Usage |
|---|---|---|---|
| A | 8½ | 11 | Cover Sheets for Wire Lists, BOM's Data Lists, etc. |
| B | 11 | 17 | Small, Simple Components |
| C | 17 | 22 | General Use |
| D | 22 | 34 | General Use |
| E | 34 | 44 | Not Recommended for General Use |

Figure 6.4 STANDARD VLA DRAWING FORM SIZES

# NRAO CHANGE ORDER

CHANGE ORDER NO. 78 01 20 DWW 3 MODULE/RACK TYPE _____

DATE – INITIALS – SEQUENCE NO.

PREPARED BY _____ DATE _____ APPROVED BY _____ DATE _____

DESCRIPTION OF CHANGE: ☐ MODULE ☐ RACK ☐ DRAWING ONLY

YEAR

MONTH

DAY OF MONTH

UPDATED NUMBER OF CHANGE ORDERS REQUESTED BY ORIGINATOR DURING CURRENT YEAR

ORIGINATOR'S INITIALS

ATTACHMENTS: ☐ MARKED PRINT ☐ SKETCH ☐ CHG. CONT. ON ANOTHER SHT. ☐ OTHER: _____

NRAO DRAWINGS AFFECTED

☐ HOLD FOR VLA APPROVAL FROM SITE ☐ CV APPROVAL O.K., BY _____

| DRAWING NO. | TITLE | DRAWING NO. | TITLE |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

FIRST SERIAL NO. AFFECTED: _____

ROUTING INSTRUCTIONS (C'VILLE ONLY)

RCVD. BY DRAFTING _____ DATE _____

DWG. CHANGES BY _____ DATE _____

MOD./RACK CHG. BY _____ DATE _____

☐ CHK. PRINTS SENT TO SITE DATE: ☐ APPROVAL FROM SITE DATE:

COPIES: ☐ _____ ☐ _____ ☐ _____ ☐ _____ ☐ _____ ☐ _____

C.O. NO.

FIGURE 6.5

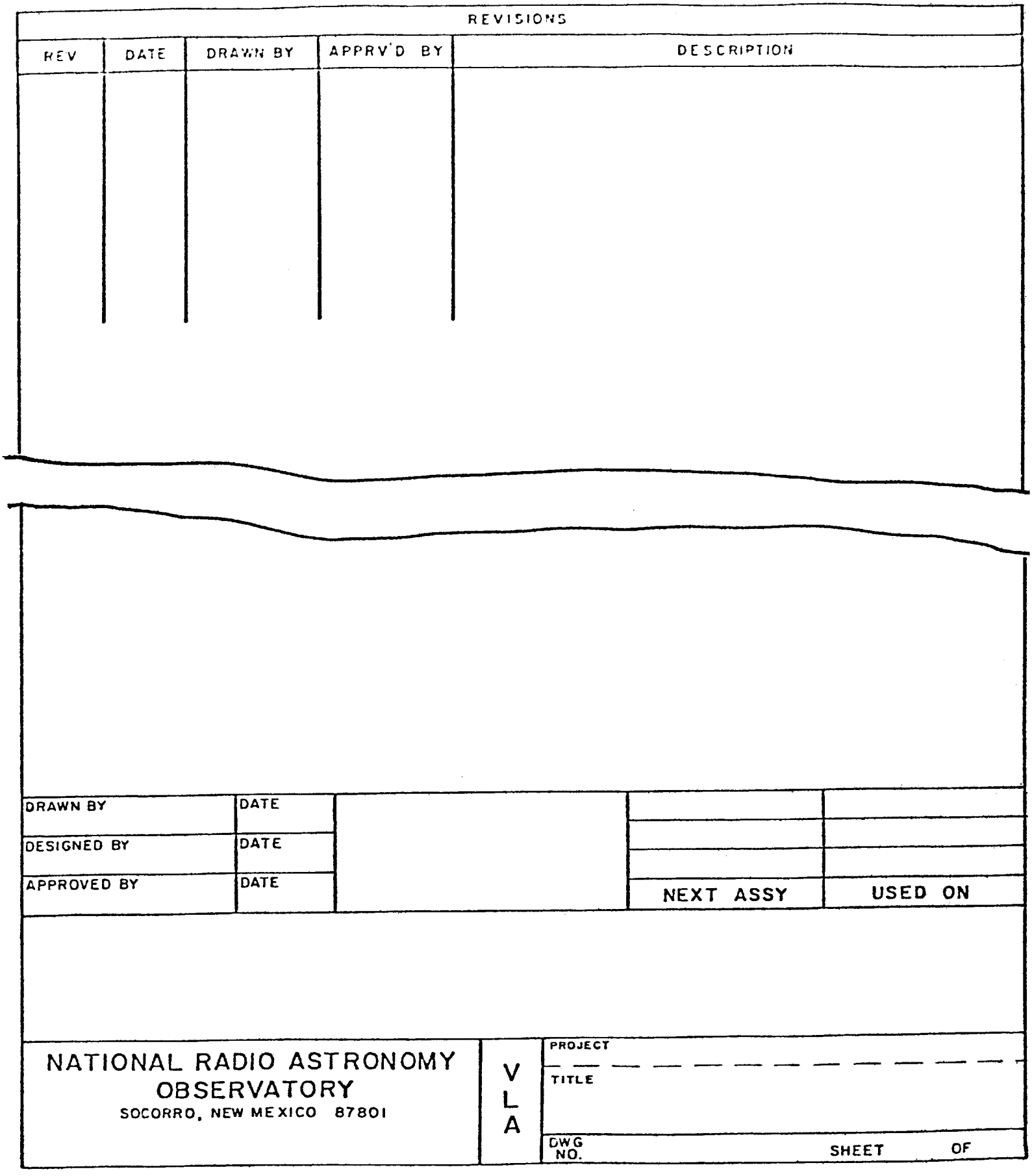
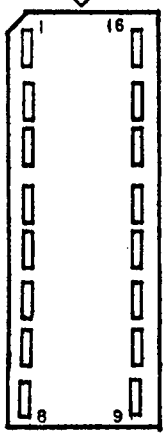

REVISIONS
REV
DATE
DRAWN BY
APPRV'D BY
DESCRIPTION
DRAWN BY
DATE
DESIGNED BY
DATE
APPROVED BY
DATE
NEXT ASSY
USED ON
NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO 87801
V
L
A
PROJECT
TITLE
DWG NO.
SHEET
OF

Figure 6.6

| DESCRIPTION | VALUE | MFG | MFG P/N |
|---|---|---|---|
| DIP HEADER | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |



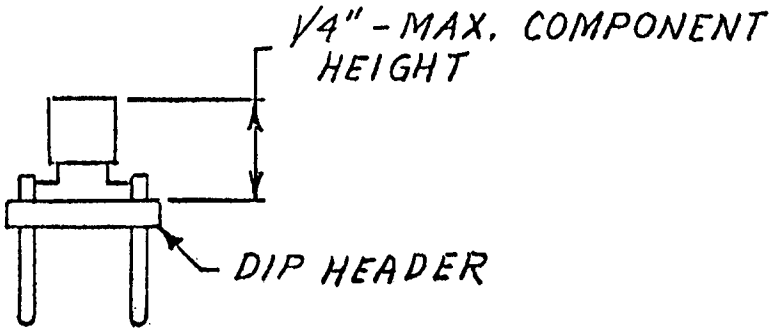




Figure 6.7

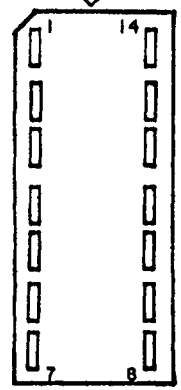


DWG. NO.

SHEET

RE

| DESCRIPTION | VALUE | MFG | MFG P/N |
|---|---|---|---|
| DIP HEADER | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |



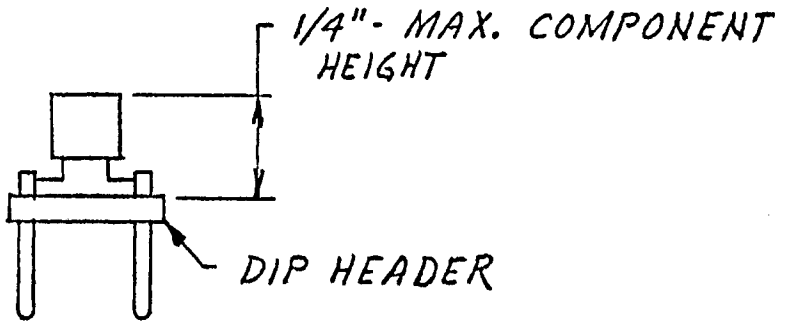




Figure 6.8



DWG. NO.

SHEET

REV

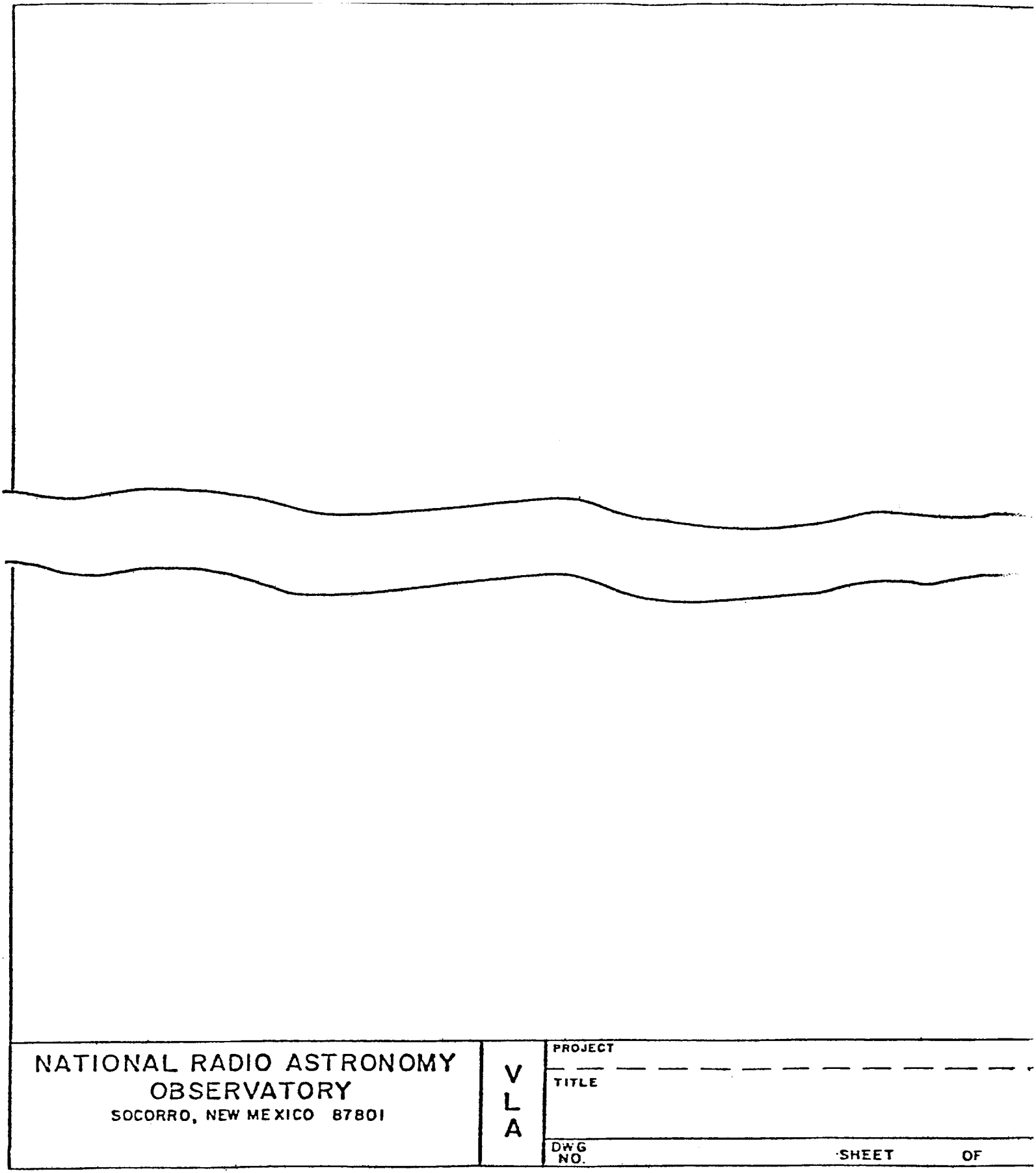
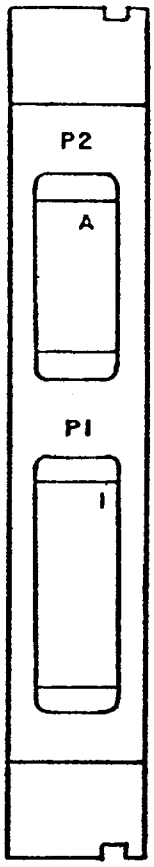
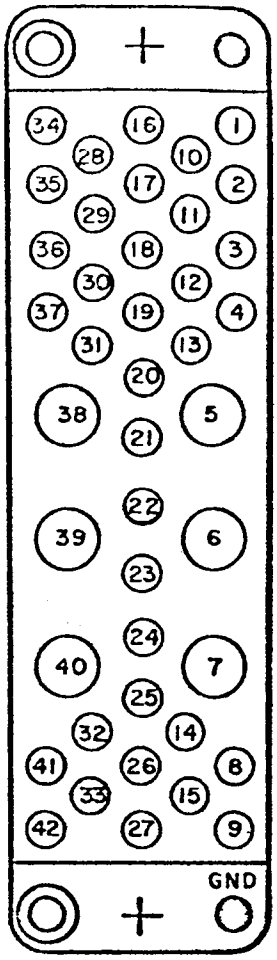

NATIONAL RADIO ASTRONOMY
OBSERVATORY
SOCORRO, NEW MEXICO 87801
V
L
A
PROJECT
TITLE
DWG
NO.
SHEET
OF

Figure 6.9




SINGLE WIDE MODULE
( REAR VIEW )

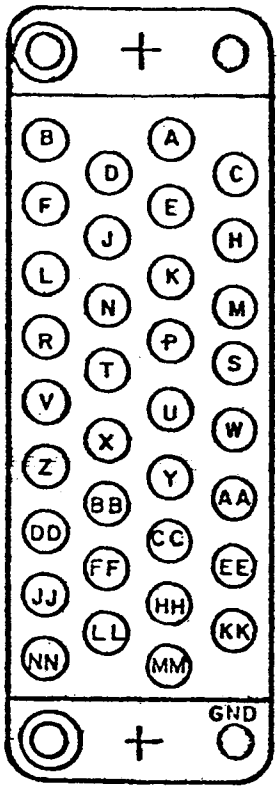



P1 (REAR VIEW)

| P1 | | | | | |
|---|---|---|---|---|---|
| PIN | FUNCTION | WIRE COLOR | PIN | FUNCTION | WIRE COLOR |
| 1 | | | 22 | | |
| 2 | | | 23 | | |
| 3 | | | 24 | | |
| 4 | | | 25 | | |
| 5 | | | 26 | | |
| 6 | | | 27 | | |
| 7 | | | 28 | -28VDC | GREEN |
| 8 | | | 29 | +28VDC | GREY |
| 9 | | | 30 | | |
| 10 | +5VDC | ORANGE | 31 | | |
| 11 | -5VDC | BROWN | 32 | | |
| 12 | | | 33 | | |
| 13 | | | 34 | PWR. GROUND | BLACK |
| 14 | | | 35 | | |
| 15 | | | 36 | | |
| 16 | +15VDC | RED | 37 | | |
| 17 | -15VDC | YELLOW | 38 | | |
| 18 | | | 39 | | |
| 19 | | | 40 | | |
| 20 | | | | | |
| 21 | | | | AL. GROUND | |

* INDICATES A FUNCTION NOT FOUND

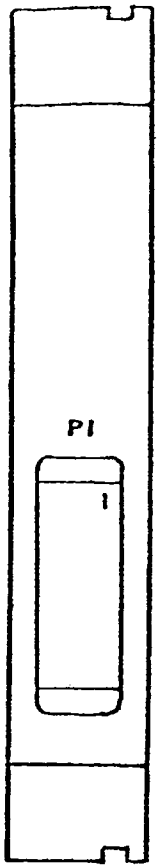
Figure 6.10



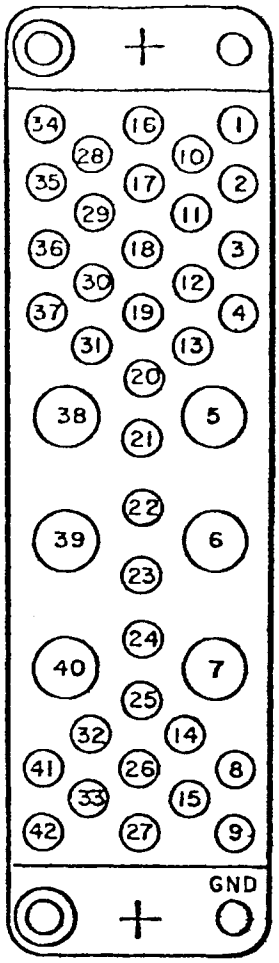

P2 (REAR VIEW)

| P2 | | | | | |
|---|---|---|---|---|---|
| PIN | FUNCTION | WIRE COLOR | PIN | FUNCTION | WIRE COLO |
| A | | | V | | |
| B | | | W | | |
| C | | | X | | |
| D | | | Y | | |
| E | | | Z | | |
| F | | | AA | | |
| H | | | BB | | |
| J | | | CC | | |
| K | | | DD | | |
| L | | | EE | | |
| M | | | FF | | |
| N | | | HH | | |
| P | | | JJ | | |
| R | | | KK | | |
| S | | | | | |
| T | | | | | |
| U | | | | | |

Figure 6.11




SINGLE WIDE MODULE
( REAR VIEW )

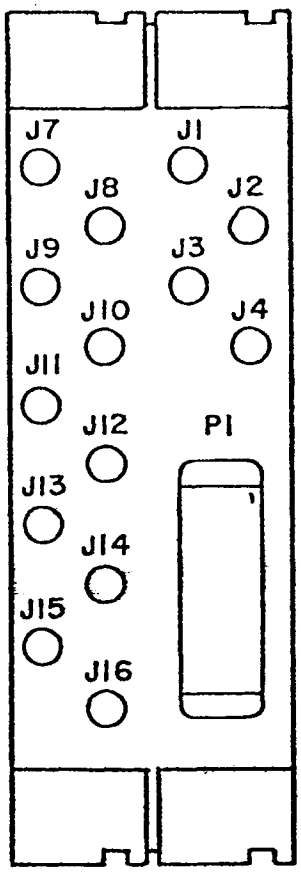



P1 (REAR VIEW)

| P1 | | | | | |
|---|---|---|---|---|---|
| PIN | FUNCTION | WIRE COLOR | PIN | FUNCTION | WIRE COLOR |
| 1 | | | 22 | | |
| 2 | | | 23 | | |
| 3 | | | 24 | | |
| 4 | | | 25 | | |
| 5 | | | 26 | | |
| 6 | | | 27 | | |
| 7 | | | 28 | -28VDC | GREEN |
| 8 | | | 29 | +28VDC | GREY |
| 9 | | | 30 | | |
| 10 | +5VDC | ORANGE | 31 | | |
| 11 | -5VDC | BROWN | 32 | | |
| 12 | | | 33 | | |
| 13 | | | 34 | PWR. GROUND | BLACK |
| 14 | | | 35 | | |
| 15 | | | 36 | | |
| 16 | +15VDC | RED | 37 | | |
| 17 | -15VDC | YELLOW | 38 | | |
| 18 | | | 39 | | |
| 19 | | | | | |
| 20 | | | | | |
| 21 | | | | AL. GROUND | |

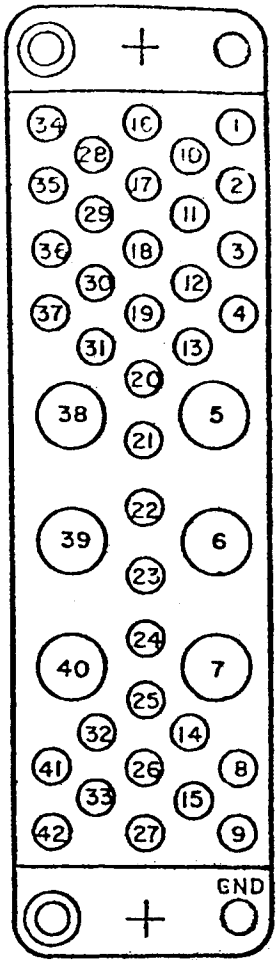
* INDICATES A FUNCTION NOT FOUN

Figure 6.12




DOUBLE WIDE MODULE
(REAR VIEW)

| CONN | FUNCTION |
|---|---|
| J1 | |
| J2 | |
| J3 | |
| J4 | |
| J7 | |
| J8 | |
| J9 | |
| J10 | |
| J11 | |
| J12 | |
| J13 | |
| J14 | |
| J15 | |
| J16 | |




P1 (REAR VIEW)

P1

| PIN | FUNCTION | WIRE COLOR | PIN | FUNCTION | WIRE COLOR |
|---|---|---|---|---|---|
| 1 | | | 22 | | |
| 2 | | | 23 | | |
| 3 | | | 24 | | |
| 4 | | | 25 | | |
| 5 | | | 26 | | |
| 6 | | | 27 | | |
| 7 | | | 28 | −28VDC | GREEN |
| 8 | | | 29 | +28VDC | GREY |
| 9 | | | 30 | | |
| 10 | +5VDC | ORANGE | 31 | | |
| 11 | −5VDC | BROWN | 32 | | |
| 12 | | | 33 | | |
| 13 | | | 34 | PWR. GROUND | BLACK |
| 14 | | | 35 | | |
| 15 | | | 36 | | |
| 16 | +15VDC | RED | 37 | | |
| 17 | −15VDC | YELLOW | 38 | | |
| 18 | | | 39 | | |
| 19 | | | | | |
| 20 | | | | | |
| 21 | | | | IAL. GROUND | |

* INDICATES A FUNCTION NOT FOUND

Figure 6.13

| RACK: | BIN: | SLOT: | MODULE: | TYPE: |
|---|---|---|---|---|
| LIST BY: | | WIRE BY: | | |
| CONNECTOR TYPE: 34 PIN | | CONNECTOR PAGE: 1 of 2 | | |

| PIN | FUNCTION | WIRE TYPE | FROM | TO |
|---|---|---|---|---|
| A | | | | |
| B | | | | |
| C | | | | |
| D | | | | |
| E | | | | |
| F | | | | |
| H | | | | |
| J | | | | |
| K | | | | |
| L | | | | |
| M | | | | |
| N | | | | |
| P | | | | |
| R | | | | |
| S | | | | |
| T | | | | |
| U | | | | |
| V | | | | |
| W | | | | |
| X | | | | |
| Y | | | | |
| Z | | | | |
| AA | | | | |
| BB | | | | |
| CC | | | | |
| DD | | | | |
| EE | | | | |
| FF | | | | |
| HH | | | | |
| JJ | | | | |

| NATIONAL RADIO AST | DATE: |
|---|---|
| TITLE: | REV: |
| | SHEET OF |

Figure 6.14

## 7.0 DRAWING PROCEDURES

This section sets forth drafting procedural guidelines.

### 7.1 Drawing Control

At present, VLA electronics design control authority operates at two levels:

System Level - At the System Level the Systems Engineer defines system performance requirements, interface specifications and system configuration. The Systems Engineer may direct design/drawing changes by means of a Change Order or Revision Request. This would usually be done in consultation with the engineer responsible for the particular subsystem.

Responsible Engineer Level - The engineer responsible for a system/subsystem may direct drawing revisions which do not conflict with the VLA System specifications. Design changes which might impact these specifications must be approved by the Systems Engineer. Within these constraints the Responsible Engineer (or his delegate) may issue any Revision Requests or generate any required drawings to implement designs, correct errors and improve performance, reliability or manufacturability.

Drawing changes are not permitted outside the authorization areas cited above.

At some future date drawing revision authority may be changed to a more formal approval procedure than that cited above.

### 7.2 Change Orders and Procedures

Major changes in the VLA system configuration, rack wiring, module design, component selection and drawings are directed

by a Change Order. The form and entry conventions are shown in Figure 6.5. Change Orders are used for all changes directed to Charlottesville by the VLA site engineers and for major changes at the VLA site by site personnel.

Entries on the form provide an orderly check list for distribution, drawing and hardware changes and serial numbers affected by the Change Order.

Change Orders are generated by engineers and technicians and are reviewed by the Systems Engineer.

When a Change Order is generated a copy of the Change Order and associated data should be sent to the VLA site drafting files.

## 7.3 Drawing Revisions

It often becomes necessary to change drawings to correct errors and improve performance, manufacturability or maintainability. This process is called drawing revision and is initiated by a Revision Request or Change Order.

The Revision Request should cite the affected drawings and include a written statement of the required changes. A red-lined (annotated) print may serve as an alternate to the written directions. The Revision Request is placed in a pending revision file in drafting and will be implemented in the queue order if the change is not urgent.

The Responsible Engineer (or a delegate) should carefully review and approve the revised drawings.

The revision blocks on the drawing should be updated to show the new revision level, date, a succinct description of the change (including Change Order number, if appropriate) and approval initials by the Responsible Engineer (or his delegate).

Revisions need not be made for a very small change (such as a screw detail, etc.) but should be made for major performance/configuration changes or when a number of small changes have

accumulated. If a unit is to be built by a contractor all drawing errors should be corrected prior to the issuance of an RFQ.

Avoid the protracted use of red-marked prints, as change details are easily lost or forgotten and red-marked prints quickly become dog-eared or misplaced.

If drawing revisions are extensive or there is the possibility of configuration confusion then another set of reproducible drawings may be required to record the pre-revision configuration, even though the older configuration may be in a transient state. This requirement for separate reproducibles may be necessary because of the time required to implement the changes and the number of units which may still be in service. All units in service must be backed up by a reproducible set of drawings. When upgrading modifications are completed the older or transient drawings should be marked "obsolete" and dated and signed by the Responsible Engineer. The obsolete drawings should be kept in a dead file for a while.

A complete set of reproducible drawings shall be retained in the drawing files in cases where a unit is built to early drawings and is retained in service in its unmodified state.

When a unit is retired from service and will no longer be used (even in emergencies), then the associated reproducible drawings should be marked "obsolete" and dated and signed by the Responsible Engineer. The obsolete drawings should be retained in a dead file for a while.

If revisions are very extensive the "Model" documentation scheme discussed below should be considered.

## 7.4 New Designs

In the course of executing a new design the engineer should formulate a drawing plan which outlines the types and quantities

of drawings to be prepared. The engineer will generally have a packaging concept which will produce the best performance; this should be the basis for the package design. The engineer should work out the drawing structure with the draftsmen who will make suggestions as to the most appropriate means of incorporating the construction requirements in the drawings.

Figure 7.1 is a generalized documentation tree which is recommended for all VLA electronics modules and major assembly documentation. The composition of drawing types must of course be tailored to the application, but by the use of this structure one can be sure that the documentation for a unit is complete, coherent and completely defines the construction requirements.

A Top Assembly and Top BOM drawing should always be generated, no matter how simple the assembly. All the dominant configuration features are derived from this pair of drawings; typical items are I/O connector numbers, subassembly names, wire harness routing, semi-rigid coax routing, maintenance access and test points, assembly procedures and constraints, etc.

Where there are important process or assembly requirements, such as the assembly procedure for OMQ connectors, the appropriate specification should be cited in the assembly drawing notes.

Circuit schematics, logic diagrams, wire lists and assembly drawings should be prepared so that the unit's operating principles are easily understood from the drawings. Maintenance information such as signal levels and tolerances, critical and alignment adjustments, troubleshooting notes, signal waveforms, etc. should be included on the schematics and block diagrams wherever possible.

Each module and system in the VLA has (or will have) a Manual which serves as a maintenance manual and design description. The manual will typically contain a theory of operation, performance and interface specifications; diagnostic and trouble-shooting

information, schematic and logic diagrams, parts lists, data sheets for special purpose components, and a documentation tree (or drawing list). These manuals should be updated to reflect revisions or model changes and should state explicitly to which models they apply.

It is desirable to add the manual number and title to the associated documentation tree.

## 7.5 Model Documentation

When there exists more than one hardware type of a unit with significant differences between them use "Model" documentation in which there exists a set of reproducible drawings for each model. This practice can simplify the drawings for the two (or more) units by eliminating the need for complex and extensive configuration notes on one set of drawings. The second set of reproducible drawings can be generated quite easily by making a mylar sepia copy of one configuration. The copy then may be particularized for one model and the original set may be particularized for the other model. With care, an almost unlimited set of reproducible drawings may be generated which are never more than one generation from the original. Only a few hours are required to generate and detail a set of model drawings.

Drawings for items which are common to the two (or more) models should not be duplicated, but it may be desirable to update the "Used On" and "Next Assembly" blocks in the Title Block. It is generally desirable to generate a documentation tree for each model if there is a possibility of configuration confusion.

The criteria for the use of Model documentation are highly judgemental, but, in general, if there is more than one implementation of a unit with differences in design, operating characteristics, signal levels, I/O connections, components or physical configuration, then the Model approach should be used.

In using this approach one should assign new drawing numbers to the "new" model drawings or indicate model level in the Title Block. Revisions and changes can be made to each model set independent of the other model drawings.

When a new model is generated (either by modification or new construction) the module serial numbers should be altered to reflect the change. Specification A1301ONlA, Section C states:

> "Each module will have a 2 or 3 character serial number such as A1 or B13. The first character notes a particular version or revision; the second character is a consecutive serial number not affected by the revision letter (i.e., if 2 version A modules, A1 and A2, were built the first revision B module would be labeled B3). The serial number shall be marked with 1/8" letters on the lower front panel."

In conformance to this specification a new model (i.e., version) would incorporate the next alphabetic letter in the serial number.

Examples of model documentation are the Models C and D Data Sets which are logically identical but have significant differences in hardware components and internal wiring.

## 7.6 Drawing Checks

The site VLA Electronic Drafting Group does not usually provide a drawing checker service. This task is currently the responsibility of the Responsible Engineer but some assistance may be provided by drafting if requested and if the workload permits.

## 7.7 VLA/CV Drafting Liaison

The VLA site and Charlottesville draftsmen are responsible for liaison between the two drafting groups to coordinate

drawing number usage, revisions, the interchange of check prints and replenishment of the VLA print library. When additional copies of prints or some drafting-related service is required, the draftsmen at either facility should be contacted.

The draftsmen are also responsible for coordination, drawing revisions and the acquisition and distribution of check prints associated with Change Orders or Charlottesville-generated drawings.

## 7.8 VLA Print Library

A complete set of copies of Charlottesville-generated VLA drawings is maintained by drafting in a print library. When new drawings are generated in Charlottesville, they are added to the library files. When drawings are revised by Charlottesville drafting, copies are placed in the library files. Prints are available on request for any drawings which are stored in the site drawing files.

## 7.9 Drawing Number Assignments

Drawing numbers are assigned by the VLA draftsmen and recorded in a log book by title, number, size and drawing originator. The Charlottesville and VLA draftsmen coordinate the number assignments but do not maintain duplicate logbooks. The engineer should supply the project number associated with the unit to be drawn as it is incorporated in the drawing number.

## 7.10 VLA Drawing Number/Title Lists

Computer-generated drawing listings are available which list all VLA electronics drawings on the basis of module association. This listing can quickly answer a question like "What are the drawings for the Data Set?"

The computer data files containing this information are periodically updated. This program and the data files currently

reside in the Charlottesville 360, but it is planned to implement this listing capability in the DEC-10 System. The data formats for entry into the data files are depicted in section 9.5 of this manual.

## 7.11 Drawing Priority

The priority levels normally used by the VLA site electronic drafting group are as follows:

1. Drawings and revisions necessary for construction or impending contractual use.
2. Revisions, drawings of various sorts which are not required for imminent construction.
3. Manual illustrations, etc.

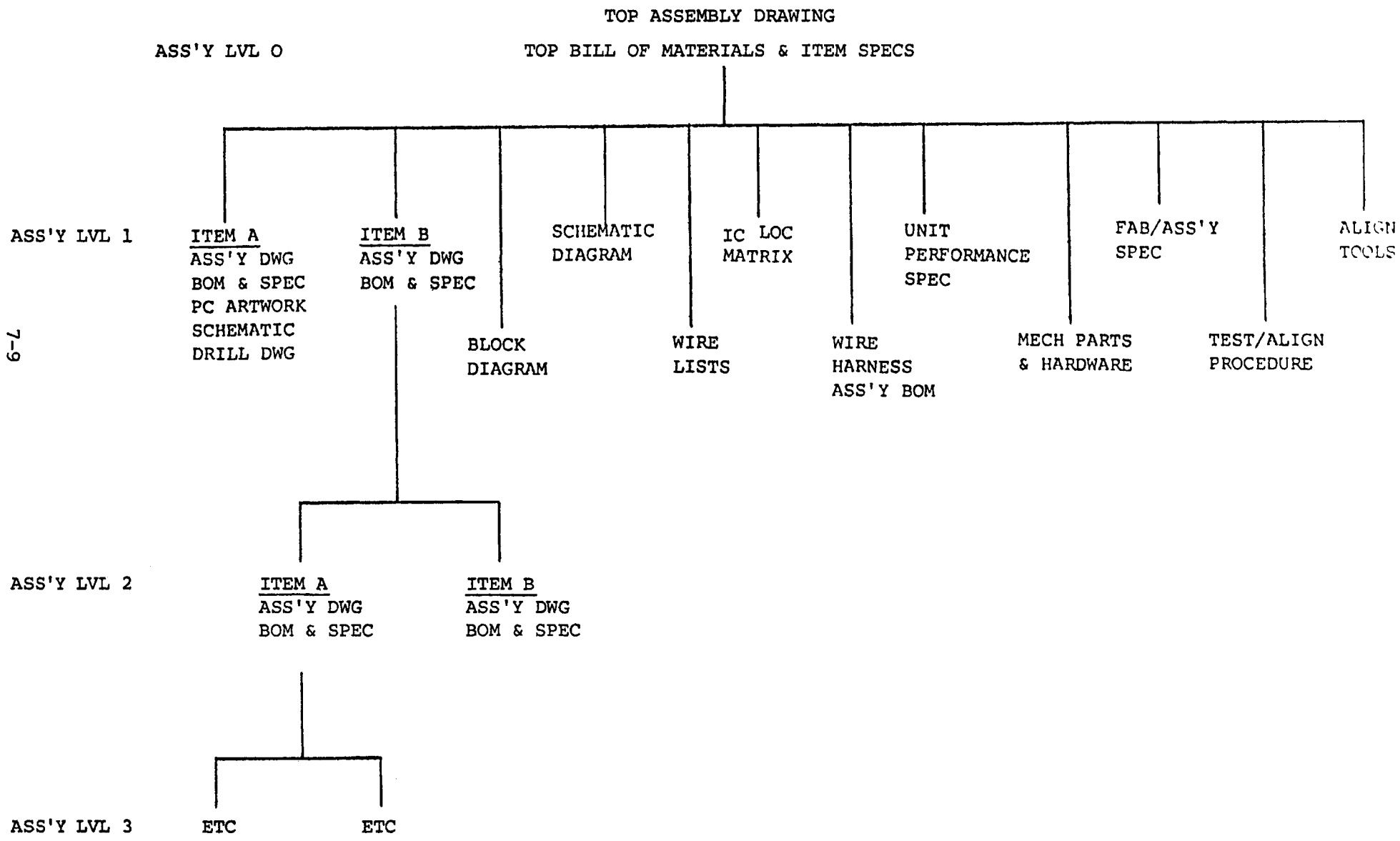



FIGURE 7.1 GENERALIZED DRAWING TREE

# 8.0 DRAFTING CONVENTIONS

## 8.1 General Requirements

8.1.1 A drawing shall contain only the minimum of delineation, but with sufficient technical information so that the items may be fabricated and inspected. Drawings may be prepared by the use of instruments, or freehand (unless specified otherwise). Use of aids such as a grid underlay and templates are encouraged.

8.1.2 Simplified drafting [the elimination of extra views, unnecessary elaboration (e.g., shading), superfluous lines and repetitive information] shall be used to reduce the time and effort in producing the drawings. Figures 8.1 and 8.2 illustrate this principle.

8.1.3 Reproducibility and legibility - Drawings, including those made freehand, shall be legible and shall be reproducible to at least a second generation reproducible drawing capable of being reduced.

8.1.4 Views vs. shape by description - Avoid views when the shape can be given by description (e.g., HEX, SQ, DIA, THK). Show only partial views of symmetrical objects.

8.1.5 Repetitive detail - Avoid the use of elaborate or repetitive detail and avoid repetitive data by use of general notes. Encode identical items on assembly drawings wherever possible.

8.1.6 Hardware details - Omit nonessential details of nuts, bolt heads, and other hardware. Show plain outlines when it is necessary to indicate/position. Knurling shall not be shown.

8.1.7 Detail of parts on assembly drawings - Omit details of parts on assembly drawings, except when such details are necessary to show the location and orientation of the item. Do not show chamfers or corner radii when these features are not necessary for interpretation of the assembly drawing.

8.1.8 Hidden lines - Avoid the use of hidden lines which do not add clarification. Do not dimension to hidden lines.

8.1.9 Cross-sectioning - Use partial cross-sectioning only, and then only when the clarity of the drawing depends upon it.

8.1.10 Shading shall not be used.

8.1.11 Drafting aids - Make maximum use of available templates and decals.

8.1.12 Simplified drafting illustrations - The illustrations in figures 8.1 and 8.2 offer some practical suggestions on the application of the above principles.

8.1.13 Views, projections and sections - Views, projections and sections on drawings shall comply with good drafting practices utilizing third angle projection. If other forms of illustrations are utilized (e.g., isometrics), they must be complete to the degree necessary for proper delineation of the intended item.

8.1.14 Scale - With the exception of freehand applications, drawings should show an object or assembly to full scale. When full size is not practicable, drawings may be prepared to reduced or enlarged scale. Should views and/or sections be of a scale other than that given for the drawing, the appropriate scale shall be indicated.

8.1.15 Hardware - Use simple commercial hardware items rather than Mil Spec components and use simple commercial references such as screw, 6-32 x 1/2, flat head, slotted, stainless steel rather than Mil-XXXXX.

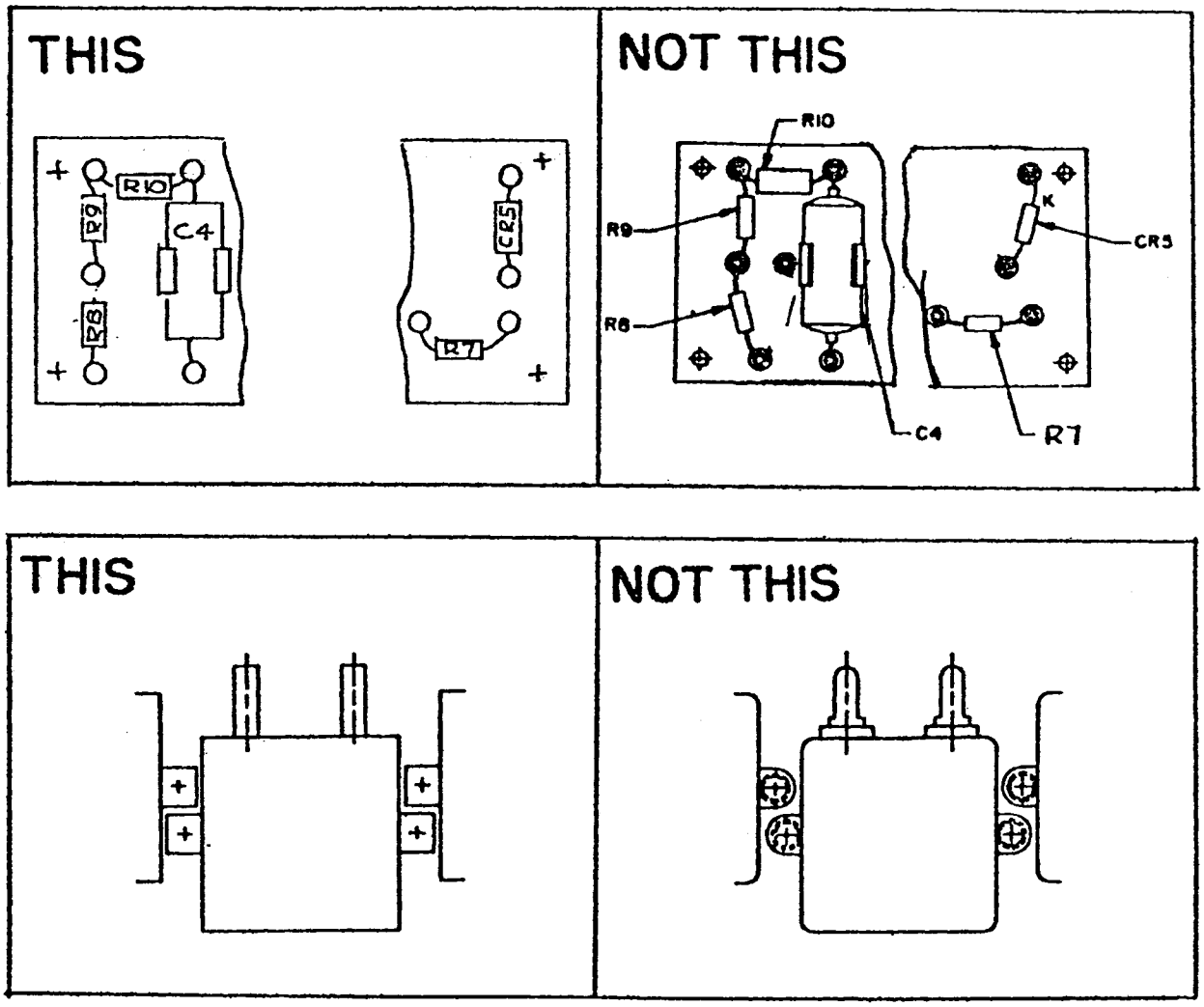



FIGURE 8.1

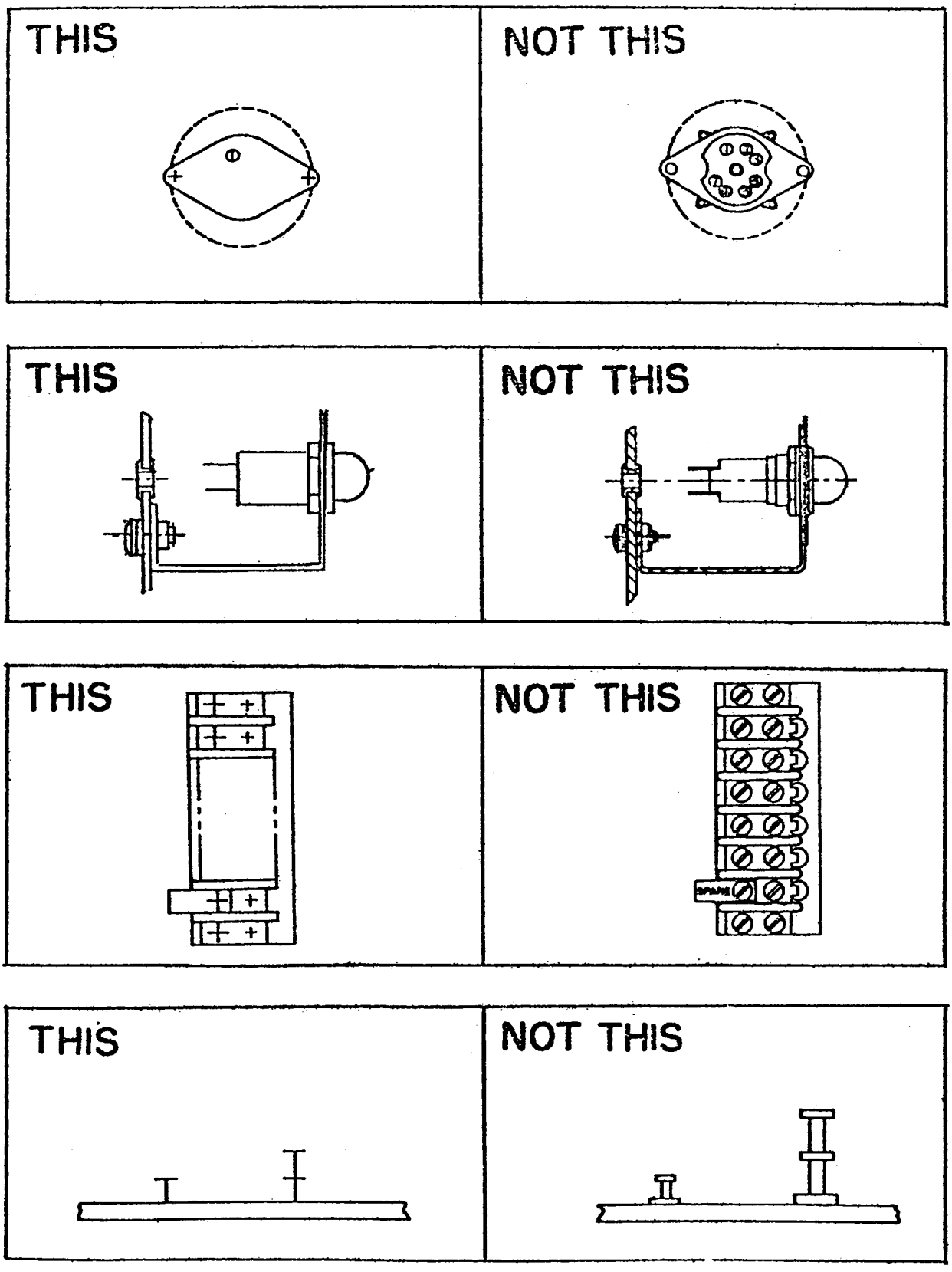



FIGURE 8.2

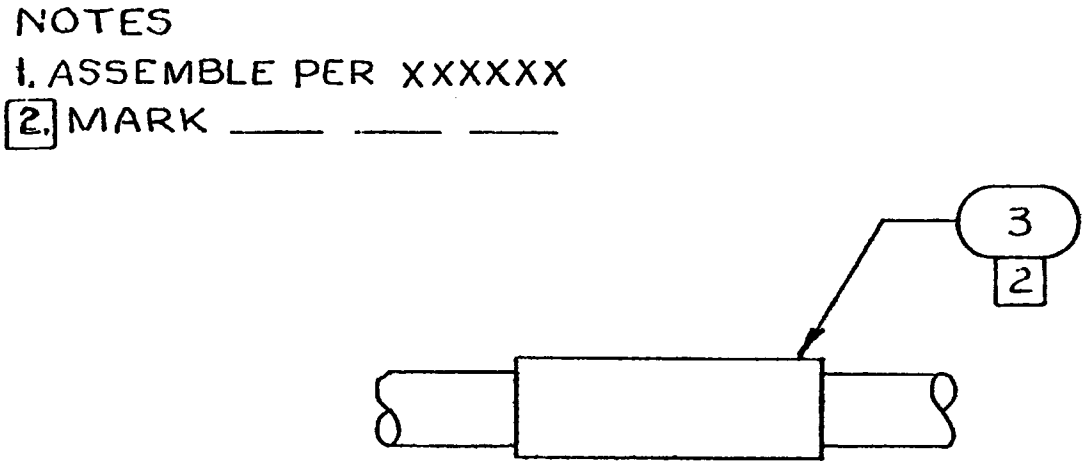
8.1.16 Titles, drawing - Keep drawing titles as brief as possible. Use upper case letters. No title search is required. Make the main part of the title a noun or brief noun phrase describing the item. Use similar titles on assemblies and their associated documents.

## 8.2 Notes on Drawings

8.2.1 Local notes are located in the field of a drawing adjacent to the point of application and usually apply only to a specific feature of the item described on the drawing.

8.2.2 General notes are grouped together and placed in a convenient location, preferably on the left-hand side of the drawing. General notes apply to the entire drawing (e.g., protective finish, heat treatment or to a specific feature which appears in several locations).

8.2.3 A note number, when enclosed by a box, in the general notes indicates a reference in the field of the drawing. See figure below:




EXAMPLE OF NOTE NUMBER REFERENCE

8.2.4 On multi-sheet drawings, place the general notes on sheet 1.

8.2.5 Material designation - The material designation should be specified either in the Title Block (preferred) or in the general notes. When material is specified in the general notes, it must be preceded by the word "material" (e.g., MAT'L, ALUM, 6061-T6). Reference the note number in the Material Block.

8.2.6 The note "Reference" denotes a redundant item call-out on an assembly drawing and is generally associated with additional views which illustrate some aspect of the assembly.

8.3 Marking

If item identification and/or general marking is required, the marking shall be as follows:

8.3.1 Location - Do not dimension the location of the marking unless the location is critical.

8.3.2 Method of application

a. When no specific marking process is required, a general note may be specified on the drawing.

Example: MARKING SHALL BE -- HIGH, LEGIBLE AND PERMANENT. LOCATE APPROX WHERE SHOWN

b. When a specific marking process is required, the process will be specified in the general notes.

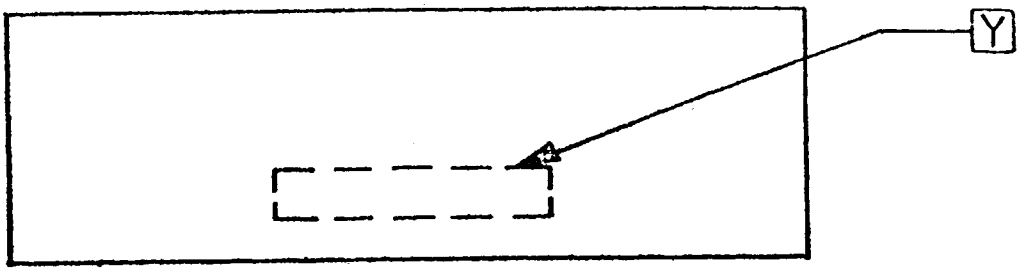
Examples: ENGRAVE _____ HIGH _____

HOT DIE STAMP _____ HIGH BLACK _____

8.3.3 Size - Specify the size of marking such that its minimum size will be legible.

8.3.4 Item identification marking - To be delineated at the appropriate drawing level.

a. Assemblies and details. Required marking may be shown, per figure below, with a reference to the general notes, which call out the marking required.




Notes:

Y Mark part number. Indicate the number or name you want marked.

8.4 Revisions of Drawings and Lists

8.4.1 No controlled drawing or list may be altered in any manner without authorization via an approved Change Order or the direction of the responsible engineer.

8.4.2 When practical, make changes to scale.

8.4.3 Delete a view, detail, section, local or general note, or entry on a manually prepared list by erasure or lining out (preferred unless confusing).

8.4.4 Record each revision or authorization in the revision block, including date and initials of participants.

| REV. | DATE | DRAWN BY | APPRV'D BY | DESCRIPTION |
|---|---|---|---|---|
| A | 6/5/76 | | | DELETED ITEMS 7 & 9 ZONE C-2 |
| B | 9/14/76 | | | ALL RESISTOR VALUES CHANGED FROM 1KΩ TO 100 KΩ PER C.O. NO.---- |

EXAMPLE OF REVISION BLOCK ENTRIES

8.4.5 When a drawing or list is revised or redrawn, identify the revision by the revision letter next in sequence.

8.4.6 A redrawn document need not include the previous revision record, deleted views or notes.

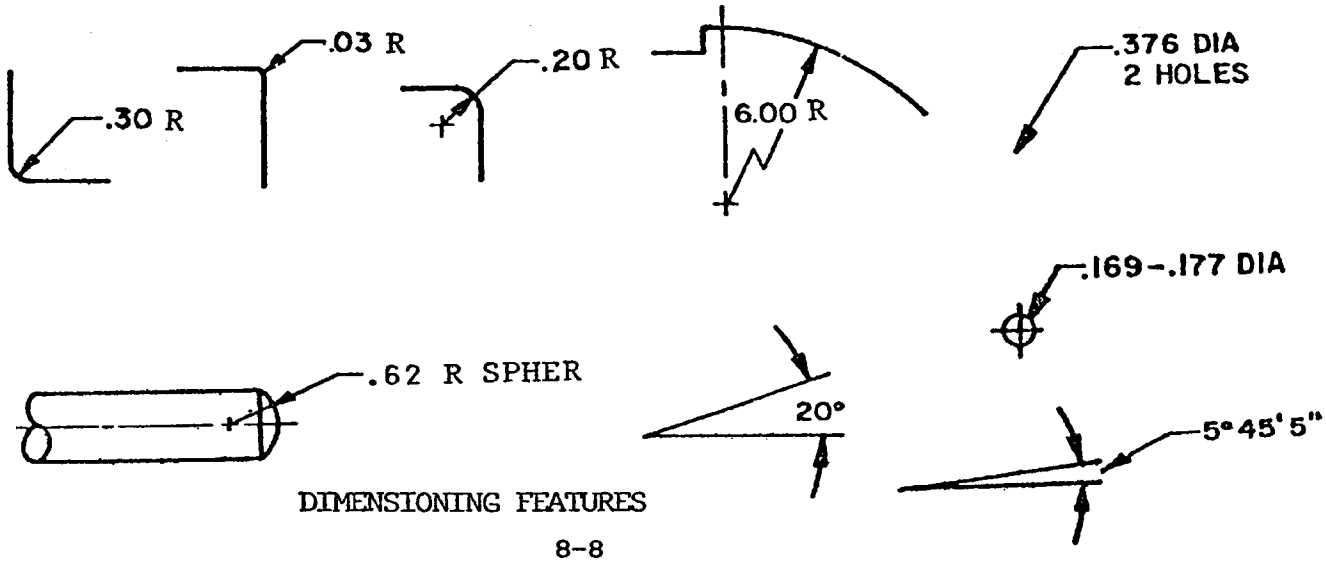
8.4.7 Inactivation of drawings and lists - No controlled drawing or list shall be inactivated unless such action is authorized by the responsible engineer or a Change Order.

## 8.5 Dimensioning and Tolerancing

8.5.1 Fundamental rules for dimensioning - Dimension and tolerance parts to ensure interchangeability. Show only enough dimensions so that sizes, shapes, and locations can be determined without calculating or assuming any distances. ANSI Y14.5-1973 shall be the standard for dimensional practices.

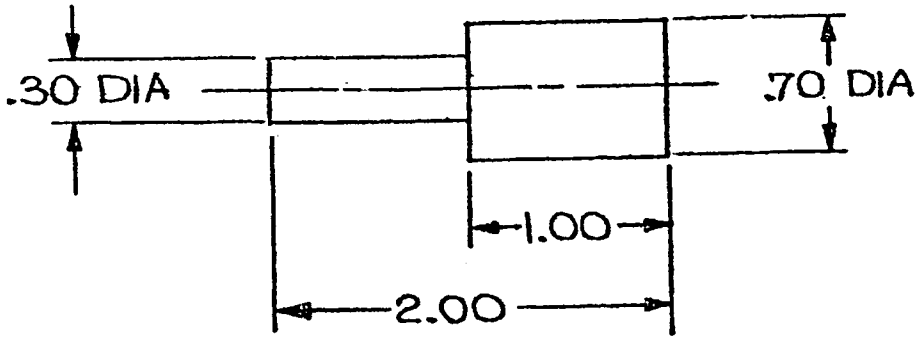
8.5.2 The decimal system of dimensioning is preferred. The fractional system is optional.

8.5.3 Dimensioning features - Dimensions that indicate size and position are drawn as linear distances or angles. They may be drawn with dimension lines and extension lines that show their direction and extent, or provided in the form of notes with leaders that direct them to the point of application.



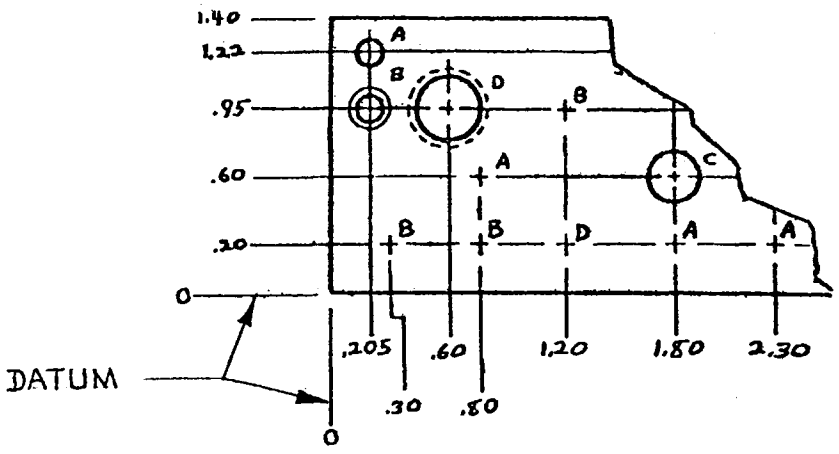

DIMENSIONING FEATURES

8.5.4 Conventional dimensioning - Show the dimensions between points, lines, or surfaces which have a specific relationship to each other. Select and arrange dimensions to avoid accumulations of tolerances. Show each dimension only once. Overall dimensions should be shown on the plan view and projections rather than on detached sectional views.

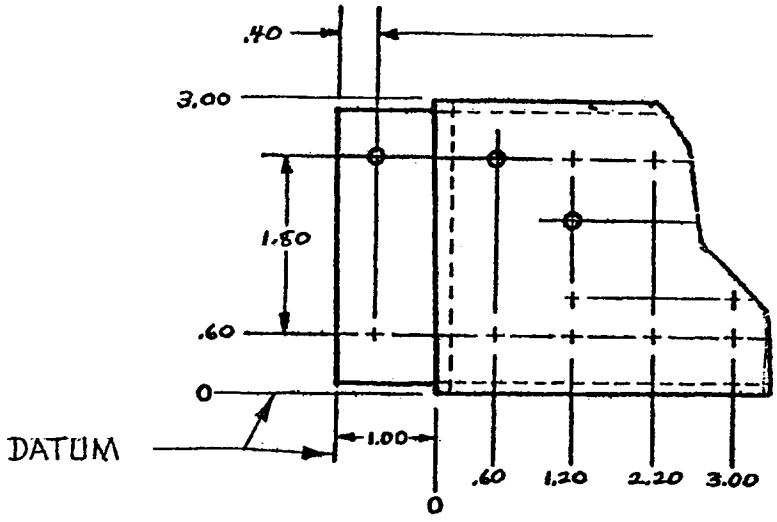



CONVENTIONAL DIMENSIONING EXAMPLE

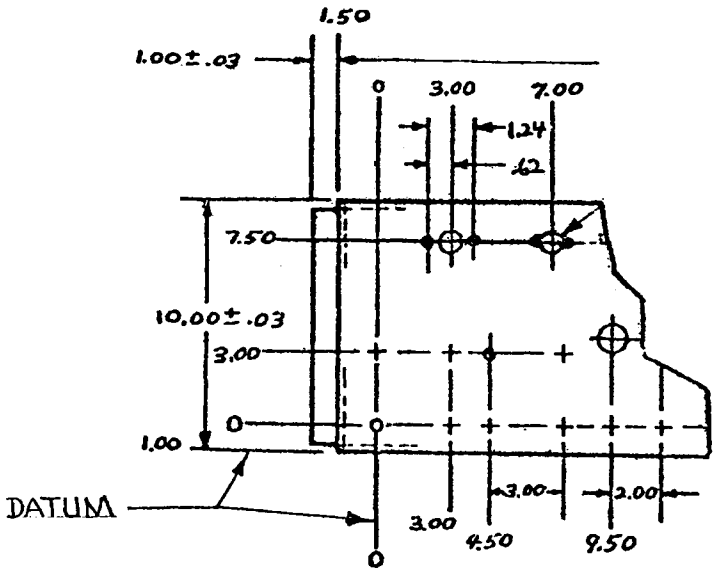
8.5.5 Basic Dimension - A numerical value used to describe the theoretically exact size, shape or location of a feature or datum target. It is the basis from which permissible variations are established by tolerances on other dimensions, in notes or by feature control symbols.




a. EXAMPLE OF ORDINATE DIMENSIONING FROM A CUT EDGE




b. EXAMPLE OF ORDINATE DIMENSIONING FROM A FORMED EDGE




c. EXAMPLE OF ORDINATE DIMENSIONING FROM A FEATURE

FIGURE 8.3

8.5.6 Ordinate (arrowless) dimensioning - Establish two mutually perpendicular datum lines for each view. Normally, a cut edge or a formed edge should be used. See Figure 8.3 a and b above. When tolerances for fabrication of a part are greater than those for the location of features within the part, the first row of features may be used to establish a datum line, as shown in Figure 8.3 c. In such cases, the overall fabrication dimension shall be conventional. Identify the datums as zero.

8.5.7 All ordinate dimensions are shown with respect to the datum lines. Locate the dimension at the ends of extension lines, preferably in a single line, as shown in Figure 8.3 above.

8.5.8 Do not place conventional dimensions in line with ordinate dimensions.

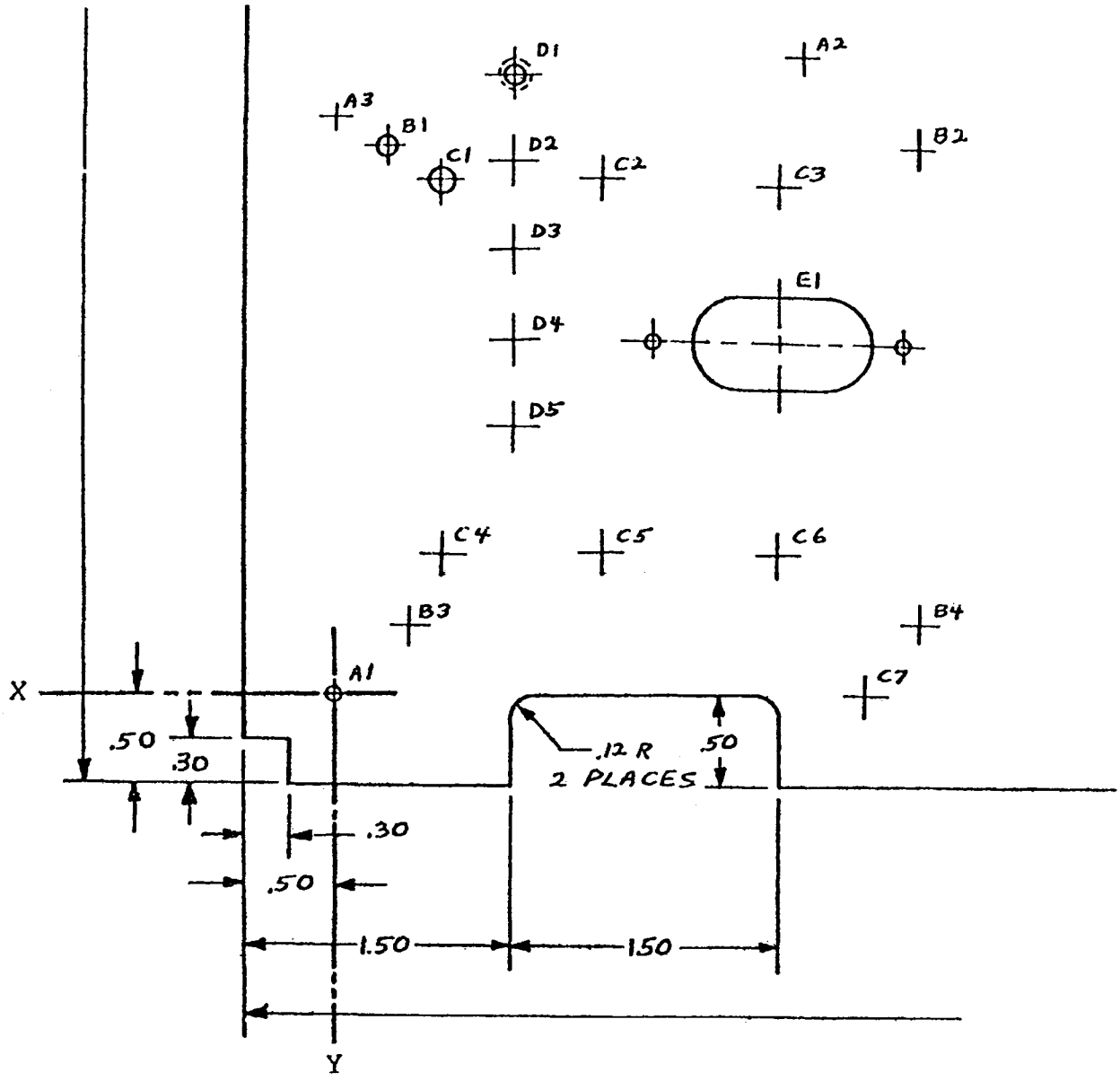
8.5.9 Show only 1 datum per axis.

8.5.10 Ordinate (arrowless) dimensioned drawings may also employ conventional dimensions between related features or to locate datum lines not established by formed or cut edges.

8.5.11 Tabular dimensioning - When a large number of similarly shaped features must be located, use tabular dimensioning.

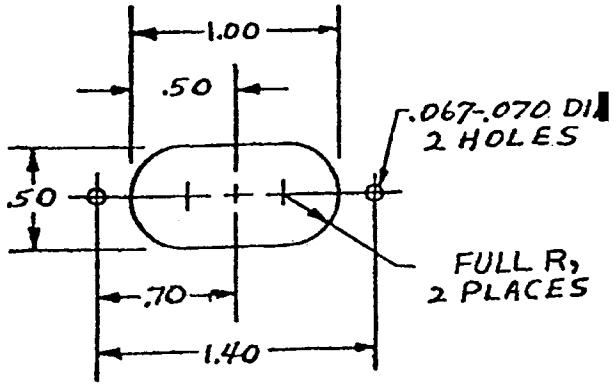
Identify each feature which is to be tabulated with a letter and numeric suffix, omitting I, O, Q, and X. For identical features, use the same letter with sequential numerals (e.g., A1, A2, A3). Make a table listing each feature, its position, and size as shown in Figure 8.4.

Establish two mutually perpendicular datum lines, using formed or cut edges, or a hole location. Indicate the




.75 | 2.00 | 2.00

| HOLE IDENT | POSITION X → | POSITION Y ↑ | HOLE SIZE |
|---|---|---|---|
| A1 | .00 | .00 | .067-.070 DIA |
| A2 | 2.62 | 3.62 | |
| A3 | .00 | 3.25 | |
| | | | |
| B1 | .30 | 3.10 | .093-.096 DIA |
| | | | |
| E1 | 2.50 | 2.00 | VIEW E |
| E2 | 5.00 | 2.00 | |



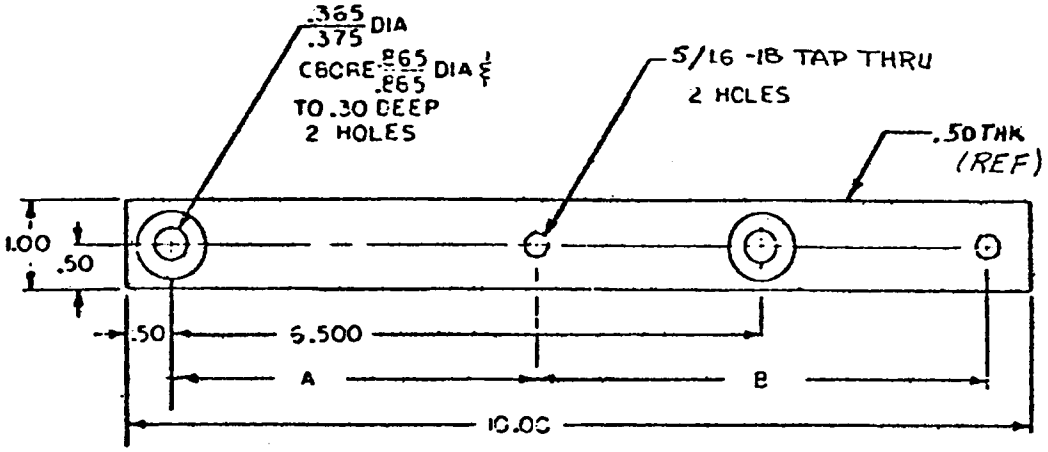

VIEW E

FIGURE 8.4 EXAMPLE OF TABULAR DIMENSIONING

direction of X and Y coordinates as shown in Figure 8.4. Relate all tabular dimensions with respect to these datums.

All dimensions of form for the part containing the features tabulated shall be conventional dimensions.

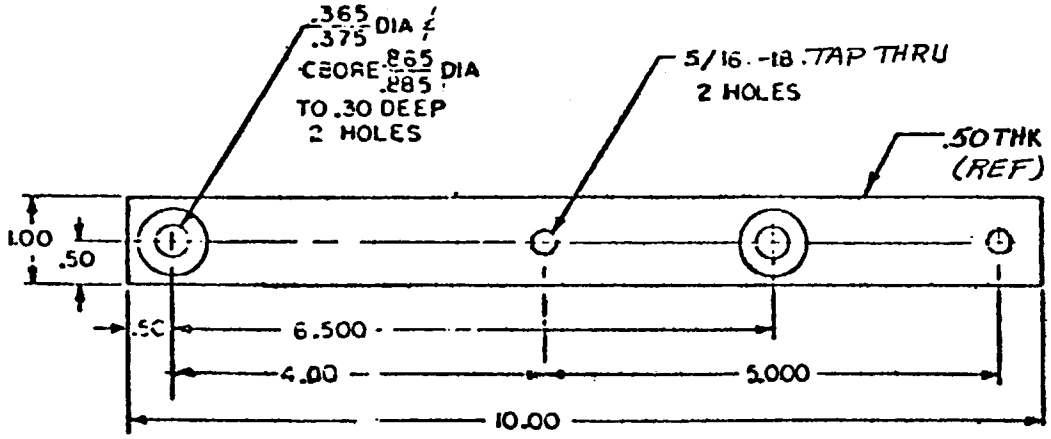
8.5.12 Tabulated detail drawing - Generate when required to depict two or more parts which have the same basic shape, but vary in size, finish or other characteristics.




| PART NO. | A | B |
|---|---|---|
| XXXXXX-1 | 4.00 | 5.000 |
| -2 | 3.50 | 4.000 |

EXAMPLE OF TABULATED DETAIL

8.5.13 Monodetail drawing - Depict complete end item requirements for a single part.




EXAMPLE OF MONODETAIL

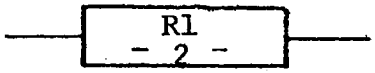
## 8.6 Electrical Component Parts

8.6.1 Wherever possible minimize the necessity for reference to other drawings for simple information like component values, reference designators, etc. by incorporating this information on schematic diagrams.

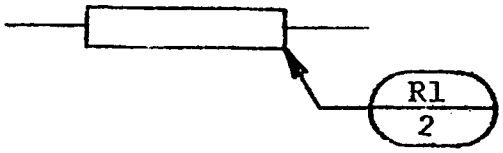
8.6.2 Use "typical" value notations to minimize repetitious detail on drawings. For example, if the same value of limiting resistor is used for a group of LED's then the value should be entered once with the adjacent note "Typical."

8.6.3 Electrical component parts may be identified on assembly drawings and on BOMs in any of the following ways.

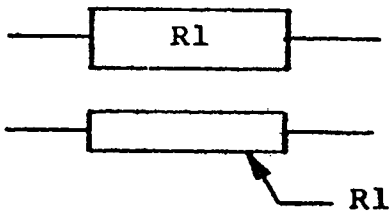
a. They may have the reference designation and item number on the component view.




b. They may have the reference designation and item number in a balloon with a leader to the component.




c. Reference designations may be used as item numbers and shall be shown on the component view.



d. Reference designations may be shown on the component view as (c) and included in the description column of the BOM.

8.6.4 When nominal value components are to be selected at unit or system test, the component shall be identified on the assembly view with either "NU" or "NS" as applicable, and the range of values may be listed in the BOM or on a separate document which is listed in the BOM. See also paragraph 8.7.7.7.

## 8.7 Schematic and Logic Diagrams and Interconnections

8.7.1 Title - Title the diagrams the same as the corresponding assemblies plus "SCHEMATIC DIAGRAM" OR "INTERCONNECTION DIAGRAM," e.g., "POWER SUPPLY SCHEMATIC DIAGRAM."

8.7.2 Symbols - Use IEEE and ANSI standard electronic symbols.

8.7.3 Lines - Wherever possible use only horizontal or vertical lines, avoiding closely grouped parallel lines (min. spacing .3 inch). Minimize the crossing of lines and make line junctions unambiguous as shown below.

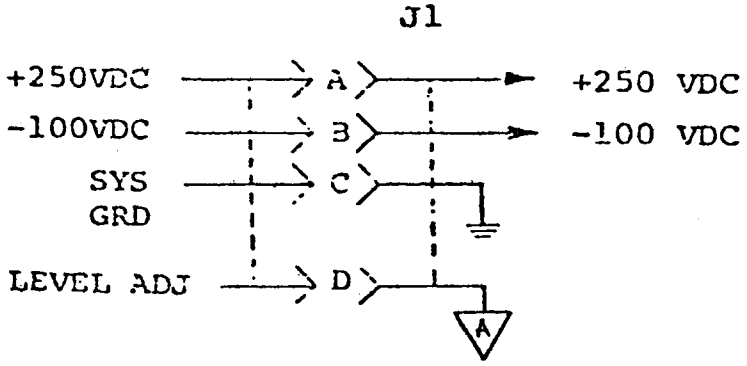
**Two Single Junctions**
**(Use in place of double junction)**

8.7.4 Layout - Preferably lay out the circuit flow from left/top (input) to right/bottom (output). Identify all input and output signals. Utilize same pictorial layout for repeated stages.

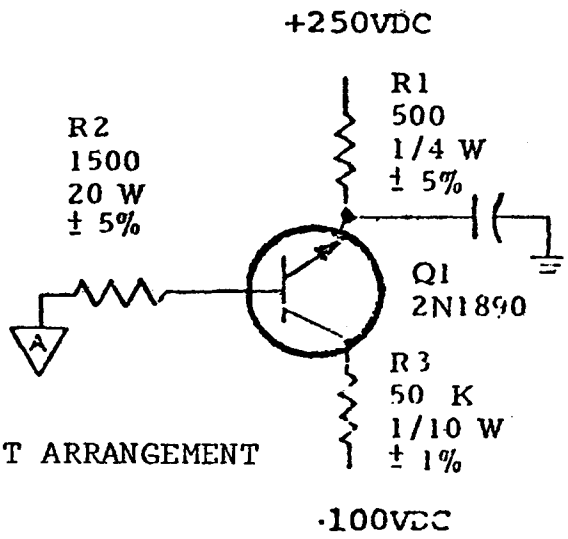
8.7.5 Multisheet - Identically identify corresponding lines between sheets.

Arrange logically related circuit functions on the same sheet to minimize the number of sheet-to-sheet references. This can be quite burdensome to a drawing user. Do not use arrows on these references.

8.7.6 Common points of potential, properly identified, need not be physically connected, except in interconnection diagrams.




INPUT CONNECTOR




CIRCUIT ARRANGEMENT

8.7.7 Component identification

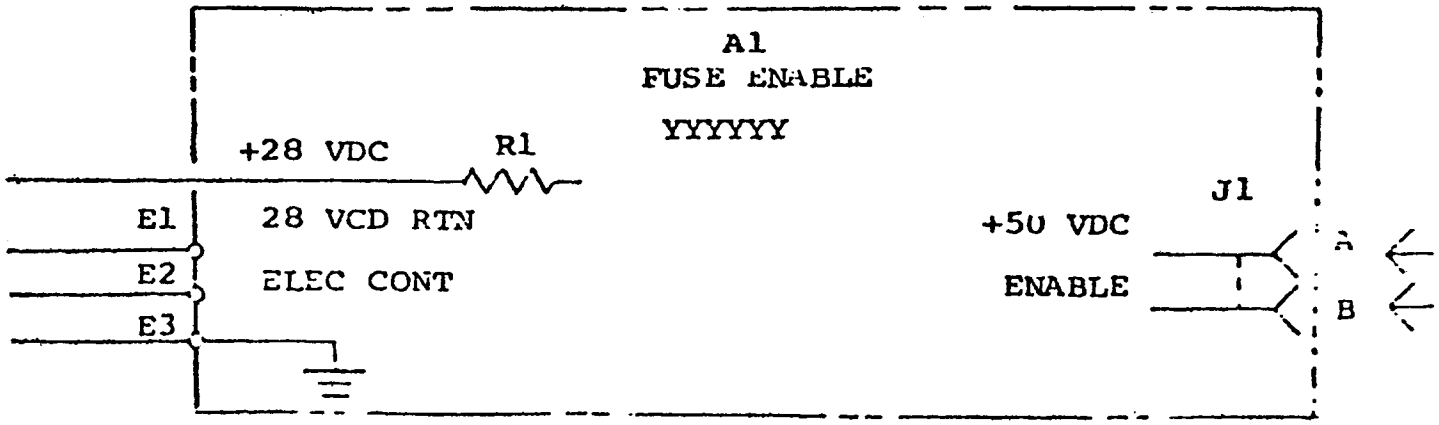
8.7.7.1 Place reference designation and electrical value, including wattages, voltages and tolerances adjacent to each part symbol.

8.7.7.2 Common wattages, voltages and tolerances may be shown in the general notes.

8.7.7.3 For tubes and all seminconductor devices, place type designators beneath each reference designation.

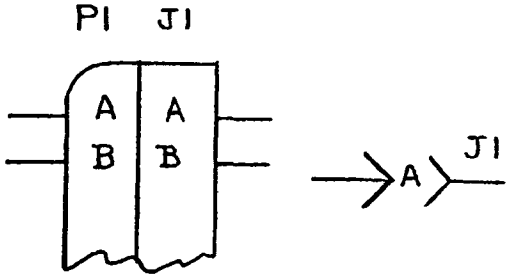
8.7.7.4 Components with unmarked terminals require a physical diagram on the schematic, showing terminal orientation and assigned designations.

8.7.7.5 Subassemblies having their own schematics are shown on the next higher schematic by phantom lined rectangular boxes, including schematics only if necessary for proper analysis.

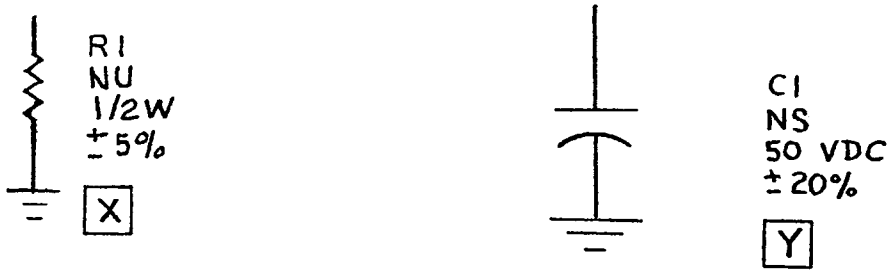



When schematic or logic diagrams encompass circuitry which is packaged on two or more subassemblies (e.g., two or more printed circuit boards) phantom lines should enclose the subassembly circuitry.

8.7.7.6 Subdivide symbols where needed and where parts are identified.



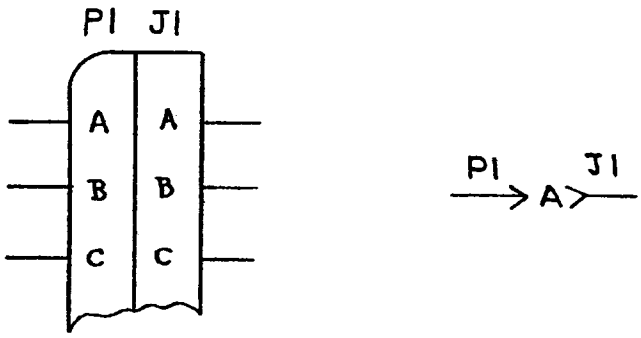
8.7.7.7 Nominal components - When a design dictates that the value of a component, such as a capacitor or resistor, cannot be predetermined, the symbol NU (at unit level) or NS (at system level), shall be inserted in lieu of the component's value. Also provide a note specifying the range of selection.



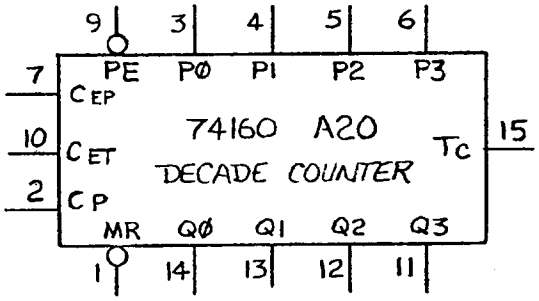

8.7.8 Use wire lists for unit wiring rather than wiring schematics as they are easier to generate and read. They also permit better control of wire routing. Indicate wire harness routing and breakouts on assembly drawings by heavy dashed lines and notes.

8.7.9 Use the symbols P and J to denote plugs and jacks on connectors. Plugs are <u>always</u> the removable connector and jacks are <u>always</u> the fixed connector, irrespective of the physique of the contacts in the plugs and jacks.

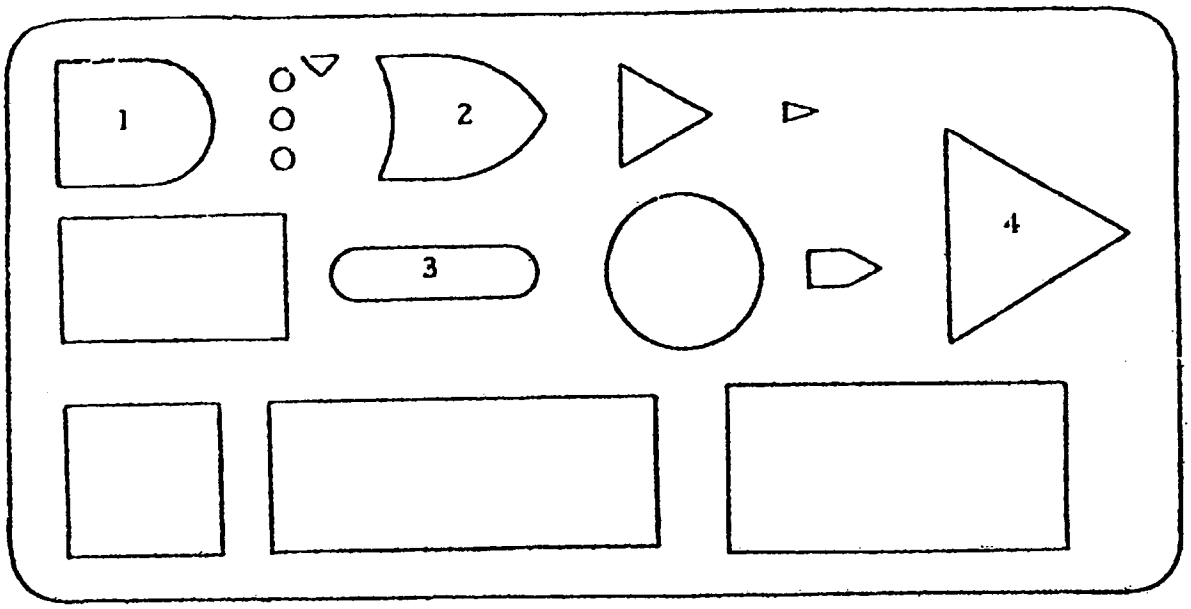
Represent connectors by either of the symbols below. Note that the plug has rounded corners to indicate its movability. In the other style the arrow indicates a pin and the sideways yoke indicates a socket.



8.7.10 Logic diagrams and symbology - Use the correct symbols for logic functions like gates, inverters, and buffers. More complex functions like counters, shift registers, etc. shall use box-like or rectangular symbols with the negation circle to indicate activation by low true signals. Enter the logic element part number, location designator, device descriptor and logic term code in the interior of the box and pin numbers on the outside, above and on the left side of the signal lines as shown below. Unused inputs and outputs should also be drawn, labeled and numbered. The symbols shall be uniform for all drawings.



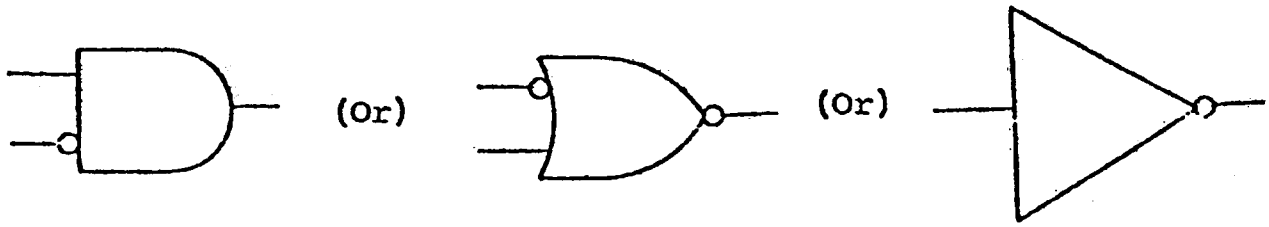

Symbol orientation does not usually affect the symbol meaning, but gate or amplifier symbols indicate the direction of signal flow.



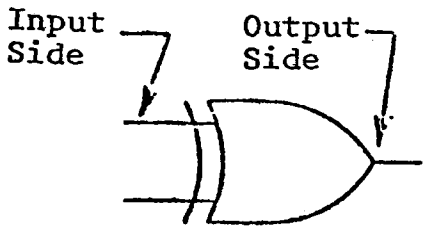

Logic Symbol/Template (Rapidesign No. 541), available in

full, 3/4 size (shown), half size, 3/8 size or 1/4 size.
1 = And  2 = Or  3 = Time Delay  4 = Amplifier

Negation and exclusive OR - A small circle drawn at the point where a signal line joins a logic symbol indicates a logic negation.

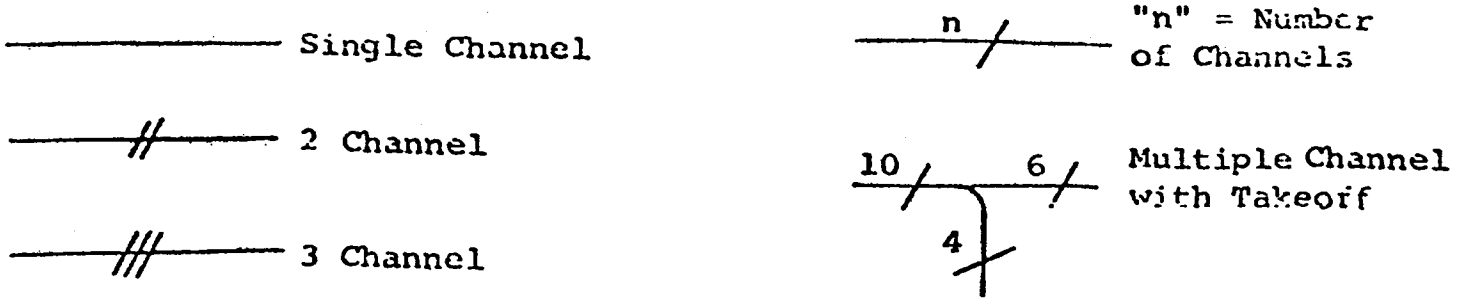



TYPICAL LOGIC NEGATION




EXCLUSIVE OR SYMBOL

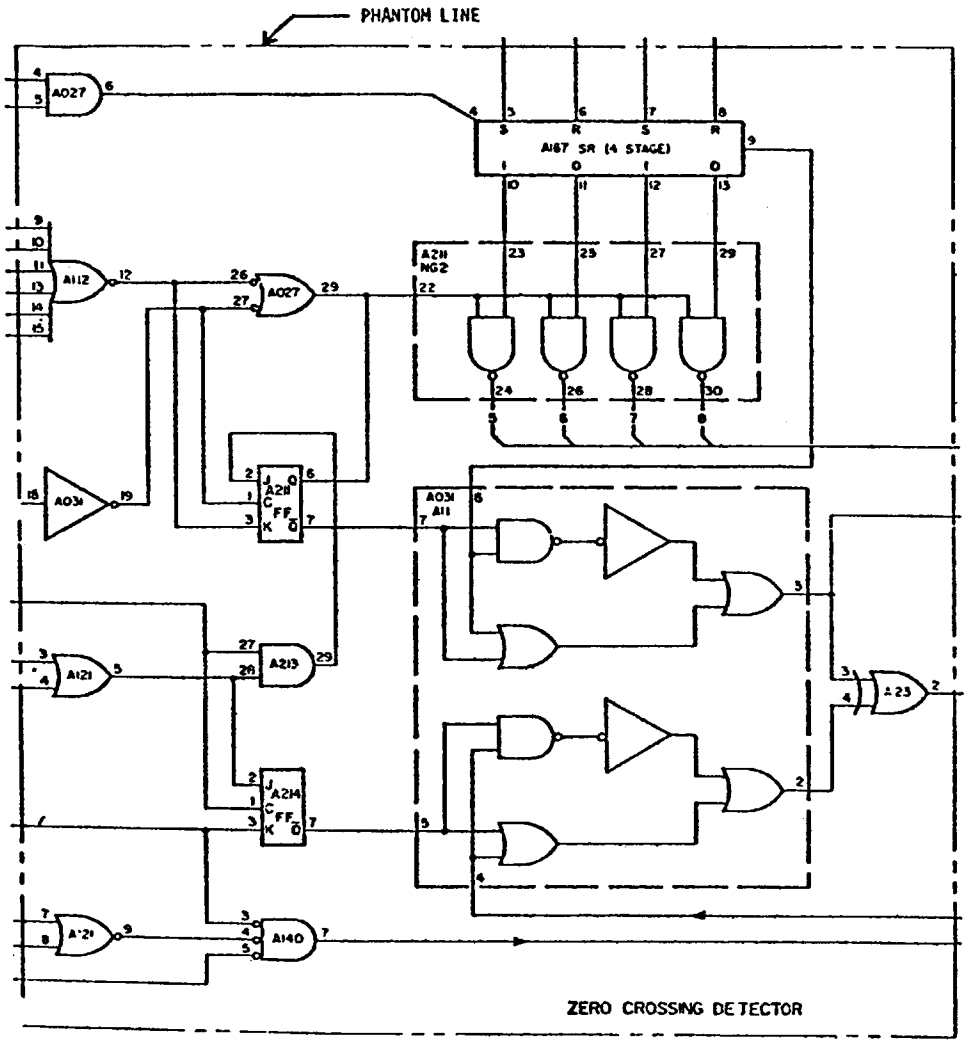
To simplify schematics, signal paths may be delineated thus:




Signals may be assigned a number as shown in the example on the next page and run in a common path with a breakout downstream identified by the signal number.

Signal wiring bulk on logic drawings can also be minimized by encoding terms with mnemonic names which then are placed adjacent to the pins they are connected to.

Note that the placement of logic symbols on a logic diagram does not control the actual wire routing of the interelement wiring; the routing is usually controlled by a wire list to minimize total run length, or control harnessing.



## 8.8 Wiring Harness and Cable Assembly Drawings

8.8.1 When large quantities are involved, a wiring harness assembly drawing symbolically depicting a group of wires bundled together in a specified configuration is required. This configuration contains unattached leads which are generally soldered or welded and is normally secured within a unit. See figures 8.8.1 and 8.8.2.

8.8.2 Draw all wiring harness drawings used as templates full scale on stable base material. Draw the harness outline to the approximate diameter of the finished harness.

8.8.3 Tolerances - Where dimensions are placed in the field of the drawing, show their tolerances to the nearest tenth of an inch.

8.8.4 Contour - Show all items attached to or located within the contour such as sleeving, connectors, sleeves or ferrules.

8.8.5 Revisions - Make all drawing changes of wiring harnesses to scale.

(a) Whenever runs are deleted from the harness, erase the breakouts, reference designators, and station numbers from the view.

(b) Whenever runs are added, draw the breakouts, apply proper reference designation, and assign the station numbers as follows: If there is a gap in the sequence of numbers, use the missing numbers; if there is no gap in the sequence of numbers, use the lower station number with a letter suffix (interim station number) i.e., 43, 43A, 43B, 44.

8.8.6 Show a lead breakout, reference designation, and station number for each unique lead termination on the drawing.

8.8.7 Unique stripping information may be indicated on the drawing either in the general notes or in a chart.

8.8.8 Add the notation "SHLD" to external shield lead breakouts. Add color notations to lead breakouts, when required.

8.8.9 Cable assembly drawings - A cable assembly drawing symbolically depicts cables normally used between equipments or units, and whose terminations are usually plugs, sockets, or connectors.

8.8.10 Wherever possible, structure cables to use simple single runs and avoid multi-breakout complex cables as they are difficult to fabricate and more liable to have wiring errors.

8.8.11 A cable assembly drawing may be drawn as a single line presentation as shown in figure 8.8.1 (preferred) or in a more pictorial manner where required to depict assembly procedures.

8.8.12 Cable assembly overall dimensions - When the addition of overall dimensions is a critical requirement of the cable assembly drawings, position the connector views in line with, and adjacent to, the fabrication view so that dimensions can be illustrated as shown in figure 8.8.2.

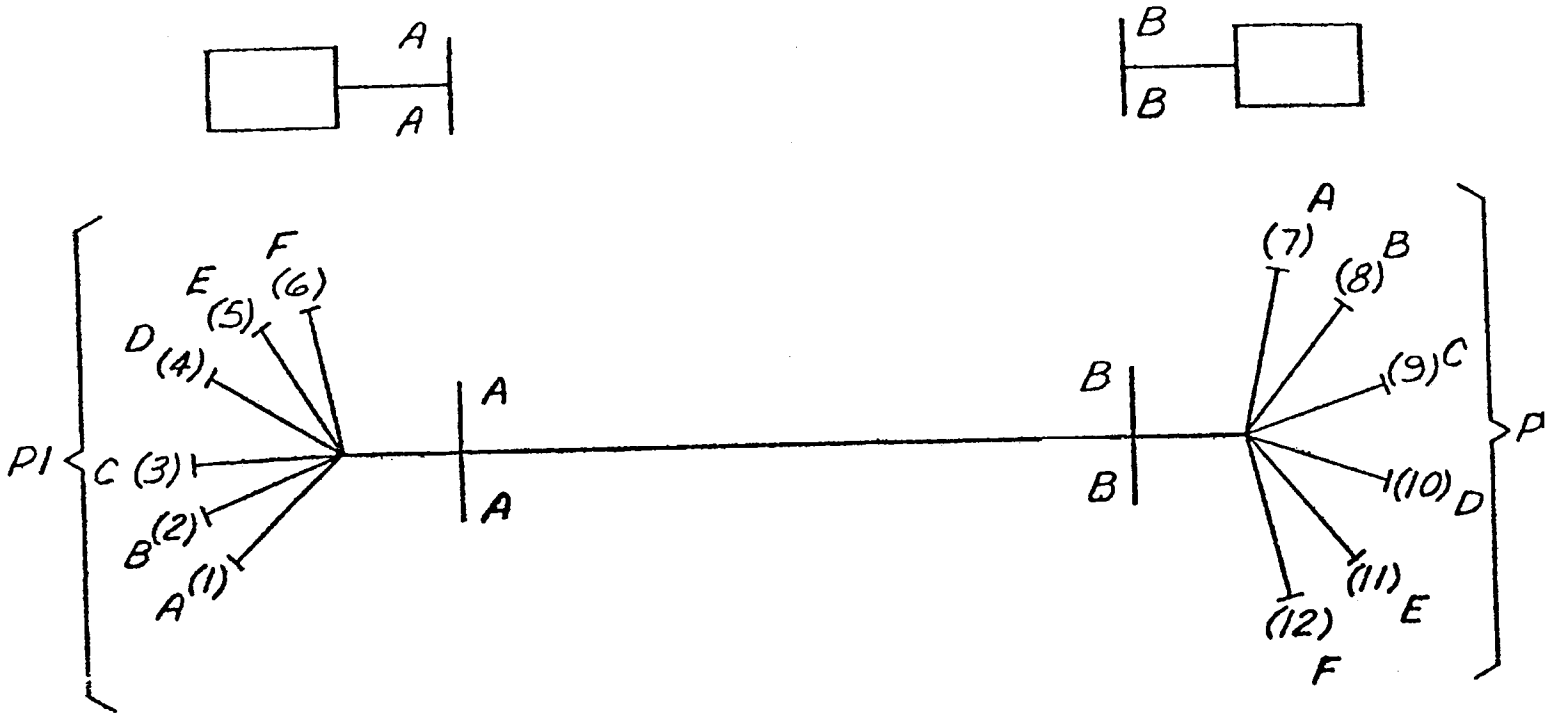



Figure 8.8.1 EXAMPLE OF CABLE ASSEMBLY SINGLE LINE PRESENTATION

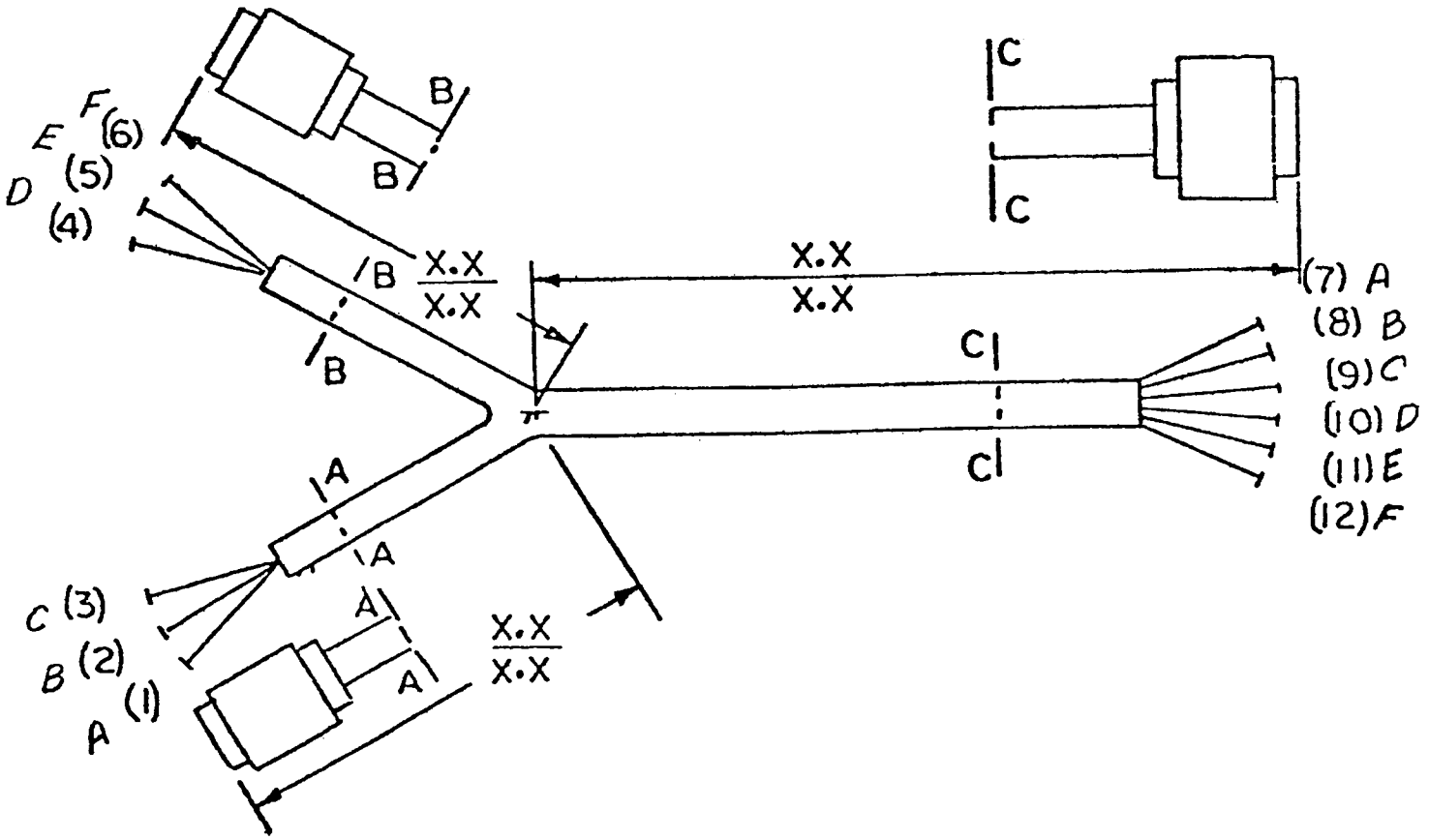



Figure 8.8.2 EXAMPLE OF CABLE ASSEMBLY OVERALL DIMENSIONS

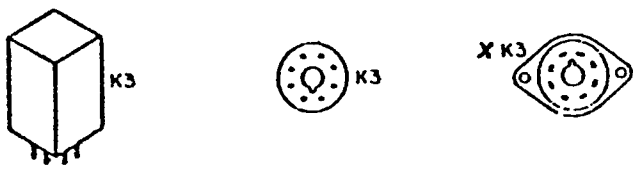
8.8.13 Cable assembly marking - Cable assembly drawings shall require each cable be properly marked with its reference designation (when applicable) and item identification. The drawing shall also indicate markings on all mechanically removable items such as lugs, pins, contacts, terminals, and connectors. Markers shall be identified by an item number callout (marker lengths and marking notes shall be added as applicable).

8.8.14 Tabulated cable assemblies - Cable assemblies having identical parts (connectors and wire) and identical connections but requiring different markings or lengths, may be tabulated.

8.8.15 General marking (reference designation, control and function identification, warning signs, etc.) - Whenever possible, general purpose marking shall be delineated at the detail (piece part) drawing level.

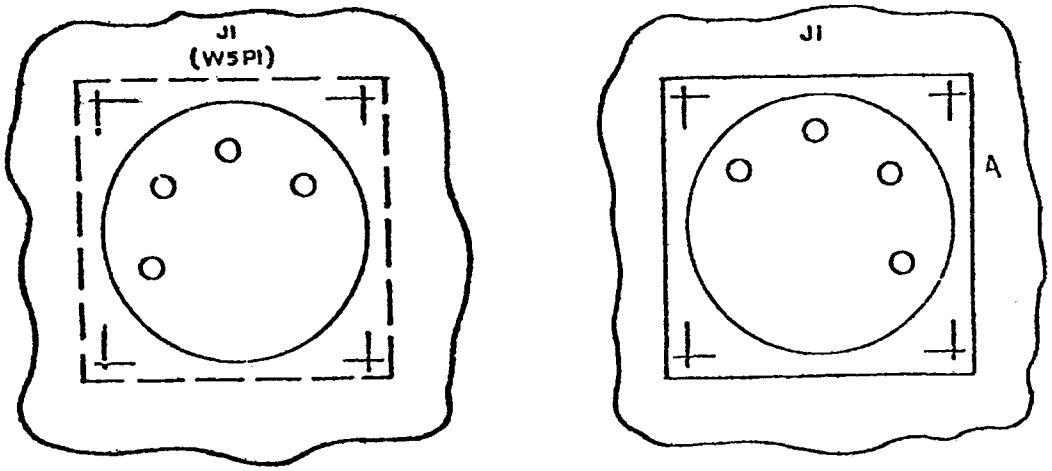
8.8.16 Reference designations - Reference designations, if required, shall be marked adjacent to each item and located in such a position as to identify the location of the item. Whenever possible, the marking must be visible in the item's assembled position.

a. Components and assemblies - The marking on the wiring side may include class letter "X" prefixing the reference designation of the mounted part for socket or plug-in items. The marking on the mounting or plug-in side shall only be the reference designation of the mounted item.




EXAMPLE OF COMPONENT REFERENCE DESIGNATION MARKING

b. Interconnection connectors - The wiring side of a unit may be marked with connector reference designations. The plug-in side may also include the mating connector designation in parenthesis.



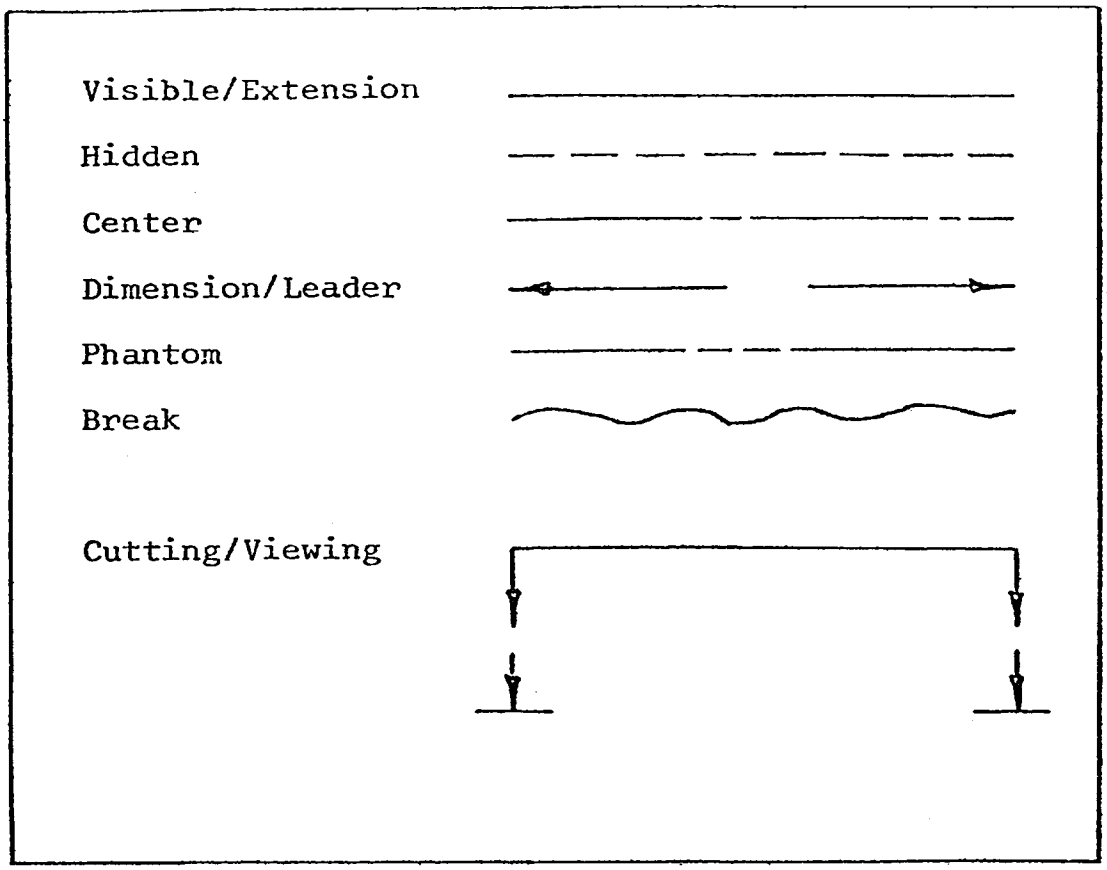

PLUG-IN SIDE
(EXTERNAL)

WIRING SIDE
(INTERNAL)

EXAMPLE OF CONNECTOR REFERENCE DESIGNATION MARKING

8.9 Linework and Lettering

Linework and lettering should meet the requirements for legibility and reproducibility.




LINEWORK CONVENTIONS

8.9.1 Lettering height

8.9.1.1 All lettering in the field of the drawing should be a minimum of .12 (1/8) high.

8.9.1.2 Drawing number and title should be a minimum of .18 (3/16) high on all drawings.

8.9.1.3 Typing and varitype lettering are permissible on the body of all drawing sizes, and may be used for the drawing number and title on A and B size drawings.

Isolated terminals - The location of isolated terminals shall be marked, if required, with reference designation "E" followed by a numeric character (e.g. E1, E2, E3).

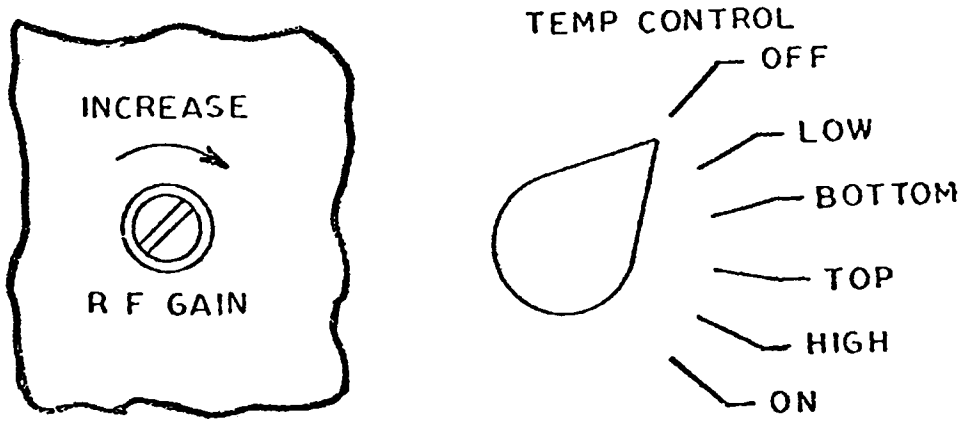
8.9.1.4 Control and functional marking

a. Components mounted on the front panel of a cabinet which are visible while the equipment is in operation are normally marked with the function designation. Reference designations may be marked on the wiring side of a panel as follows:


FRONT PANEL SIDE WIRING SIDE

EXAMPLE OF FUNCTIONAL MARKING

b. Continuously variable operating controls shall be provided with markings which will permit the operator to set the control to a pre-determined setting or indicate an increase or decrease in setting.




EXAMPLES OF CONTROL MARKING

# 9.0 VLA DOCUMENTATION/DRAWING SPECIFICATIONS

## 9.1 VLA Specifications

The following specifications are a collection of packaging, drawing and notational conventions which have been in effect in the VLA project.

Interoffice

# NATIONAL RADIO ASTRONOMY OBSERVATORY
## VLA PROJECT
## MAGDALENA, NEW MEXICO 87825

To: VLA Electronics Staff, R. M. Mitchell, Systems Integration, Synchronous Computer Div. September 22, 1976

From: A. R. Thompson

Subject: NUMBERING SYSTEM FOR RACKS, BINS AND MODULES

Attached is a revised version of a specification written over two years ago. It has been updated to include all types of units now in used.

The only change in our current numbering system relates to the IF/LO racks in the central electronics room of the control building. These are to be known in the future as type D racks and individual racks will be designated by D followed by the serial number, which will run from 1 to 27. Up to now the designation has been W followed by the serial number. The letter N, E or W followed by a number will be an alternate means of designating individual racks, but the number will in the future be that of the associated waveguide channel. This second designation will not be applicable until a rack has been positioned in one of the three rows in the central electronics room.

I should like to request of the Charlottesville group that serial numbers of type D racks henceforth include the letter D instead of N, E or W. The bin type descriptions should also be marked on the bins before shipment from Charlottesville.

Please ensure that present usage and any future designations conform to the specifications.

ART:cb

Distribution:

D. S. Bagri
K. Barbier
C. Broadwell
E. M. Caloccia
K. Clayton
B. Cohee
D. Coombs
L. D'Addario
W. Dumke
F. Dunn
R. Escoffier
J. Guin
S. Maas
A. Miller
P. Napier
M. Ogai
J. Oty
R. Schweigert
R. Serna
P. Temple
D. Weber
J. Campbell
G. Barrell
C. Pace
R. Harris
G. Patton
V. Herrero
L. Blankenship
J. Spargo
A. Herzog
B. G. Clark
G. Hunt
K. Sowinski
P. Dooley
M. Fusco

NATIONAL RADIO ASTRONOMY OBSERVATORY
Post Office Box "O"
Socorro, New Mexico 87825

SPECIFICATION NO.: A13010N1A

NAME: VLA Electronics Rack, Bin, Module, and Connector Numbering System.

DATE: June 24, 1974 Revised September 21, 1976

PREPARED BY: S. Weinreb
A. R. Thompson
L. R. D'Addario

APPROVED BY:

## A. APPLICATION

This numbering system applies to all equipment in the module-bin system; it does not apply to digital equipment utilizing card and motherboard packaging.

## B. MODULE TYPE NUMBER

Each module type will be identified by a 2 or 3 character code such as F2 or L12. The first character denotes subsystem:

F ≡ Front-end
L ≡ Local Oscillator
T ≡ Signal Transmission or IF
M ≡ Monitor and Control
P ≡ Power Supply
D ≡ Delay and Multiplier

The second character is a one or two digit number denoting a particular type of module in a subsystem. The module type number shall be marked with 3/16" letters on the lower front panel. (The module name shall also be marked on the upper front panel.)

C. MODULE SERIAL NUMBER

Each module will have a 2 or 3 character serial number such as A1 or B13. The first character notes a particular version or revision; the second character is a consecutive serial number not affected by the revision letter (i.e., if 2 version A modules, A1 and A2, were built the first revision B module would be labeled B3). The serial number shall be marked with 1/8" letters on the lower front panel.

D. RACK TYPE DESIGNATION

Letters are used to designate types of racks in the system as follows:

A ≡ Front-end Rack (antenna vertex room)
B ≡ IF/LO Rack (antenna vertex room)
C ≡ Pedestal Room Rack (antenna pedestal room)
D ≡ IF/LO Rack (control building, central electronics room)
M ≡ Master LO (control building, central electronics room)

One each of types A, B, C and D is required for each antenna.

Racks and antennas will have serial numbers in the range 1 to 28. In general racks located at antennas (types A, B and C) will be chosen so that their serial number is the same as that of the antenna. Racks of type D are not permanently related to a particular antenna, but are related by their location to a particular arm of the wye and waveguide channel number. Individual D racks can be referred to by arm (N, E or W) and channel number (e.g., W5) as well as by serial number.

E. BIN NUMBER

Bins will be lettered as follows:

| | | |
|---|---|---|
| | G, F | Front-end Rack |
| J, H, L, K | ~~H, I, J, K~~ | IF/LO Rack at Antenna (top to bottom) |
| | Q, S, R | IF/LO Rack at Control Room (top to bottom) |
| | T, U | Master LO Rack |

CF. C.O. 771205LRD3

F. SLOT NUMBER

Slots within a bin will be numbered 1 through 12 (1 through 20 for bin G which is extra wide) from left to right as viewed from front and right to left as viewed from rear. If a module occupies more than one slot width its location will be designated by the lowest slot number it occupies.

G. CONNECTOR AND PIN NUMBER

Plugs and jacks will be noted P or J, respectively, followed by a number which increases from top to bottom of the slot. For multi-pin connectors this will be followed by a dash and the pin number; i.e., J1-42.

H. EXAMPLE

In most cases the complete number will not be necessary; i.e., we will refer to "Rack B1", "Bin H" or "Module T2". However, an example of a specific pin number is 27BH12J1-42 which refers to antenna 27, rack B, bin H, slot 12, jack 1, and pin 42.

NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia
VERY LARGE ARRAY PROJECT

SPECIFICATION NO: A13030N1, Rev. B

NAME: Paint Specification for NRAO VLA Electronic Equipment

DATE: July 7, 1975

PREPARED BY: _____ APPROVED BY: _____

## 1. SCOPE

This specification covers painting of the NRAO VLA Electronic cabinets, panels, modules and bins.

## 2. TYPE OF PAINT:

GALLON OR OVER

| | | | | |
|---|---|---|---|---|
| * | Mint Gray- | Hewlett Packard | 6010-0331 | Panel |
| * | Alkyd Enamel | Glidden | 19988X | |
| * | Olive Gray- | Hewlett Packard | 6010-0334 | Cabinets |
| * | Vinyl Texture | Glidden | 19997X | |

## * 3. TYPE OF THINNERS:

A. For Use with Mint Gray:

Chevron 1200 (fast dry) or 1250 (slow dry) - PREFERRED

Xylene - General Purpose

B. For Use with Olive Gray:

Hewlett-Packard 6010-0035 (Base Coat)

Hewlett Packard 6010-0390 (Texture Coat)

* 4. APPLICATION:

In accordance with your normal shop procedure for baked enamel finish. Exact matching of paint gloss, color and texture is not required. Recommended baking time is 1/2 hour at 290°F. Allow flash off period of 5 minutes prior to baking.

* 5. PAINT PREPARATION:

A. Alkyd Enamel (Mint Gray)

1. Cold Spray Viscosity Zahn Cup No. 2: 24 sec. @ 65°F.
2. Hot Spray Viscosity Zahn Cup No. 2 : 28 sec. @ 65°F.

   Hot Spray Temperature 135° ±2°F.

B. Vinyl Enamel (Olive Gray)

1. Smooth Coat-Base Coat

   a. Cold Spray Viscosity Zahn Cup No.2: 39 sec. @ 65°F.

   b. Hot Spray Viscosity Zahn Cup No. 2: 47 sec. @ 65°F.

   c. Hot Spray Temperature: 135° ±2°F.

   d. Cold Spray Temperature: 65°-72°F.

2. Texture Coat

   Cold Spray Viscosity Zahn Cup No. 3: 52 sec. @ 65°F.

   NOTE: Texture coat not to be sprayed hot.

*Indicates areas of revision

NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia
VERY LARGE ARRAY PROJECT

SPECIFICATION NO: A13050N2 Revision A

NAME: VLA Module System Dimension Standards

DATE: August 5, 1974

PREPARED BY: _____ APPROVED BY: _____

1. Vertical Dimensions, Heights

| | | |
|---|---|---|
| Bin Spacing | 8.750 | |
| Bin-to-Bin-Gap | .030 | |
| Bin Height | 8.720 | |
| Module Hole Spacing | 8.220 | |
| Horiz. Bar to Horiz. Gap | 7.720 | |
| Runner-to-Runner | *7.387 | ±0.005 |
| Runner-to-Guide Gap | .040 | ±.022 |
| Guide-to-Guide | *7.346 | ±.005 |
| Module Outside Height | 7.220 | ±0.010 |
| XUA Inside Clear | 5.720 | |
| XUA Vent-to-Vent | 6.410 | |
| XSA Inside Clear | 6.470 | |
| Bottom Guide Surface to Rear Panel Bottom | * .067 | +000 −.005 |
| Bin Rear-Panel Lower Mounting Hole to Module Rear-Panel | .686 | ±.010 |

2. Horizontal Dimensions, Widths

| | | |
|---|---|---|
| Bin Panel Width | *19.000 | ±.030 |
| Rack Hole Spacing | 18.310 | ±.030 |
| Bin Outside | 17.495 | ±.030 |
| Bin Inside | 16.995 | |
| Bin Panel Space | 16.745 | |
| 1X Spacing | * 1.395 | ±.005 |
| 1X Panel Width | * 1.385 | ±.005 |
| 1X Module, Outside | * 1.360 | ±0.005 |
| 1UA Inside Clear | 1.172 | |

*Indicates critical dimension, 100% inspection

2. (cont.)

| | |
|---|---|
| 1SA Inside Clear | 1.110 |
| 2X Spacing | * 2.790 ±.005 |
| 2X Panel Width | * 2.780 ±.005 |
| 2X Module, Outside | * 2.760 ±.010 |
| 2UA Inside | 2.510 ±.010 |
| NX Spacing | *Nx 1.395 |
| NX Panel Width | *Nx 1.395 -.010 |
| NX Module Width | *Nx 1.395 -.030 |
| NUA Inside, N ≥ 2 | Nx 1.395 -.280 |
| Front-Panel Gap | .010 ± .010 |
| Module Gap | .030 ± .010 |
| Runner Width | * .250 ± .008 |
| Guide Slot Width | * .275 ± .005 |
| Horizontal Guide Gap | .025 ± .013 |

3. Depth Dimensions

| | |
|---|---|
| Bin Overall, Excluding Connectors | 20.426 |
| Front Panel | .125 |
| Rear Panel, 1UA | .125 |
| Panel-to-Panel, Bin Inside | *20.176 +.015 −000 |
| Module, Inside-Front, Outside-Rear Panel | *19.312 +0.000 −0.010 |
| Bin-to-Module Rear Panel Gap | * .864 +.015 −.005 |
| OMQ Connector Plate Offset | .464 ±.005 |
| OMQ Connector Panel Gap | * .400 +.020 −.015 |
| XUA Module Inside | 19.187 |
| Rear Panel 1SA | .250 |
| XSA Module Inside | 19.062 |

4. Countersink for straight internal threads shall be 85° ± 10° to depth of major diameter of thread.

*Indicates critical dimension, 100% inspection

NATIONAL RADIO ASTRONOMY OBSERVATORY
CHARLOTTESVILLE, VIRGINIA
VERY LARGE ARRAY PROJECT

SPECIFICATION NO.: A13050N3 REV. A

NAME: Engraving Specification for NRAO VLA Electronic Equipment

DATE: August 9, 1974

PREPARED BY: _____ APPROVED BY: _____

## 1. SCOPE

This specification covers engraving of the NRAO VLA electronic module front and rear panels. Contents of this specification must be called out on detail drawings that require engraving.

## 2. ENGRAVED CHARACTER SIZES

(a) Type: Gorton normal or condensed, or equivalent (as specified on panel drawings)

(b) Height: 3/16", 1/8", and 3/32" (as specified on panel drawings)

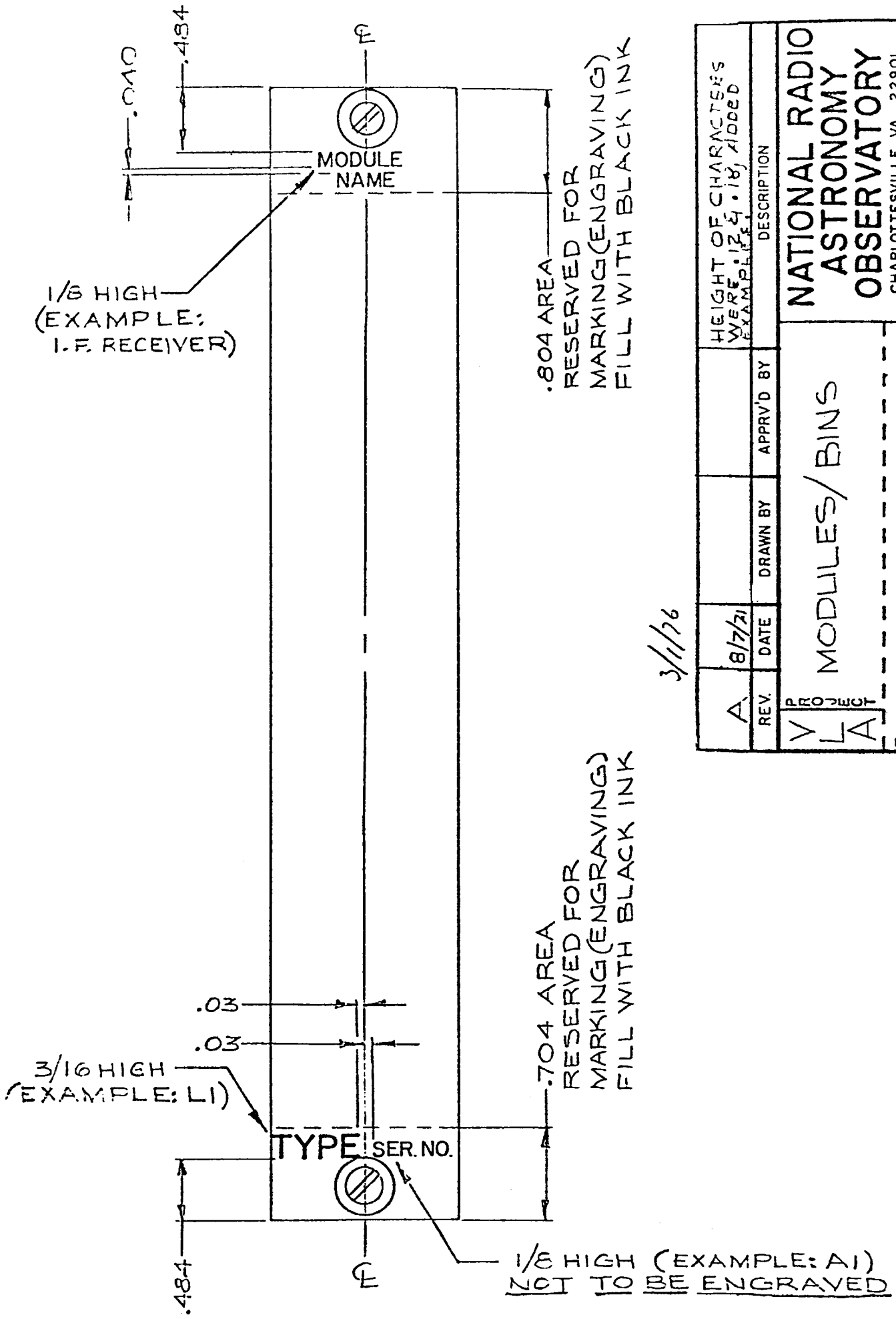
(c) Line Width: .020" ± .002"

(d) Type of Cutter: "V" groove

## 3. FILLING

Groove shall be filled with black epoxy ink.

(See Drawing A13050M43)


.040
.484
MODULE NAME
1/8 HIGH (EXAMPLE: I.F. RECEIVER)
.804 AREA RESERVED FOR MARKING (ENGRAVING) FILL WITH BLACK INK
.03
.03
3/16 HIGH (EXAMPLE: L1)
.704 AREA RESERVED FOR MARKING (ENGRAVING) FILL WITH BLACK INK
TYPE
SER. NO.
.484
1/8 HIGH (EXAMPLE: A1) NOT TO BE ENGRAVED
3/11/76
HEIGHT OF CHARACTERS WERE INCREASED .187 ADDED
REV. A
DATE 8/7/21
DESCRIPTION
DRAWN BY
APPR'D BY
NATIONAL RADIO ASTRONOMY OBSERVATORY
CHARLOTTESVILLE, VA. 22901
DRAWN BY
DESIGNED BY
APPROVED BY
DATE
DATE
DATE
PROJECT
VLA
MODULES/BINS
STANDARD MARKING LOCATIONS FOR ALL MODULE FRONT PANELS
SHEET NUMBER
DRAWING NUMBER A13050M43
REV. A
SCALE 1/1

NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia
VERY LARGE ARRAY PROJECT

SPECIFICATION NO: A13230N1

NAME: Assembly of UT-141A .141 Semi Rigid Coaxial Cable to Type OMQ Connector

DATE: June 27, 1975

PREPARED BY: _____ APPROVED BY: _____

## 1. GENERAL

To provide a step by step procedure for proper installation of the .141 D1A Semi Rigid Coax to Omni/Spectra Connector nos. OMQ 3033-75 and OMQ 3043-75. To identify component parts of connector assemblies and designated tooling used to complete the cable/connector installation.

## 2.0 SPECIAL TOOLING REQUIRED:

2.1 Center Contact Crimp Tool: *OSI T-6873-2 Common

2.2 Center Contact Positioner: OSI T-6873-7 Common

2.3 Fixture Base: OSI T-6869-1 Common

2.4 Cable Clamp Insert: OSI T-4700-1 Common

2.5 Locator Screw: OSI T-6874-2 (#3033-75 only)

2.6 Locator Screw: OSI T-6872-2 (#3043-75 only)

2.7 Assembly Fixture: NRAO #C13050T1-1 (#3033-75 only)

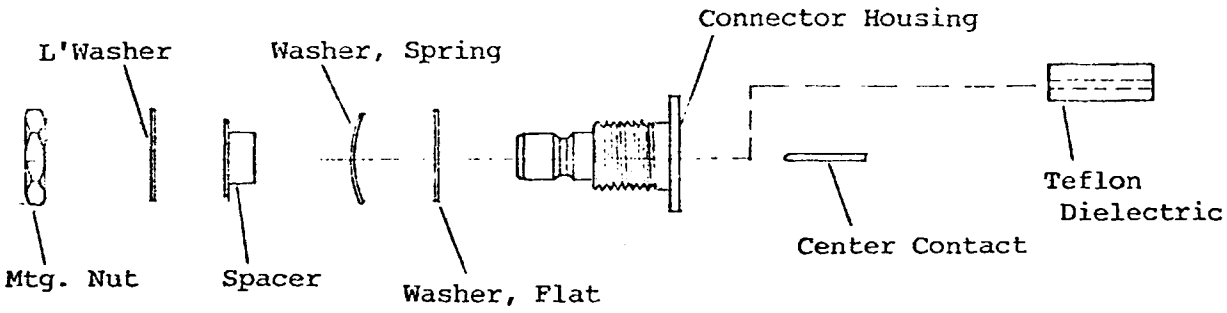
2.8 Assembly Fixture: NRAO #C13050T1-2 (#3033-75 only)

2.9 Assembly Fixture: NRAO OSI T-4554

## 3.0 OMQ 3033-75A Connector

*Omni/Spectra Incorporated

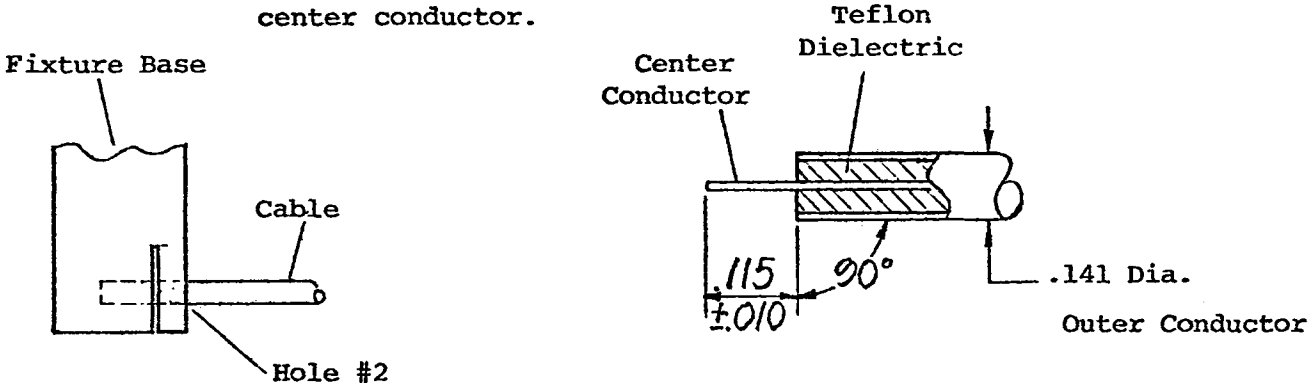
3.1 Identification of Parts




Parts Shown As Packaged By OSI

3.2 Preparation of Cable

3.2.1 Choose a length of semi-rigid coax .141 dia. cable and insert one end into fixture base T-6869-1 (hole on lower corner) as shown. Use jewler's saw or equivalent to make an annular cut through copper wall. Remove from fixture and using a razor blade, cut through the teflon exposing the center conductor. CAUTION: Do not nick center conductor.




View Showing Cable Preparation For Crimping

3.3 Contact Crimp

3.3.1 Set knob to position 6 of crimp tool T-6873-2.

3.3.2 Place center contact into positioner T-6873-7 and bottom.

3.3.3 Insert cable inner conductor into center contact and bottom cable in positioner. Crimp.

## 3.4 Installation of Cable Sub-Assembly to Connector Housing

3.4.1 Remove teflon dielectric from connector housing.

3.4.2 Insert aluminum spacer NRAO C13050T1-1 into contact end of connector housing replacing teflon. (After soldering, spacer must be removed.)

3.4.3 Using fixture base T-6869-1 and locator screw T-6874-1, insert the crimped contact end of cable through the connector housing, as the opposite end is aligned with the locator screw. Allow the cable to be clamped between jaws T-4700-1 while locator screw is tightened snuggly capturing the whole assembly. Note the illustration on NRAO drawing C13050T1-1 for additional details.

3.4.4 Burnish area to be soldered using fine sand paper. Then apply non-corrosive flux in areas to be soldered. Proceed to solder the annular surface at point of insertion into the connector housing using rosin core solder, 60% tin, 40% lead. Allow assembly to cool before removing from fixture. Remove aluminum spacer. Soldering mode is complete.

## 3.5 Procedure for Installing Teflon Dielectric

3.5.1 Assembly fixture, NRAO C13050T1-2 is used in this procedure to align the contact end of connector housing so the dielectric sleeve may be seated into cavity around contact without any damage to teflon or the center contact.

3.5.2 Engage knurled knob to the threads of the connector housing and tighten the assembly until it becomes rigid.

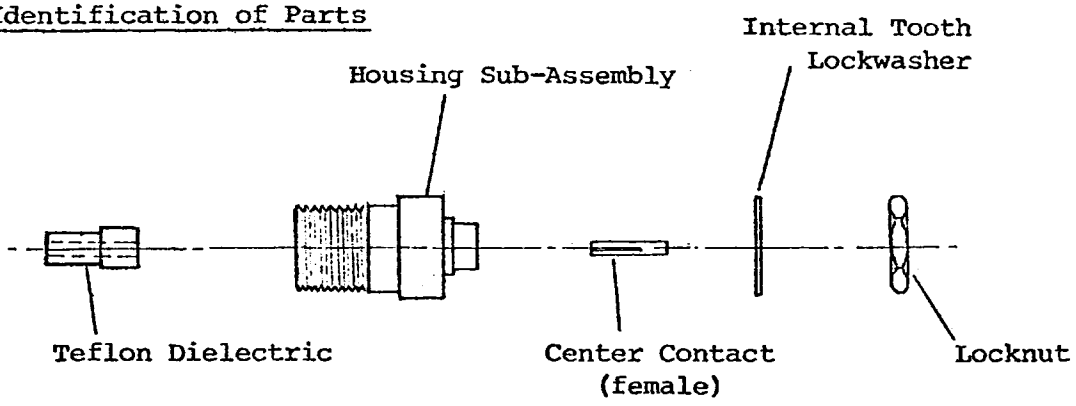
3.5.3 Place teflon dielectric into opening of mandrel C13050T1-2-1 and using plunger C13050T1-2-2 to force teflon down into cavity surrounding contact in connector housing. Refer to NRAO drawing C13050T1-2 for complete illustration.

3.5.4 Remove connector from fixture and inspect the dielectric. If properly seated, the housing shoulder should be just visible to the eye. Connector should now be ready for installation into racks or modules.

3.5.5 Use inspection gage NRAO # C13050T3, (see dwg. for inspection procedure).

## 4.0 OMQ 3043-75 CONNECTOR

### 4.1 Identification of Parts




Parts Shown as Packaged By OSI

### 4.2 Preparation of Cable:

4.2.1 Choose a length of semi-rigid coax .141 diameter cable and insert one end into fixture base T-6869-1 (hole on lower corner) as shown. Use small jewler's say or equivalent to make an angular cut through copper wall. Remove from teflon exposing the center conductor.

CAUTION: Do not nick center conductor.

4.3 Contact Crimp:

4.3.1 Set knob to position 6 of crimp tool T-6873-2.

4.3.2 Place center contact into positioner T-6873-7 and bottom.

4.3.3 Insert cable inner conductor into center contact and bottom cable in positioner. Crimp.

4.4 Installation of Cable Sub-Assembly to Connector Housing

4.4.1 Remove teflon dielectric from connector housing.

4.4.2 Insert aluminum spacer NRAO drawing C13050T1-1-6 into contact end of connector taking the position of the teflon. (After soldering, spacer must be removed.)

4.4.3 Using fixture base T-6869-1 and locator screw T-6872-2, insert the crimped contact end of cable through the connector housing, as the opposite end is aligned with the locator screw. Allow the cable to be clamped between jaws T-5700-1 while locator screw is tightened snugly capturing the whold assembly. Note the illustration on NRAO drawing C13050T1-1 for additional details.

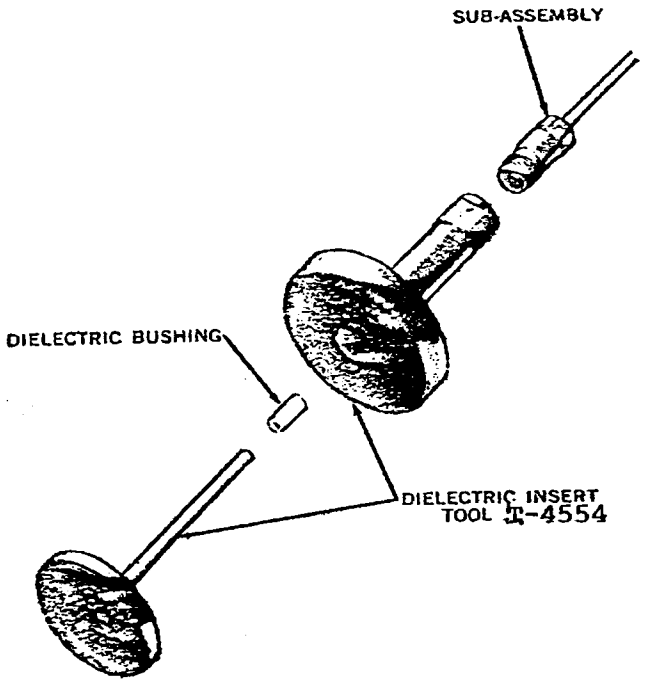
4.4.4 Burnish area to be soldered using fine sand paper. Then apply non-corrosive flux in areas to be soldered. Proceed to solder the annular surface at point of insertion into the connector housing. Also solder shoulder as this tends to come off connector when put into service, using rosin core solder, 60% tin, 40% lead. Allow

assembly to cool before removing from fixture. Remove aluminum spacer. Soldering mode is complete.

## 4.5 Procedure for Installing Teflon Dielectric

4.5.1 Assembly fixture OSI T-4554 is used in this procedure to align the contact end of connector housing so the dielectric sleeve may be seated into cavity around contact without any damage to center contact or to grip fingers around teflon. See illustration below.

**INSERT DIELECTRIC BUSHING INTO SUB-ASSEMBLY**




4.5.2 Secure dielectric insert tool housing to threads of connector.

4.5.3 Remove plunger from tool housing.

4.5.4 Insert dielectric bushing into center hole of tool housing.

4.5.5 Push firmly with plunger until flange bottoms on tool housing shoulder.

## 9.2 Module Type/Name List

The following defines the official module types and names at the date of January 1, 1978.

Interoffice

# National Radio Astronomy Observatory

Very Large Array

January 5, 1978

To: VLA Electronics Staff, R. M. Mitchell, S. Weinreb, V. Herrero

From: A. R. Thompson

Subject: Module Names

The following is a revision of my memorandum of January 28, 1977 which listed the type numbers and names of modules. All new modules resulting from the latest system modifications are included.

| | |
|---|---|
| D1 | Sampler |
| F1 | Bias Control |
| F2 | Upconverter Pump |
| F3 | 17-20 GHz L.O. |
| F4 | Frequency Converter |
| F5 | Front End Control |
| F6 | RF Splitter |
| F7 | Front End IF Filters |
| F8 | IF Offset |
| L1 | 5-50 MHz VCXO |
| L2 | 50 MHz Harmonic Generator |
| L3 | L.O. Transmitter |
| L4 | L.O. Receiver |
| L5 | L.O. Control |
| L6 | 2-4 GHz Synthesizer |
| L7 | Fringe Generator |
| L8 | Timing Generator |
| L9 | Central L.O. Receiver |
| L10 | Central L.O. Transmitter |
| L11 | Central L.O. Control |
| L12 | Master L.O. Offset |
| L13 | 600-1800 MHz Multiplier |
| L14 | Central L.O. Filter |
| L15 | Master L.O. Phase-Lock |
| L16 | Synthesizer Control |
| L17 | Synthesizer Phase-Lock |
| L18 | Variable Frequency Driver |
| L19 | Master L.O. Driver |
| L20 | Master L.O. Control |
| L21 | Synthesizer Phase-Lock Emergency Power |
| L22 | Modem Offset Oscillator |

M1 Data Set
M2 Data Tap
M3 Central Buffer
M4 Antenna Buffer
M5 Command Simulator
M7 Focus/Rotation Control
M8 Focus/Rotation Power Supply
P1 to P5 Power Supplies
T1 Modem
T2 IF Combiner
T4A, T4B L.O. Offset (to be replaced by T4: IF Converter in future retrofit)
T5 IF Receiver
T6 IF Control

ART/drg

## 9.3 Plug In Wire Wrap Board Conventions

Figure 9.3 shows the format conventions for the plug in wire wrap boards which are used in L.O. modules and the Delay-Multiplier system. Two sizes of boards are used which differ only in size; the larger size is shown in 9.3.

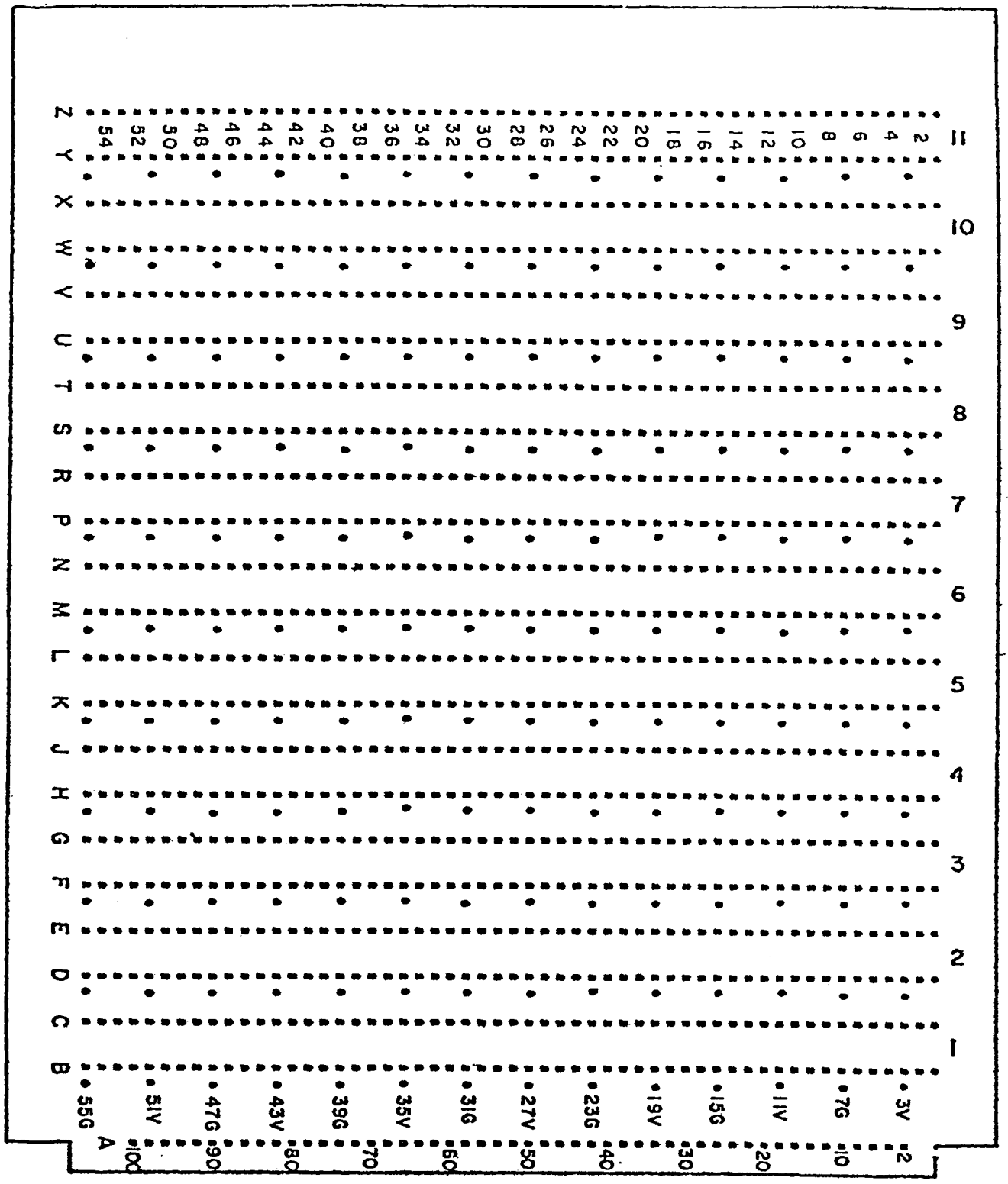


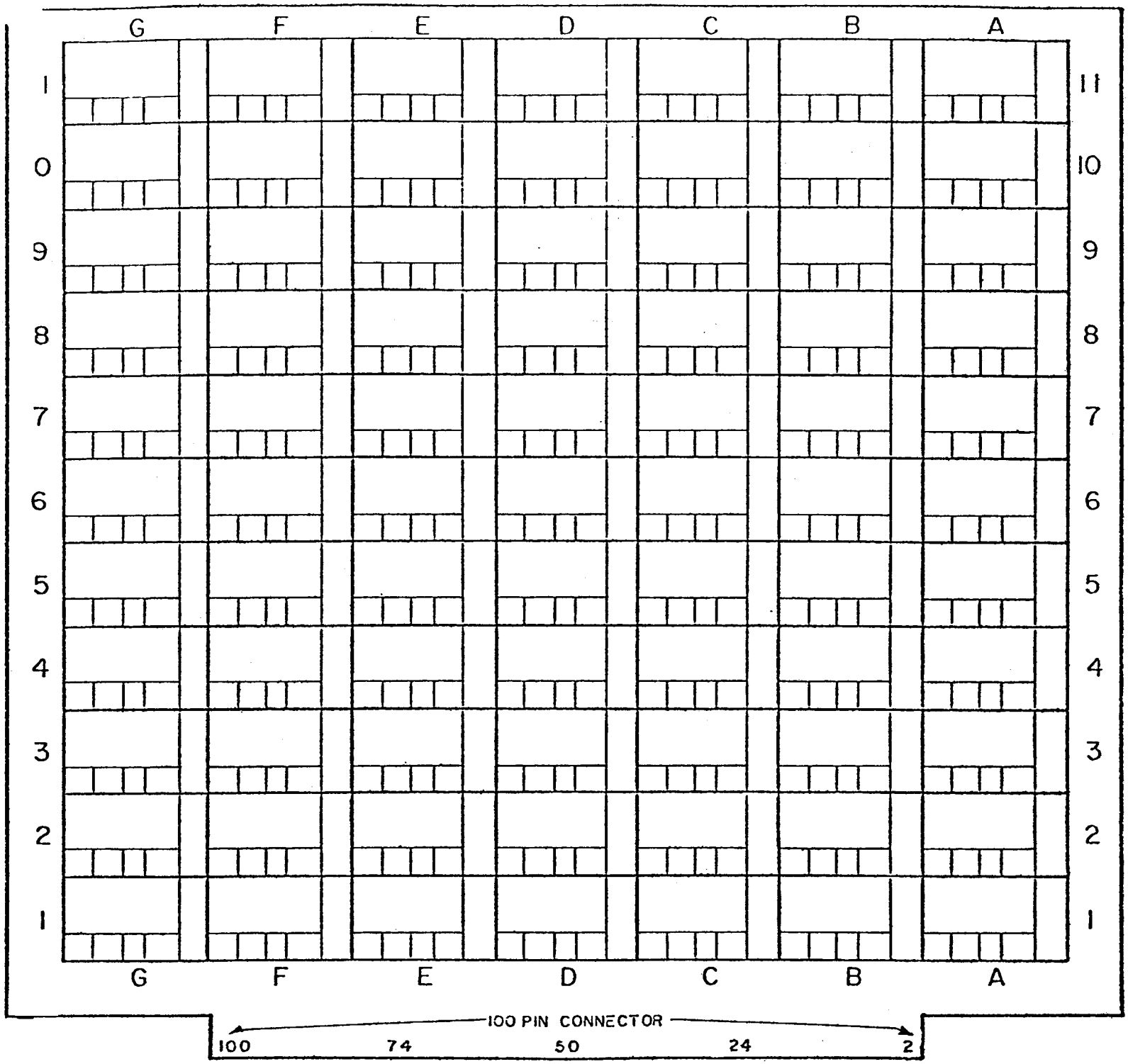

FIGURE 9.3a PLUG-IN WIRE WRAP BOARD

NRAO

LOCATION

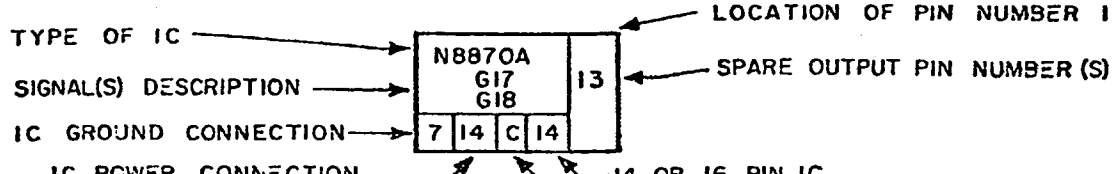
BY _____

DATE _____



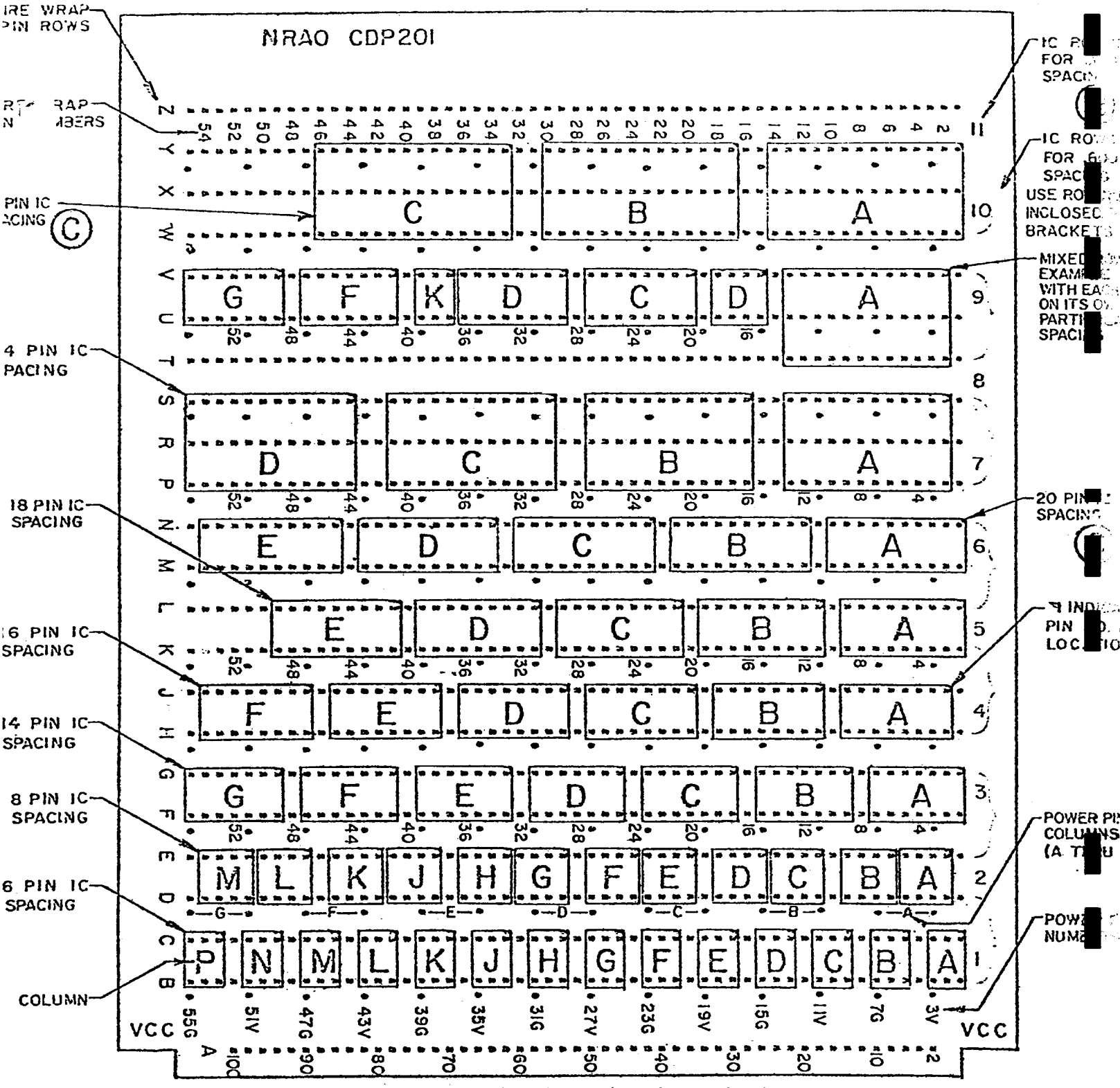

NOTES:

1. SAMPLE BOX




2. TOP VIEW, COMPONENT SIDE OF BOARD
3. THIS COLUMN NOT AVAILABLE
4. VCC CONNECTOR PINS: P2,4,98 27, 49, 73, 97, 99

FIGURE 9.3b



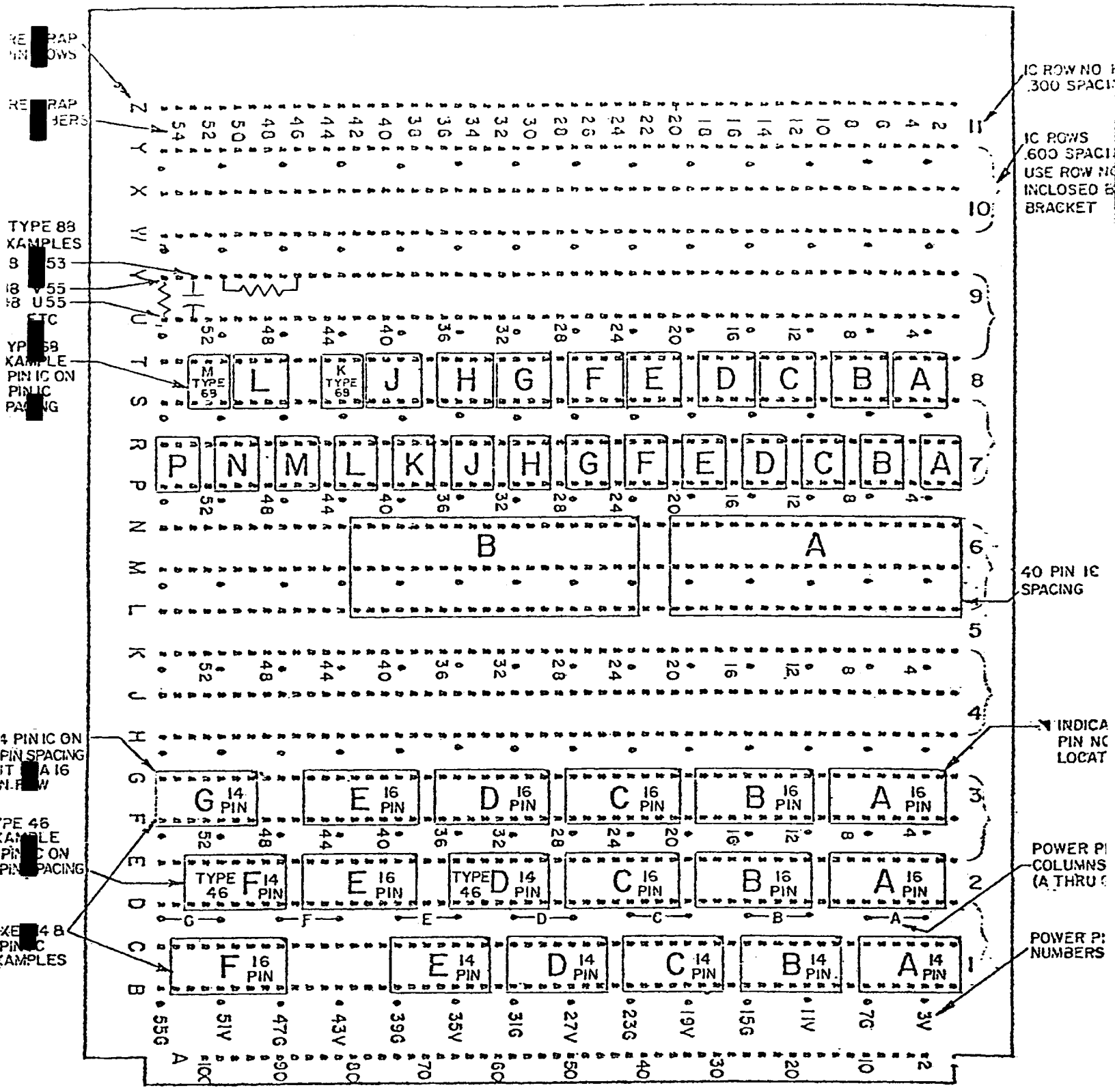

NOTES:

1. COMPONENT SIDE OF BOARD SHOWN
2. THE CDP202 BOARD HAS ONLY 5 IC ROWS AVAILABLE INSTEAD OF THE 11 IC ROWS SHOWN.
3. Vcc PLANE I/O CONNECTIONS: 2, 4, 98, 100
4. GND PLANE I/O CONNECTIONS: 1, 3, 27, 28*, 49, 50*, 73, 74*, 97, 99
5. 6 & 14 PIN ICs ARE ON SAME SPACING
6. 8 & 16 PIN ICs ARE ON SAME SPACING

* GND BUS CONNECTIONS ONLY.
NO P.C. CONNECTIONS ON W.W

| | |
|---|---|
| A | ADDED 9-25-73 JE |
| B | .300 WAS .030<br>.600 WAS .060<br>1-17-74 JE |
| C | ADDED 9-19-74 SSR |
| D | CHANGED .600 SPACING NOTATION 10-10-74 SSR |

FIGURE 9.3c
WIRE WRAP BOARD IC LAYOUT (SHEET 1 OF 2)




SEE NOTES ON SHEET 1 (FIGURE 3).

WIRE WRAP BOARD IC LAYOUT (SHEET 2 OF 2)

FIGURE 9.3d

NRAO
Wire Wrap Printed Circuit Board Conversion Chart
February 23, 1972
16 PIN CHIP

| IC Row | | | | | | | | | | | IC Column | | | | | | IC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | A | B | C | D | E | F | Pin No. |
| C | E | G | J | L | N | R | T | V | X | Z | 2 | 11 | 20 | 29 | 38 | 47 | 1 |
| | | | | | | | | | | | 3 | 12 | 21 | 30 | 39 | 48 | 2 |
| | | | | | | | | | | | 4 | 13 | 22 | 31 | 40 | 49 | 3 |
| | | | | | | | | | | | 5 | 14 | 23 | 32 | 41 | 50 | 4 |
| | | | | | | | | | | | 6 | 15 | 24 | 33 | 42 | 51 | 5 |
| | | | | | | | | | | | 7 | 16 | 25 | 34 | 43 | 52 | 6 |
| | | | | | | | | | | | 8 | 17 | 26 | 35 | 44 | 53 | 7 |
| E | G | J | L | N | R | T | V | X | Z | | 9 | 18 | 27 | 36 | 45 | 54 | 8 |
| Wire Wrap Row | | | | | | | | | | | Wire Wrap Pin No. | | | | | | |

| IC Row | | | | | | | | | | IC Column | | | | | | IC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | A | B | C | D | E | F | Pin No. |
| D | F | H | K | M | P | S | U | W | Y | 9 | 18 | 27 | 36 | 45 | 54 | 9 |
| | | | | | | | | | | 8 | 17 | 26 | 35 | 44 | 53 | 10 |
| | | | | | | | | | | 7 | 16 | 25 | 34 | 43 | 52 | 11 |
| | | | | | | | | | | 6 | 15 | 24 | 33 | 42 | 51 | 12 |
| | | | | | | | | | | 5 | 14 | 23 | 32 | 41 | 50 | 13 |
| | | | | | | | | | | 4 | 13 | 22 | 31 | 40 | 49 | 14 |
| | | | | | | | | | | 3 | 12 | 21 | 30 | 39 | 48 | 15 |
| | | | | | | | | | | 2 | 11 | 20 | 29 | 38 | 47 | 16 |
| | | | | | | | | | | 3V | 11V | 19V | 35V | 43V | 51V | V |
| B | D | F | H | K | M | P | S | U | W | 7G | 15G | 23G | 39G | 47G | 55G | G |
| Wire Wrap Row | | | | | | | | | | Wire Wrap Pin No. | | | | | | |

Examples:

IC Wiring List No.

2C4
5E12
2CV
7FG
P15

P.C. Wire Wrap No.

E23
K42
D19V
P55G
A15

FIGURE 9.3e



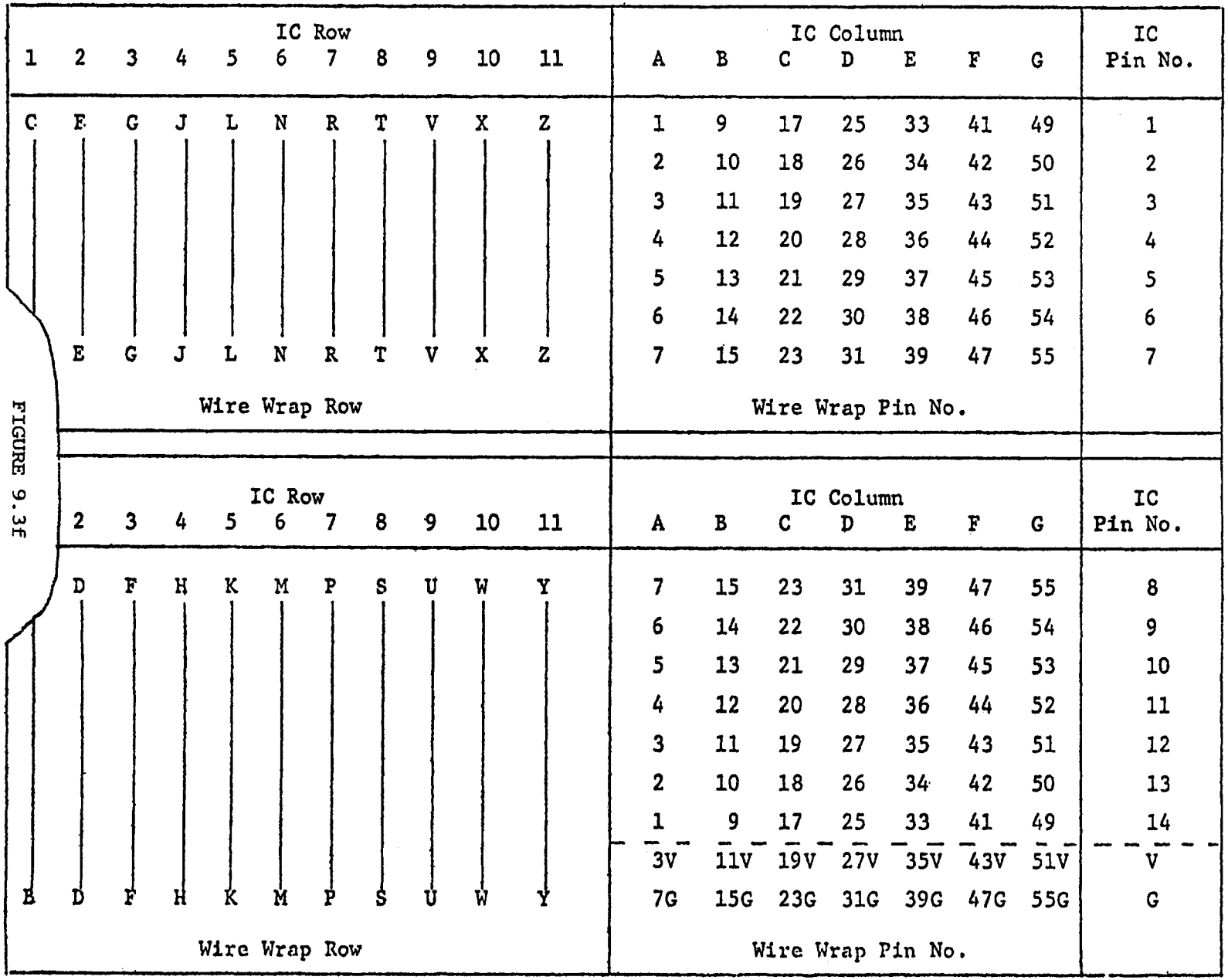
Row P same as Wire Wrap Row A → 1 to 100

NRAO

[redacted] Printed [redacted] Board [redacted] Check

February 23, 1972

14 PIN CHIP




Examples:

IC Wiring List No.

3D5
7F13
3FV
10AG
P15

P.C. Wire Wrap No.

G29
P42
F43V
W7G
A15

FIGURE 9.3f



IC Row P same as Wire Wrap Row A. 1 to 100

NRAO

WIRE WRAP PRINTED CIRCUIT BOARD CONVERSION CHART

September 4, 1973

18 Pin Chip

| IC Row | | | | | | | | | | | IC Column | | | | | IC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | A | B | C | D | E | Pin No. |
| C | E | G | J | L | N | R | T | V | X | Z | 1 | 11 | 21 | 31 | 41 | 1 |
| | | | | | | | | | | | 2 | 12 | 22 | 32 | 42 | 2 |
| | | | | | | | | | | | 3 | 13 | 23 | 33 | 43 | 3 |
| | | | | | | | | | | | 4 | 14 | 24 | 34 | 44 | 4 |
| | | | | | | | | | | | 5 | 15 | 25 | 35 | 45 | 5 |
| | | | | | | | | | | | 6 | 16 | 26 | 36 | 46 | 6 |
| | | | | | | | | | | | 7 | 17 | 27 | 37 | 47 | 7 |
| | | | | | | | | | | | 8 | 18 | 28 | 38 | 48 | 8 |
| E | G | J | L | N | R | T | V | X | Z | | 9 | 19 | 29 | 39 | 49 | 9 |
| WIRE WRAP ROW | | | | | | | | | | | WIRE WRAP PIN NO. | | | | | |

| IC Row | | | | | | | | | | IC Column | | | | | IC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | A | B | C | D | E | Pin No. |
| D | F | H | K | M | P | S | U | W | Y | 9 | 19 | 29 | 39 | 49 | 10 |
| | | | | | | | | | | 8 | 18 | 28 | 38 | 48 | 11 |
| | | | | | | | | | | 7 | 17 | 27 | 37 | 47 | 12 |
| | | | | | | | | | | 6 | 16 | 26 | 36 | 46 | 13 |
| | | | | | | | | | | 5 | 15 | 25 | 35 | 45 | 14 |
| | | | | | | | | | | 4 | 14 | 24 | 34 | 44 | 15 |
| | | | | | | | | | | 3 | 13 | 23 | 33 | 43 | 16 |
| | | | | | | | | | | 2 | 12 | 22 | 32 | 42 | 17 |
| B | D | F | H | K | M | P | S | U | W | Y | 1 | 11 | 21 | 31 | 41 | 18 |
| | | | | | | | | | | | 3V | 11V | 19V | 35V | 43V | V |
| | | | | | | | | | | | 7G | 15G | 23G | 39G | 47G | G |
| WIRE WRAP ROW | | | | | | | | | | | WIRE WRAP PIN NO. | | | | | |

EXAMPLES:

IC Wiring List No.

2C4
5E12
2CV
7EG
P15

P.C. Wire Wrap No.

E24
K47
D19V
P47G
A15

FIGURE 9.3g

## 9.4 Monitor and Control System Notational Conventions

The Monitor and Control System Module package design uses wire wrapped logic connector boards which hold up to 30 fourteen or sixteen pin logic elements. Up to six of these 30 chip connector boards are used in a given module and are designated A through F starting from the rear panel as shown in Figure 5.2. Logic elements on the logic diagrams use a location designation based upon the board designator (A through F) and chip location (marked 1 through 30) on the board. Thus, A24-13 designates pin 13 on a logic chip located on board A, chip location 24. This notation is used on the wire lists and is prefixed by an X which is an ANSI convention for a plug-in socket. When fourteen pin chips are inserted into the sixteen pin sockets the logic element pins 8 through 14 are renumbered 10 through 16 on the logic diagrams. Pins 1 through 7 are unaffected in this case, but pins 7 and 8 are interconnected by a jumper wire to provide logic ground to the chip. Pins 8 and 16 on the connector board are committed to logic ground and +5 volts respectively.

Wire strings are designated by a unique signal name based upon the logic diagram sheet number and the location designation of the signal source that drives the string. The first character of the signal name is alphabetic and designates the logic sheet; thus, signal CD1306 is generated by logic gate D13, pin 6 on sheet 3 (i.e., C).

There are four wire list formats for the Monitor and Control modules; these are the Master, Hand, Machine and Connector lists. The Master Wire list contains all the wiring in the module, but the Machine and Hand Wire lists are subsets of the Master Wire list and describe two separate classes of wiring: the Machine (levels 1 and 2) and Hand (level 3 and power wires). Machine wires are levels 1 and 2 interconnections (only) on the logic connector boards and are machine-wired. Hand wire level 3 wire wrap wires are used for I/O wires between the logic connector

boards and the I/O connectors and may be either machine-wired or hand-wired. An "H" and "M" in the wiring input data designate Hand and Machine Wire classes.

The Connector Wire list is a snapshot of each logic connector and shows the Signal Name and the "From" and "To" points in the string.

## 9.5 Drawing Listing and Parts Listing Coding Forms

Figure 9.5a depicts the Drawing Listing coding format. This data is sorted by a listing program to produce a listing of drawings by module. At present (1/1/78) this program resides in the CV 360, but it is planned to eventually implement it on the DEC-10 System.

Figure 9.5b depicts the Parts Listing coding format. This data is sorted to produce a collated listing of module parts versus quantities required. This program also resides in the CV 360 but has been implemented in a simplified form in the Tech 360 and is being altered to operate in the Dec-10 System.

DRAWING LIST CODING FORMS

| Column No. | Description |
|---|---|
| 1 - 3 | Module number |
| 5 - 20 | Drawing number and -X number plus - (module number) if a common part |
| 21 | Revision letter (if none -) |
| 22 - 24 | Day of year (1 to 365) |
| 25 & 26 | Last 2 numbers of year (76) |
| 29 | ' |
| 30 - 54 | Title |
| 55 | ' |
| 57 | Number of sheets |
| 59 | + Drawing microfilmed with master in CV |
| | - Drawing not microfilmed with master in CV |
| | A Drawing microfilmed with master in NM |
| | B Drawing not microfilmed with master in NM |
| 61 - 66 | Cost in dollars and cents with decimal point in column 64 (if no cost use 0.00) |
| 68 | Key 1 (used to produce module drawing list) |
| 70 | Key 2 (used to group items for procurement) |

FIGURE 9.5a DRAWING LIST CODING FORMS

GX28-7327-6 U/M 050
Printed in U.S.A.

IBM

FORTRAN Coding Form

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROGRAM | | PUNCHING INSTRUCTIONS | GRAPHIC | | | | | | | | | PAGE OF | |
| PROGRAMMER | DATE | | PUNCH | | | | | | | | | CARD ELECTRO NUMBER* | |

| COMM. | STATEMENT NUMBER | CONT. | FORTRAN STATEMENT | IDENTIFICATION SEQUENCE |
|---|---|---|---|---|
| | | | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 | 73 74 75 76 77 78 79 80 |
| L | 1 | C | 1 3 2 1 Ø AB Ø 1 B 2 5 2 7 5 'X 1 0. MU L T I P L I E R ' 2 1 - Ø. Ø Ø E H | |
| L | 1 | C | 1 3 2 1 Ø M Ø 2 - 1 B 1 3 1 7 6 'C O I L & T R A N S F O R M E R D A T A ' 1 - Ø. Ø Ø J U | |

*A standard card form, IBM electro 888157, is available for punching statements from this form

FIGURE 9.5a (Cont'd)

KEY 2 DESCRIPTION

| Key 2 | Description |
|---|---|
| A | Module Front Panels: Fabricate, Engrave (unless otherwise specified) Alodine, Paint and Ink Fill. |
| B | Module Front Panels: Fabricate, Silk Screen, Alodine and Paint. |
| C | Module Front Panels: Fabricate, Alodine and Paint. |
| D | Data List |
| E | Module Rear Panels: Fabricate and Alodine. |
| F | Bin Rear Panels: Fabricate and Alodine. |
| G | Module Support Bars: Fabricate and Alodine. |
| H | Module Side Plates: Fabricate and Alodine. |
| I | Informational: Application, etc. |
| J | Sub-Assembly Enclosure Components: Fabricate and Alodine. |
| K | Perforated Covers: Fabricate and Alodine. |
| L | Misc. Covers and Plates: Fabricate and Alodine. |
| M | Misc. Mechanical Parts: Fabricate and Alodine. |
| N | Wave Guide System: (133--); IF Transmission (134--); Feed System (136--) |
| O | |
| P | Racks (Purchased) |
| Q | Racks (G.B. Shop) |
| R | Bin Assemblies: Fabricate and Alodine. |
| S | Ductwork: Fabricate and Alodine. |
| T | Module Assemblies (Power Supplies): Fabricate, Engrave, Alodine, Paint and Ink Fill. |
| U | Mechanical: Fabricate, No Finish (Alodine or Paint) |
| V | Mixers: (CV Shop) |
| W | Microwave Assemblies |
| X | Misc. Dewar Parts |
| Y | Delay/Multiplier Chassis Components: Fabricate and Alodine. |
| Z | Plastic Molded Parts (Module and Card Guides) |
| 0 | Bill of Materials |
| 1 | Assembly |
| 2 | Schematic |

FIGURE 9.5a (Cont'd)

| Key 2 | Description |
|---|---|
| 3 | Logic Diagram |
| 4 | Printed Circuit Board |
| 5 | Silkscreen |
| 6 | Mechanical, Printed Circuit Boards |
| 7 | Block Diagrams |
| 8 | Wire List |
| 9 | Tool Drawing |

FIGURE 9.5a (Cont'd)

KEY 1 DESCRIPTION

| Key 1 | DWG. Code | Drawing Type |
|---|---|---|
| A | Z | Bill of Materials |
| B | P | Assembly |
| C | S | Schematic |
| D | L | Logic Diagrams |
| E | A | Printed Circuit Boards |
| F | A | Silkscreen |
| G | M | Mechanical, Printed Circuit Boards |
| H | B | Block Diagrams |
| I | W | Wire Lists |
| J | M | Mechanical |
| K | T | Tool |
| L | D | Data List |

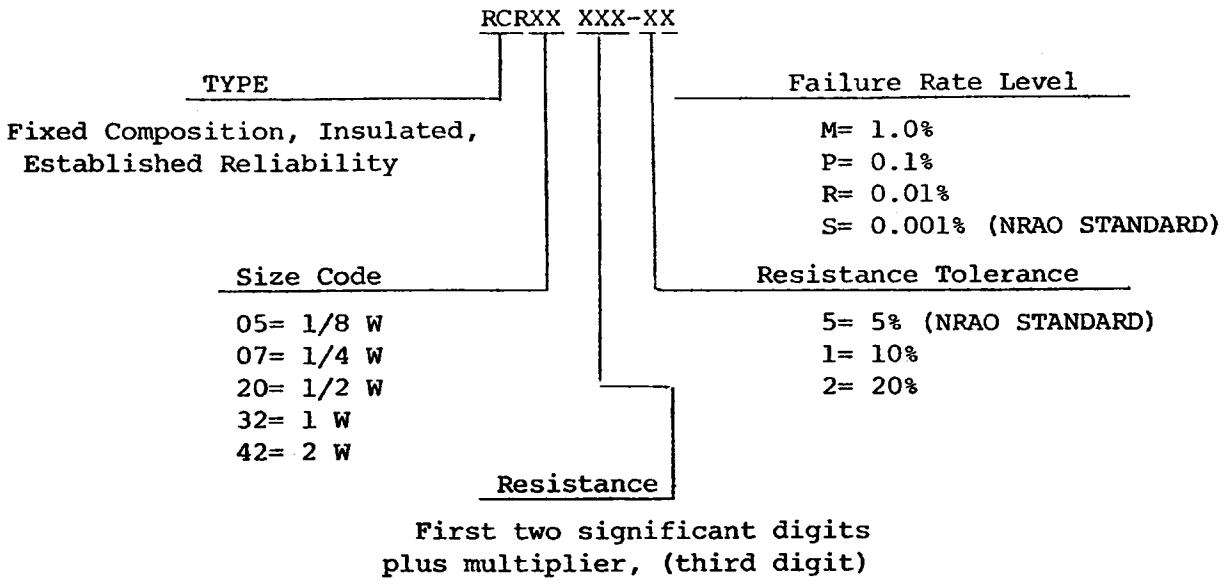
FIGURE 9.5a (Cont'd)

| Column Number | Description |
|---|---|
| 1, 2 & 3 | Module number starting col. #1 |
| 7 & 8 | Quantity<br>The first of like items is given the total quantity (See Example #1) |
| 10, 11 & 12 | Reference description letters (See Table #1) |
| 13 & 14 | Reference description numbers (See Example #1) |
| 16 - 23 | Value - decimal point in column 20 (See Example #1) |
| 24 & 25 | Value multiplier - uf, MH, K, etc. (See Example #1) |
| 27 - 44 | Mfg. Part Number for hardware sizes (screws, nuts, etc.) with X sign in col. 34 (See Example #1) |
| 46 - 58 | Manufacturer for hardware style coding (See Example #1) |
| 60, 61 & 62 | BOM item number |
| 64 - 72 | BOM number |

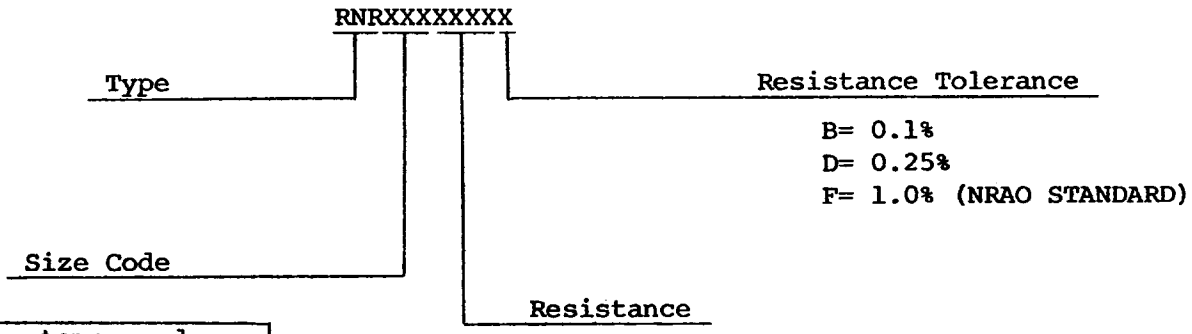
FIGURE 9.5b BOM CODING FORMS

STANDARD RESISTOR CODING

I. STANDARD 5% RESISTOR CODING:




II. STANDARD PRECISION RESISTOR CODING:




| type | temp. code | |
|---|---|---|
| | C & E | D |
| 50 | 1/20 W | -- |
| 55 | 1/10 W | 1/8 W |
| 60 | 1/8 W | 1/4 W |
| 65 | 1/4 W | 1/2 W |
| 70 | 1/2 W | 3/4 W |

Char. C & E = 125 C temp. rating
Char. D = 70 C temp. rating

RNR EXAMPLE: 1/4 W, 4.09 K ohms, 125 C temp. rating, 1% resistance tolerance;

RNR65C4091F

RCR EXAMPLE: 1/4 W, 240 K ohms, 5% resistitance tolerance, 0.001% failure rate;

RCR007 244-5S

FIGURE 9.5b (Cont'd)

PARTS REFERENCE DESIGNATION

A. STANDARD REFERENCE DESIGNATIONS

Reference designations assigned to parts for B.O.M. coding forms (lines 10 thru 14) are I.E.E.E. Standard Class Designation Letters unless otherwise specified below.

Example: (R) resistor, (CR) diode, L.E.D., etc. Letter designations are to be listed from line 10 on, with number identifier listed to right. See Fig. 1.

Line No.

| 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|
| | R | | | Ø | 2 | |
| | C | R | | 2 | 5 | |
| | | | | | | |

Figure 1

B. NON-STANDARD REFERENCE DESIGNATIONS

1. Drawings:

Bill of Materials, (Z)

NST - Top Ass'y Bill of Materials

NSA - Sub-Ass'y Bill of Materials

NSB - Sub-Sub Ass'y (2nd Generation) Bill of Materials

Non P.C. Board Assembly Drawings (P)

DST - Top Ass'y Drawing

DSA - Sub Ass'y Drawing

DSB - Sub-Sub Ass'y (2nd Generation) Drawing

Printed Circuit Board Drawings

EPCA - Printed Circuit Board Artwork

EPCD - Printed Circuit Board Mechanical (Drill Dwg.)

EPCP - Printed Circuit Board Assembly Drawings

FIGURE 9.5b (Cont'd)

Miscellaneous Drawings

DSH - Schematic Diagrams

DWW - Wire Wrap Pin Lists, Wire Data, etc.

WPC - Wire Wrap Board Detail (not Ass'y)

MPM - Top Ass'y Mechanical Drawing

MPN - Sub Ass'y (& Sub-Sub) Mechanical Drawing

MPP - Purchased Mechanical Part

MPZ - Purchased & Modified Mech. Part.

EPZ - Purchased & Modified Electrical Part

MPH - Heatsink

H - Hardware

U - All Dual-In-Line I.C. Packages

A - All other non-separable, and non-repairable I.C. packages that do not have a more descriptive I.E.E.E. Standard Class Letter Designation.

C. HARDWARE DESCRIPTIONS

All parts having hardware reference designations (H) in column 10 have been given abbreviated descriptions to be shown in columns 46 thru 58, unless purchased as special under mfr. part no.

Screws

XXXXX

- Denotes Material: (S) Stainless Steel, (N) Nylon
- Denotes Head Type: (S) Slotted, (C) Cross-recessed (Phillips)
- Denotes Head Shape: (PH) Pan Head, (FH) Flat Head, (FI) Fillister Head, (BH) Binder Head, (HSH) Hex-socket Head Cap Screw

Example: FHSS - Flat head, slotted, stainless steel screw

PHCS - Pan head, cross recessed screw

HSHS - Hex-socket head, stainless steel screw

FISN - Fillister head, slotted, nylon screw

FIGURE 9.5b (Cont'd)

Washers and Nuts

HNS - Hex Nut, Stainless Steel

HNN - Hex Nut, Nylon

FWS - Flat Washer, Stainless Steel

FWN - Flat Washer, Nylon

SLWS - Split-lock Washer, Stainless Steel

ITLWS - Internal-tooth Lock Washer, Stainless Steel

FIGURE 9.5b (Cont'd)

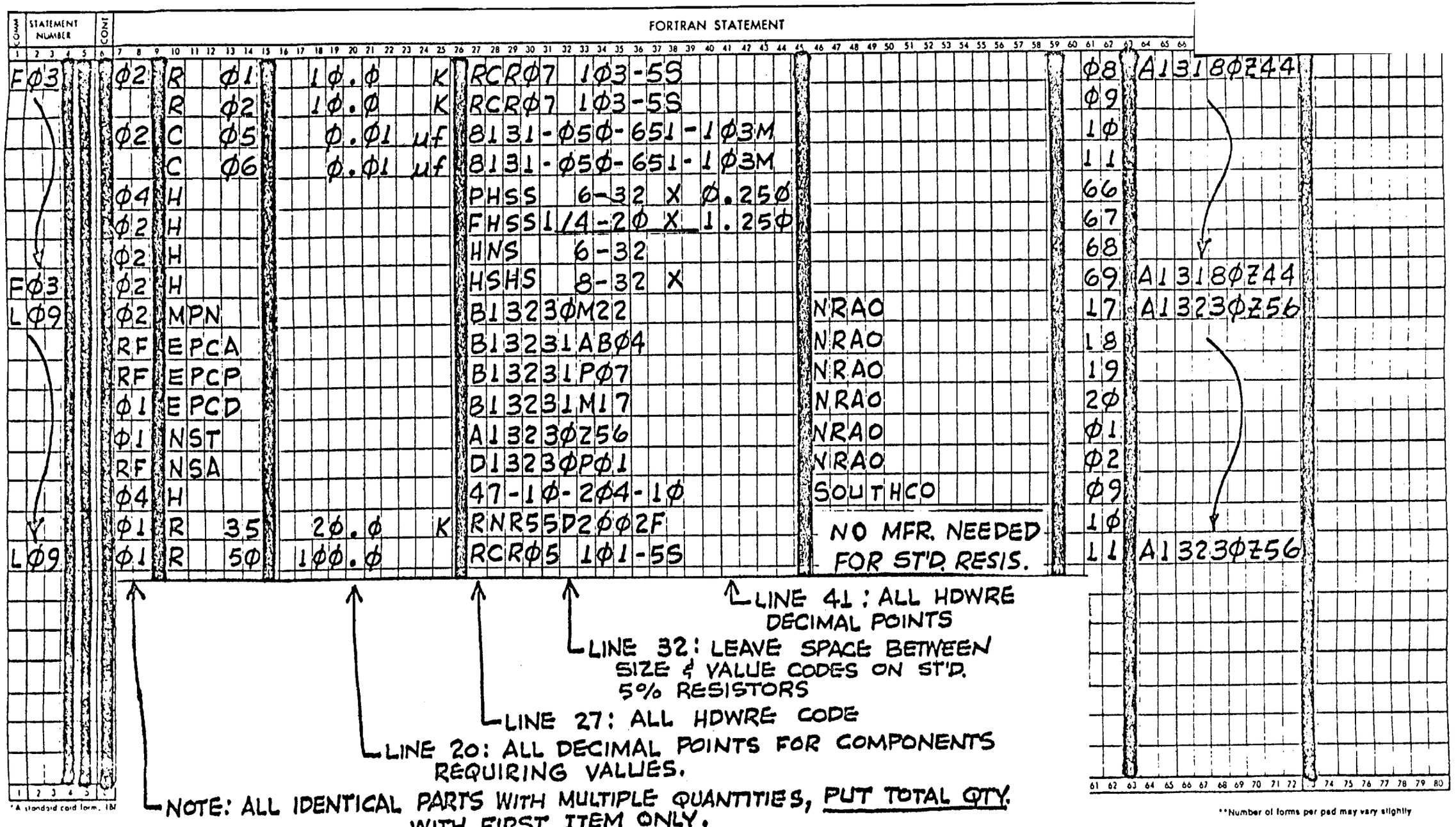



FIGURE 9.5b (Cont'd)

IBM

FORTRAN Coding Form

GX28-7327-6 Printed in U.S.A.

PUNCHING INSTRUCTIONS | GRAPHIC | PUNCH | DATE 1/23/78

FORTRAN STATEMENT

| | | | |
|---|---|---|---|
| SOUTHCO | RCRØ7 | 1Ø3-5S | RESISTOR |
| | RCRØ7 | 1Ø3-5S | RESISTOR |
| | 8131-Ø5Ø-651-1Ø3M | | CAPACITOR |
| | 47-1Ø-2Ø4-1Ø | | FASTENER |
| | RNR55D2ØØ2F | | RESISTOR |
| | RCRØ5 | 1Ø1-5S | RESISTOR |

.Ø6
.Ø5

MANUFACTURER

MANUFACTURER PART NO.

ITEM DESCRIPTION

COST (DECIMAL, LINE 66)

FIGURE 9.5b (Cont'd)

## 9.6 Standard AMP Connector Components and Tools

Table 9.6a and 9.6b are a collection of the AMP hardware which has been selected for use in VLA.

NRAO STANDARD AMP CONNECTOR BLOCKS

| Type | Module | | Bin | | Remarks |
|---|---|---|---|---|---|
| | Pin Block | Hood | Socket Block | Hood | |
| 42 Contact, Mixed | 204186-5 | 202394-2 | 202516-3 | 202579-5 | Standard crimp contact connector, crimp and coax contacts |
| 50 Contact | 201358-3 | 202394-2 | 200277-4 | 202579-5 | Standard crimp contact connector |
| 34 Contact | 201357-3 | 202434-4 | 200838-3 | 201350-2 | Standard crimp contact connector |
| 14 Contact | 201355-3 | 201347-4 | 201298-3 | 201363-4 | Standard crimp contact connector |
| 43 Contact, mixed, ww posts | 206703-1 | 202394-2 | -- | -- | Old style, short contact pre-assembled ww post connector, not recommended for new construction. Suitable if long pin ww contacts (P76-001-4142) are substituted |
| 50 Contact ww posts | -- | 202394-2 | -- | -- | Old style, short contact pre-assembled ww post connector, not recommended for new construction. Suitable if long pin ww contacts (P76-001-4142) are substituted |
| 34 Contact, ww posts | 4-205361-7 | 202434-4 | -- | -- | Old style short contact pre-assembled ww post connector, not recommended for new construction. Suitable if long pin ww contacts (P76-001-4142) are substituted |
| 42 Contact, mixed ww posts | 601488-4 | 202394-2 | -- | -- | Standard long pin pre-assembled ww post connector, recommended for new construction; also has coax contacts |
| 50 Contact, ww posts | 601488-3 | 202394-2 | -- | -- | Standard long pin pre-assembled ww post connector, recommended for new construction |
| 34 Contact | 601488-2 | 202434-4 | -- | -- | Standard long pin pre-assembled ww post connector recommended for new construction |

Table 9.6a NRAO STANDARD AMP CONNECTOR HARDWARE

CONNECTOR HARDWARE

42/50 Block Strain relief, long - 201847-1

42/50 Block Shield and cable clamp, 180° short, 2 piece - 200532-1

34 Block Strain relief, long - 201846-1

34 Block Shield and cable clamp, 180° short, 2 piece - 200517-1

Fixed male jackscrews - 200844-2

Turnable female jackscrews - 206867-2

---

STANDARD AMP CONNECTOR POWER PIN ASSIGNMENTS

| Type / Color Code | +5 Logic Orange | Logic Common Black | +15 V Red | -15 V Yellow | +20 V Blue | +28 V Gray | -28 V Dark Green | -5.2 V Brown | Hi-Q Gnd Black | 117 V AC Hot Black/White | 117 V AC Com White |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 42 mixed | 10 | 34 | 16 | 17 | 28 | 29 | | 11 | 42 | 33 | 41 |
| 50 | C | L,B | A | E | D | F | J | H | HH | N/A | N/A |
| 34 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 14 | C | - | B | E | - | A | P | R | D | N/A | N/A |

Table 9.6a Cont'd

## LOOSE PIECE PIN AND SOCKETS FOR AMP TYPE "M" CONNECTOR

| Wire Size Range | Diameter | Rating | Wire Strip Length | Ins Dia Range | Type | Pin # | Socket # | Ferrule | Retention Spring | Tool # |
|---|---|---|---|---|---|---|---|---|---|---|
| 18-16 | 0.062 | 13.0 | --- | --- | Solder | 66180-1 | 66181-1 | N.A. | N.A. | --- |
| 30 | 0.062 | 13.0 | 1 | --- | Wire Wrap | 66460-6 | 66461-6 | N.A. | N.A. | Std Wire Wrap Tool |
| 14 | 0.062 | 13.0 | 1/4 | No Ins Support | Crimp | 201570-1 | 201568-1 | N.A. | N.A. | |
| 2-#18 | 0.062 | 13.0 | 1/4 | No Ins Support | Crimp | 202725-1 | 202726-1 | N.A. | N.A. | 45098 |
| 16 | 0.062 | 13.0 | 1/4 | No Ins Support | Crimp | 204219-1* | --- | N.A. | N.A. | ** |
| 24-20 | 0.062 | 13.0 | 13/64 | .040-.062 | Crimp | 201578-1 | 201580-1 | N.A. | N.A. | 45099 |
| 30 | 0.062 | 13.0 | 1 | --- | Wire Wrap | P76-001-4142* | --- | N.A. | N.A. | |
| 24-20 | 0.062 | 13.0 | 13/64 | .075-.085 | Crimp | 204188-1 | 201328-1 | N.A. | N.A. | 45099 |
| Twisted Pair #22 or 24 Stranded | --- | --- | See Tool Instruction Booklet | .115 Both Wires | Coax | 201143-5 | 201144-5 | 328666 | 201142-2 | 45638-3 |
| RG-188 | --- | --- | " | --- | " | " | " | " | " | 45628-2 |
| RG-174 188,316 | Not Recommended for VLA | | See Tool Instruction Booklet | | Sub Min Coax | 51561-1 | 51561-1 | 1-332056-0 | N.A. | 69656 |
| --- | --- | --- | --- | --- | Guide | 200833-4 | 203964-6 | N.A. | N.A. | N.A. |
| --- | --- | --- | --- | --- | Guide (Gnd) | 202514-1 | 202512-1 | N.A. | N.A. | N.A. |

* denotes long pin contacts, all others are short pin contacts

** use the Jack Campbell special crimping tool to crimp #20-26 wire



[redacted]Tab[redacted].6b[redacted]

## 9.7 Basic Module Components

The following table contains the drawing numbers of the basic unconfigured module and bin assemblies.

| Description | Applicable Drawings |
|---|---|
| Bin | D13050M8 Bin Assembly |
| | B13050M26 Panel 42 Pin Power Connector |
| | B13050M27 Panel 42 & 34 Pin Power Connector |
| | B13050M28 Panel 14 Pin Power & (6) OMQ Connector |
| | B13050M29 Panel (10) OMQ Connectors |
| 1 UA Module | D13050P3 IUA Layout & Assembly |
| | B13050M1 Panel, Front |
| | B13050M2 Panel, Rear |
| | B13050M3 Bar Support Top & Bottom |
| | B13050M4 Guide |
| | B13050M6 Side Plate |
| | B13050M7 Perforated Cover |
| | B13050M17 Fastener Perf. Cover |
| 2UA, 3UA and 4UA Modules | D13050P6 2-4UA Layout & Assembly |
| | B13050M4 Guide |
| | B13050M18 Side Plate, Right 7 Left |
| | B13050M19 Panel, Front |
| | C13050M22 Cover, Perforated |
| | B13050M23 Bar Support Top & Bottom |
| | B13050M24 Panel, Rear |
| 1 SA Module | D13050P4 1SA Layout & Assembly |
| | B13050M4 Guide |
| | B13050M9 Bar, Support Top & Bottom |
| | B13050M10 Panel, Front |
| | B13050M11 Shield, Connector |
| | C13150M12 Right Side Plate |
| | C13150M13 Left Side Plate |
| | B13050M14 Shield, Front |
| | B13150M15 Panel, Rear |
| 1 UB Module | D13450P1 1 SB Layout & Assembly |
| | B13050M4 Guide |
| | B13050M1 Shield, Connector |
| | B13050M2 Panel, Front |
| | B13050M3 Shield, Front |
| | C13150M4 Left Side Plate, Front |
| | C13150M5 Left Side Plate, Rear |
| | B13050M6 Support, Left Side Plate |
| | B13150M7 Mounting Plate for Integrated Circuit |
| | B13150M8 Panel, Rear |
| | B13050M9 Support, Heat Sink |
| | B13050M10 Bar, Support, Top & Bottom |
| | C13050M11 Mounting Frame for Circuit Card |
| | C13050M12 Right Side Plate |

| | | |
|---|---|---|
| 1 UB Modules | D13210P2 | 1 UB Layout & Assembly |
| | B13150M1 | Panel, Front |
| | B13150M3 | Bar Support Top & Bottom |
| | B13050M4 | Guide |
| | B13150M6 | Side Plate |
| | C13150M7 | Perforated Cover |
| | B13050M17 | Fastener Perf. Cover |
| | B13210M3 | Panel, Rear |
| 2 UB Module | D13210P3 | 2 UB Layout & Assembly |
| | B13050M4 | Guide |
| | B13050M19 | Panel, Front |
| | C13050M22 | Cover, Perforated |
| | B13050M23 | Bar, Support Top & Bottom |
| | B13050M18 | Side Plate, Right & Left |
| | B13150M30 | Panel (10) OMQ Connectors |
| | C13210M4 | Panel, Rear |

## 9.8 Graphic Electrical, Electronic and Logic Symbols

IEEE Standard #315 Mar 1971 shall be used for graphic electrical and electronic symbols. American National Standard Institute ANSI Y32.14-1973 shall be used for graphic digital logic symbols.

## 9.9 Dimensioning and Tolerancing

ANSI Y1-.5-1973 shall be the applicable specification for dimensioning and tolerancing.

## 9.10 Miscellaneous Specifications

1) Mil Std 12c - Military Standard Abbreviations for use on drawings Specifications and Technical Documents

2) Federal Standard 595a, Color Chips for Desk Use

3) IEEE Recommended abbreviations, extracted from the publication "Information for IEEE Authors."

## I. Recommended prefixes

| Multiple | Prefix | Symbol |
|---|---|---|
| $10^{12}$ | tera | T |
| $10^{9}$ | giga | G |
| $10^{6}$ | mega | M |
| $10^{3}$ | kilo | k |
| $10^{2}$ | hecto | h |
| $10^{1}$ | deka | da |
| $10^{-1}$ | deci | d |
| $10^{-2}$ | centi | c |
| $10^{-3}$ | milli | m |
| $10^{-6}$ | micro | $\mu$ |
| $10^{-9}$ | nano | n |
| $10^{-12}$ | pico | p |
| $10^{-15}$ | femto | f |
| $10^{-18}$ | atto | a |

| Factor by Which the Unit Is Multiplied | Prefix | Symbol |
|---|---|---|
| $1\,000\,000\,000\,000 = 10^{12}$ | tera | T |
| $1\,000\,000\,000 = 10^{9}$ | giga | G |
| $1\,000\,000 = 10^{6}$ | mega | M |
| $1\,000 = 10^{3}$ | kilo | k |
| $100 = 10^{2}$ | hecto | h |
| $10 = 10^{1}$ | deka‡ | da |
| $0.1 = 10^{-1}$ | deci | d |
| $0.01 = 10^{-2}$ | centi | c |
| $0.001 = 10^{-3}$ | milli | m |
| $0.000\,001 = 10^{-6}$ | micro | $\mu$ |
| $0.000\,000\,001 = 10^{-9}$ | nano | n |
| $0.000\,000\,000\,001 = 10^{-12}$ | pico | p |
| $0.000\,000\,000\,000\,001 = 10^{-15}$ | femto§ | f |
| $0.000\,000\,000\,000\,000\,001 = 10^{-18}$ | atto§ | a |

## II. Recommended abbreviations

| Unit or Term | Symbol or Abbreviation |
|---|---|
| alternating current | ac |
| American wire gauge | AWG |
| ampere | A |
| ampere-hour | Ah |
| ampere-turn | At |
| amplitude modulation | AM |
| angstrom | Å |
| antilogarithm | antilog |
| atomic mass unit (unified) | u |
| audio frequency | AF |
| automatic frequency control | AFC |
| automatic gain control | AGC |
| automatic volume control | AVC |
| average | avg |
| backward-wave oscillator | BWO |
| bar | bar |
| barn | b |
| beat-frequency oscillator | BFO |
| bel | B |
| billion electronvolts* | BeV |
| binary coded decimal | BCD |
| British thermal unit | Btu |
| calorie | cal |
| candela | cd |
| candela per square foot | cd/ft² |
| candela per square meter | cd/m² |
| cathode-ray oscilloscope | CRO |
| cathode-ray tube | CRT |
| centimeter | cm |
| centimeter-gram-second | CGS |
| circular mil | cmil |
| continuous wave | CW |
| coulomb | C |
| cubic centimeter | cm³ |
| cubic foot per minute | ft³/min |
| cubic meter | m³ |
| cubic meter per second | m³/s |
| curie | Ci |
| cycle per second | c/s |
| decibel | dB |
| decibel referred to one milliwatt | dBm |
| degree Celsius | °C |
| degree Fahrenheit | °F |
| degree Kelvin | °K |
| degree (plane angle) | ...° |
| degree Rankine | °R |
| degree (temperature interval or difference) | deg |
| diameter | diam |
| direct current | dc |
| double sideband | DSB |
| dyne | dyn |
| electrocardiograph | EKG |
| electroencephalograph | EEG |
| electromagnetic compatibility | EMC |
| electromagnetic unit | EMU |
| electromotive force | EMF |
| electronic data processing | EDP |
| electronvolt | eV |
| electrostatic unit | ESU |
| erg | erg |
| extra-high voltage | EHV |
| extremely high frequency | EHF |
| extremely low frequency | ELF |
| farad | F |
| field-effect transistor | FET |
| foot | ft |
| footcandle | fc |
| footlambert | fL |
| foot per minute | ft/min |
| foot per second | ft/s |
| foot poundal | ft-pdl |
| foot pound-force | ft-lbf |
| frequency modulation | FM |
| frequency-shift keying | FSK |
| gallon | gal |
| gallon per minute | gal/min |
| gauss | G |
| gigacycle per second | Gc/s |
| gigaelectronvolt | GeV |
| gigahertz | GHz |
| gilbert | Gb |
| gram | g |
| henry | H |
| hertz | Hz |
| high frequency | HF |
| high voltage | HV |
| horsepower | hp |
| hour | h |
| inch | in |
| inch per second | in/s |
| inductance-capacitance | LC |
| infrared | IR |
| inside diameter | ID |
| intermediate frequency | IF |
| joule | J |
| joule per degree | J/deg |
| joule per degree Kelvin | J/°K |
| kilocycle per second | kc/s |
| kiloelectronvolt | keV |
| kilogauss | kG |
| kilogram | kg |
| kilogram-force | kgf |
| kilohertz | kHz |
| kilohm | kΩ |
| kilojoule | kJ |
| kilometer | km |
| kilometer per hour | km/h |
| kilovar | kvar |
| kilovolt | kV |
| kilovoltampere | kVA |
| kilowatt | kW |
| kilowatthour | kWh |
| lambert | L |
| liter | l |
| liter per second | l/s |
| logarithm | log |
| logarithm, natural | ln |
| low frequency | LF |
| lumen | lm |
| lumen per square foot | lm/ft² |
| lumen per square meter | lm/m² |
| lumen per watt | lm/W |
| lumen second | lm·s |
| lux | lx |
| magnetohydrodynamics | MHD |
| magnetomotive force | MMF |
| maxwell | Mx |
| medium frequency | MF |
| megacycle per second | Mc/s |
| megaelectronvolt | MeV |
| megahertz | MHz |
| megavolt | MV |

| Unit or Term | Symbol or Abbreviation |
|---|---|
| megawatt | MW |
| megohm | MΩ |
| metal-oxide semiconductor | MOS |
| meter | m |
| meter-kilogram-second | MKS |
| mho | mho |
| microampere | μA |
| microfarad | μF |
| microgram | μg |
| microhenry | μH |
| micrometer | μm |
| micromho | μmho |
| micron† | μ |
| microsecond | μs |
| microsiemens | μS |
| microwatt | μW |
| mil | mil |
| mile per hour | mi/h |
| mile (statute) | mi |
| milliampere | mA |
| milligram | mg |
| millihenry | mH |
| milliliter | ml |
| millimeter | mm |
| millimeter of mercury, conventional | mmHg |
| millimicron‡ | |
| millisecond | ms |
| millisiemens | mS |
| millivolt | mV |
| milliwatt | mW |
| minute (plane angle) | ...′ |
| minute (time) | min |
| nanoampere | nA |
| nanofarad | nF |
| nanometer | nm |
| nanosecond | ns |
| nanowatt | nW |
| nautical mile | nmi |
| neper | Np |
| newton | N |
| newton meter | N·m |
| newton per square meter | $N/m^2$ |
| oersted | Oe |
| ohm | Ω |
| ounce (avoirdupois) | oz |
| outside diameter | OD |
| phase modulation | PM |
| picoampere | pA |
| picofarad | pF |
| picosecond | ps |
| picowatt | pW |
| pound | lb |
| poundal | pdl |
| pound-force | lbf |
| pound-force foot | lbf-ft |
| pound-force per square inch | $lbf/in^2$ |
| pound per square inch§ | psi |
| power factor | PF |
| private branch exchange | PBX |
| pulse-amplitude modulation | PAM |
| pulse-code modulation | PCM |
| pulse-count modulation | PCM |
| pulse-duration modulation | PDM |
| pulse-position modulation | PPM |
| pulse-repetition frequency | PRF |
| pulse-repetition rate | PRR |
| pulse-time modulation | PTM |
| pulse-width modulation | PWM |
| radian | rad |
| radio frequency | RF |
| radio-frequency interference | RFI |
| resistance-capacitance | RC |
| resistance-inductance-capacitance | RLC |
| revolution per minute | r/min |
| revolution per second | r/s |
| roentgen | R |
| root-mean-square | rms |
| second (plane angle) | ...″ |
| second (time) | s |
| short wave | SW |
| siemens | S |
| signal-to-noise ratio | SNR |
| silicon controlled rectifier | SCR |
| single sideband | SSB |
| square foot | $ft^2$ |
| square inch | $in^2$ |
| square meter | $m^2$ |
| square yard | $yd^2$ |
| standing-wave ratio | SWR |
| steradian | sr |
| superhigh frequency | SHF |
| television | TV |
| television interference | TVI |
| tesla | T |
| thin-film transistor | TFT |
| transverse electric | TE |
| transverse electromagnetic | TEM |
| transverse magnetic | TM |
| traveling-wave tube | TWT |
| ultrahigh frequency | UHF |
| ultraviolet | UV |
| vacuum-tube voltmeter | VTVM |
| var | var |
| variable-frequency oscillator | VFO |
| very-high frequency | VHF |
| very-low frequency | VLF |
| vestigial sideband | VSB |
| volt | V |
| voltage controlled oscillator | VCO |
| voltage standing-wave ratio | VSWR |
| voltampere | VA |
| volume unit | vu |
| watt | W |
| watthour | Wh |
| watt per steradian | W/sr |
| watt per steradian square meter | $W/(sr \cdot m^2)$ |
| weber | Wb |
| yard | yd |

* Deprecated; use gigaelectronvolt (GeV).
† The name micrometer (μm) is preferred.
‡ The name nanometer is preferred.
§ Although the use of the abbreviation psi is common, it is not recommended. See pound-force per square inch.

Reprints of these instructions are available on request from the Editorial Department, Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, N.Y. 10017.