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HP 70000 Modular Measurement System

Mechanical

Design Guide

HEWLETT
PACKARD

Manual Part Number 5958-6627

Printed in U.S.A. August 1987

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Introduction

This document provides mechanical design information required to generate module designs that are plug-in compatible with the HP 70000 Modular Measurement System.

To aid in the design and development of compatible modules, the manual includes descriptions of mechanical development kits, complete engineering drawings for all parts in the module sub-assembly, and design examples using the HP 70000 development kits.

System Mainframe Information

The HP 70000 provides a structural environment (a mainframe) that will house a wide range of plug-in, automatic test instruments, consisting of some combination of $\frac{1}{8}$, $\frac{2}{8}$, $\frac{3}{8}$, and $\frac{4}{8}$ width modules. The HP 70001A mainframe, figure 1.1, has a capacity of eight $\frac{1}{8}$ width modules (eight one-section modules). Internal module support is a pin and bushing interface at the rear and a nesting v-groove and screw latch on the front frame (see figure 3.3).

The HP 70001A mainframe cabinet height is 177 mm (7 inches), width is EIA standard full rack—425 mm (17 inches), and length is 526 mm (20.7 inches). It is suitable for use on stacked or tilted bench tops and in racks. Appendix E identifies hardware kits for rack mounting and stacking of frames.

The HP 70001A mainframe provides cooling air to the mainframe power supply and the modules. Cooling air from the mainframe enters the modules through complimenting holes at the bottom rear of each module. The air passes through the modules, out the exit holes at the top and front of the module, and out of the mainframe side covers.

Fifty-pin connectors at the rear of the mainframe supply all mainframe-to-module electrical functions. The chapter 3 section titled "50 Pin Module Connector" which begins on page 29 provides engineering details for the module 50 pin connector.

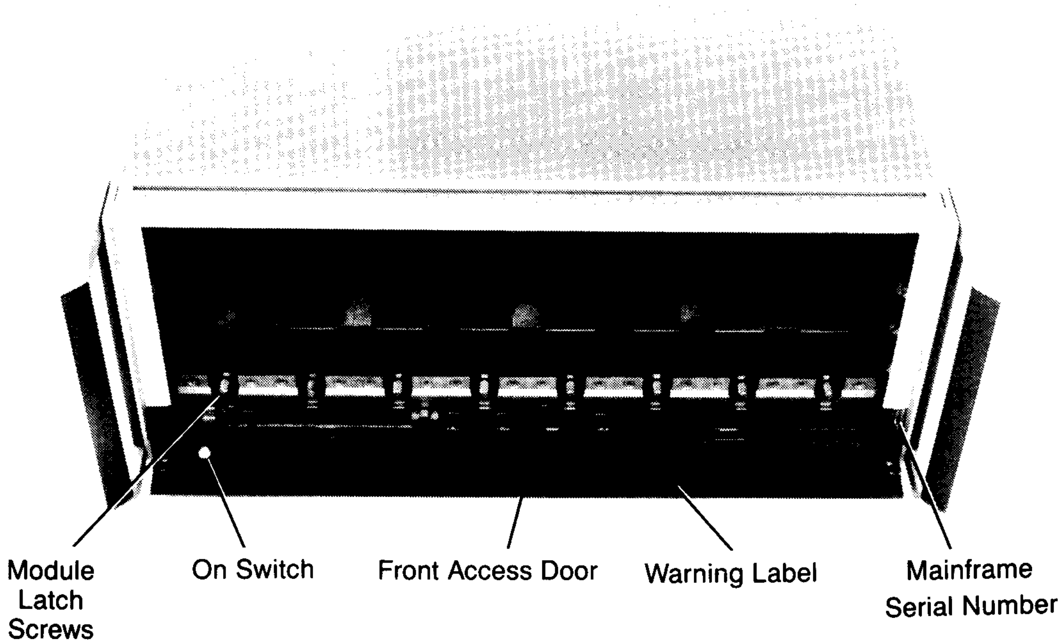


Figure 1.1: HP70001A Front Panel Features.

The mainframe power supply provides each module with regulated 40 kHz AC power. The supply can provide 25 watts per $\frac{1}{8}$ width, only 20 watts of which may be dissipated to the module. Thus, the HP 70001A mainframe supply can provide the modules with a maximum total of $(8 \times 25) = 200$ watts.

The mainframe rear panel (see figure 1.2) provides unimpeded access to module rear panel connections. When the HP 70001A mainframe is standing on end, feet on all four corners of the rear frame protect rear panel features—HP-MSIB connectors (without cables), module interconnecting semi-rigid cables, and the right angle line cord. The rear feet permit manual operation in the vertical position.

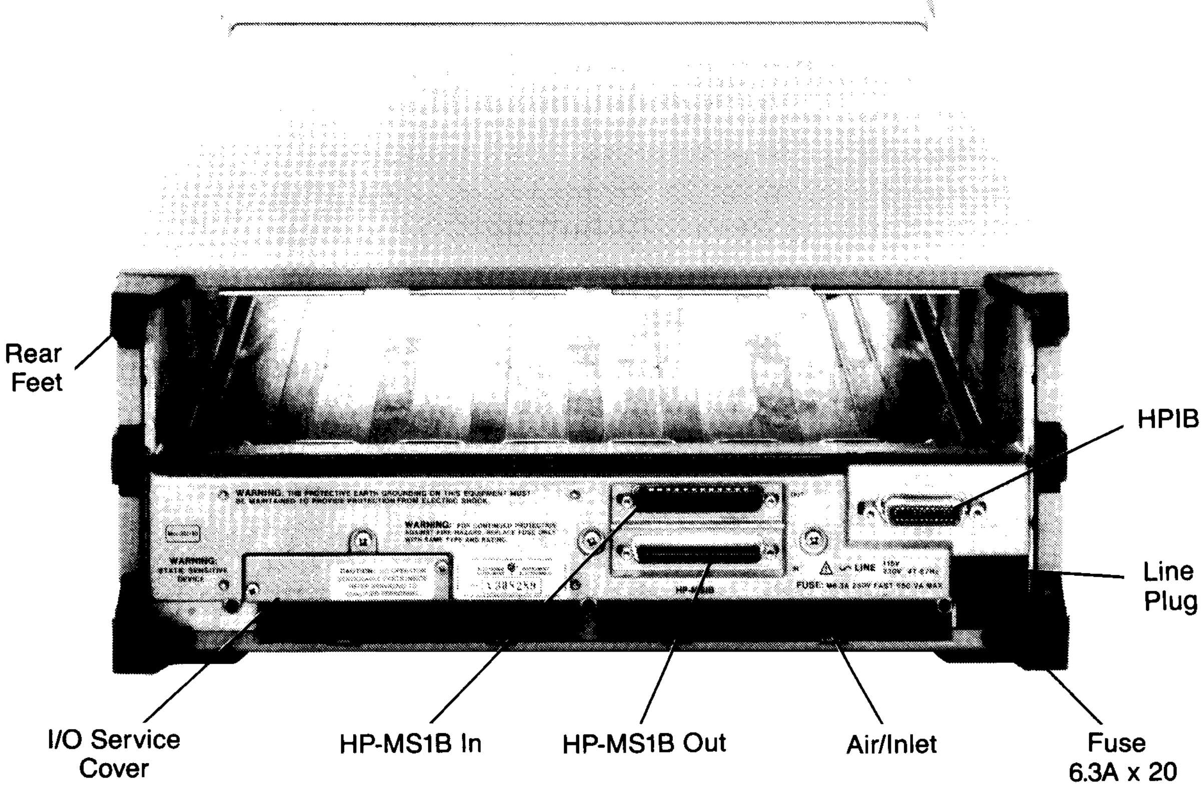


Figure 1.2: Rear Panel Features.

The HP 70001A mainframe provides a mechanical and electrical environment to allow the design of modules that comply with MIL STD 461 radiated and conducted limits. For detailed EMC (electromagnetic compatibility) discussion, refer to the *Electromagnetic Compatibility Design Guide* for the HP 70000 Modular Measurement System (Manual Part Number 5958-6628).

Compatibility Requirements

Because of interaction that may occur in modular systems, designers of HP 70000 modules must consider three classes of compatibility requirements. Throughout this document, the following requirements are boxed and labeled, and they are listed in appendix A.

- **Critical Reliability Requirements:** These requirements must be observed to avoid affecting system reliability. Failure to meet these requirements will invalidate warranties on Hewlett-Packard parts.
- **Measurement Performance Requirements:** These requirements must be observed to maintain the measurement performance of HP 70000 instruments.
- **Product Consistency Requirements:** These requirements define physical and operational attributes to maintain a consistent system design.

Designers should consider the following fourth class of compatibility concerns.

- **Design Recommendation:** This is a strong recommendation because it is an important consideration in module design. A design recommendation is intended to help module designers meet reliability and performance goals.

Hewlett-Packard Parts

The part numbers listed in appendix E are available as component parts for module manufacturers. These parts will be offered with compatible form, fit, and function over their product life. Part numbers other than those listed in appendix E are for reference only.

The kit parts described in chapter 5 provide engineered general usage parts to aid in module development. The kit parts are subject to design changes by Hewlett-Packard. Future enhancements may obsolete some mechanical parts, but it is the intent of Hewlett-Packard to maintain overall system compatibility.

2

Module Electrical Interface

AC Power Specifications

The mainframe AC power supply provides 40 kHz power, regulated to a 24.3 VAC average (*not* RMS) level, to the power supply in each plug-in module. Individual module power supplies permit optimized output voltages and help provide isolation from module-to-module conducted noise. The *Electrical Design Guide* for the Hewlett-Packard 70000 Modular Measurement System, (Manual Part Number 5958-6626) includes detailed power supply specifications. The module limits on the 40 kHz power supply are:

- Power: 25 watts maximum per $\frac{1}{8}$ mainframe width, 100 watts maximum per connector—all four AC power connector pins *must* be used, regardless of module size.
- Dissipation: Modules should dissipate internally a maximum of 20 watts per $\frac{1}{8}$ width. Power in excess of 20 watts should be dissipated external to the module (i.e. active probes, keyboards).
- Protection: Overcurrent protection is a Critical Reliability Requirement.

Critical Reliability Requirement

1 Each module *must* contain dedicated fire protection—fuse or circuit-breaker. This is required because load current conditions damaging to a module may be well below the protective limits of the mainframe.

Digital Bus Interface

The HP 70001A mainframe has available to the designer two digital communication buses: HP-IB, the Hewlett-Packard implementation of IEEE 488, and HP-MSIB, the inter-module communications interface. The module designer must be aware of several important considerations related to the HP-MSIB communications interface (referred to in this manual as the 50-pin module connector). The chapter 3 section titled "50 Pin Module Connector" which begins on page 29 provides a more detailed discussion of the connector.

Module Grounding

The module's mechanical connection to the mainframe serves two functions. It provides a path to the mainframe safety ground for fault currents, and it holds AC signal ground references at a common potential. Module ground connections must be designed, tested, and proven reliable in accordance with the system EMC goals already established. In addition to these EMC goals, there is the following system requirement:

Critical Reliability Requirement

2 The module has a carefully engineered low impedance safety grounding interface. It is a connection from the bottom of the module rear frame casting through the mainframe support pin to the mainframe rear casting, as shown in figure 2.1. This ground connection must be preserved to help ensure operator safety.

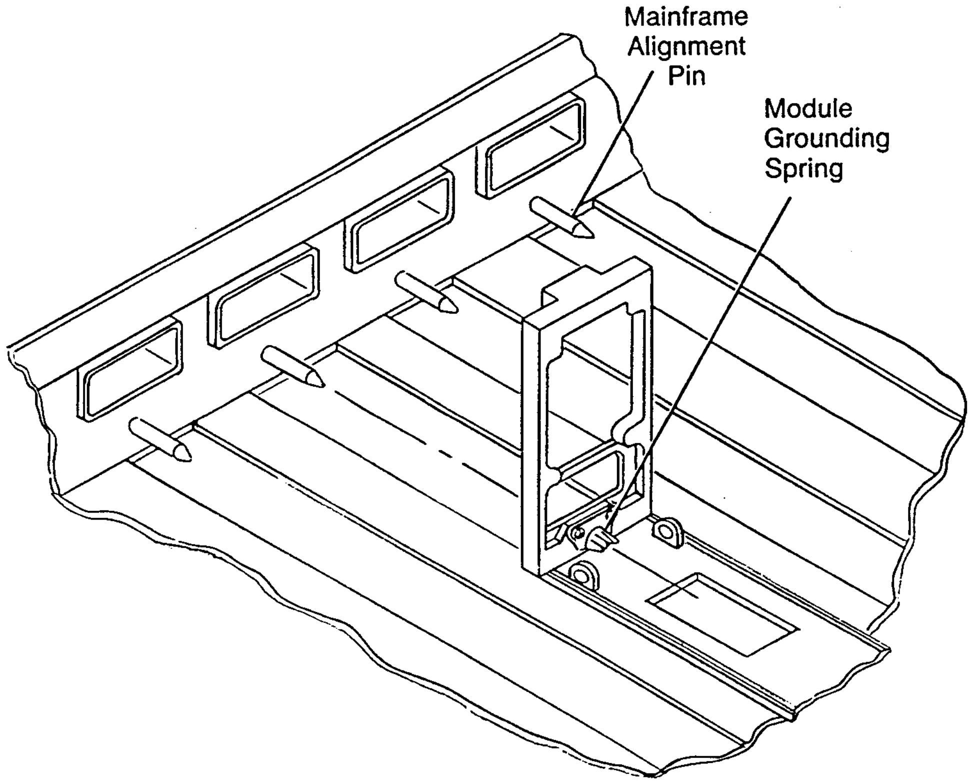


Figure 2.1: Module/Mainframe Safety Ground

Incorporation of this safety ground satisfies requirements set forth in CSA standard C-22.2, number 0.4, *Bonding and Grounding of Electrical Equipment*, paragraph 4.1.2.

There is a second ground connection at the module front frame v-groove/tongue alignment feature (see figure 5.2 page 55), but it cannot be relied upon as a definite safety ground connection, since its electrical resistance depends on latch screw torque (contact pressure).

See chapter 7, EMC Shielding, for additional module to mainframe grounding information.

Electrical and EMC Environments

The HP 70001A mainframe meets VDE B (0871); FTZ 526, 527/1979; and FCC Part 15 Subpart J Class B conducted emissions limits. The mainframe provides an environment that allows modules to pass MIL STD 461, CS01, CS02, CS06, and RE02 radiated and conducted limits. Faulty module design can adversely affect HP 70000 system performance.

The *Electromagnetic Compatibility Design Guide* includes a comprehensive discussion of module EMC specifications and some necessary guidelines for proper electrical and mechanical design.

3

Module Mechanical Interface

Module Envelope and Mechanical Acceptance Criteria

The HP 70001A mainframe module capacity is eight $\frac{1}{8}$ width modules. Four system module sizes are permitted: one, two, three, and four section ($\frac{1}{8}$, $\frac{2}{8}$, $\frac{3}{8}$, and $\frac{4}{8}$ widths).

Design Recommendation

3 The maximum recommended module width is $\frac{3}{8}$. Although $\frac{4}{8}$ modules are allowed, they are not recommended because of special constraints on the guide pin/bushing interface which require thorough engineering evaluation.

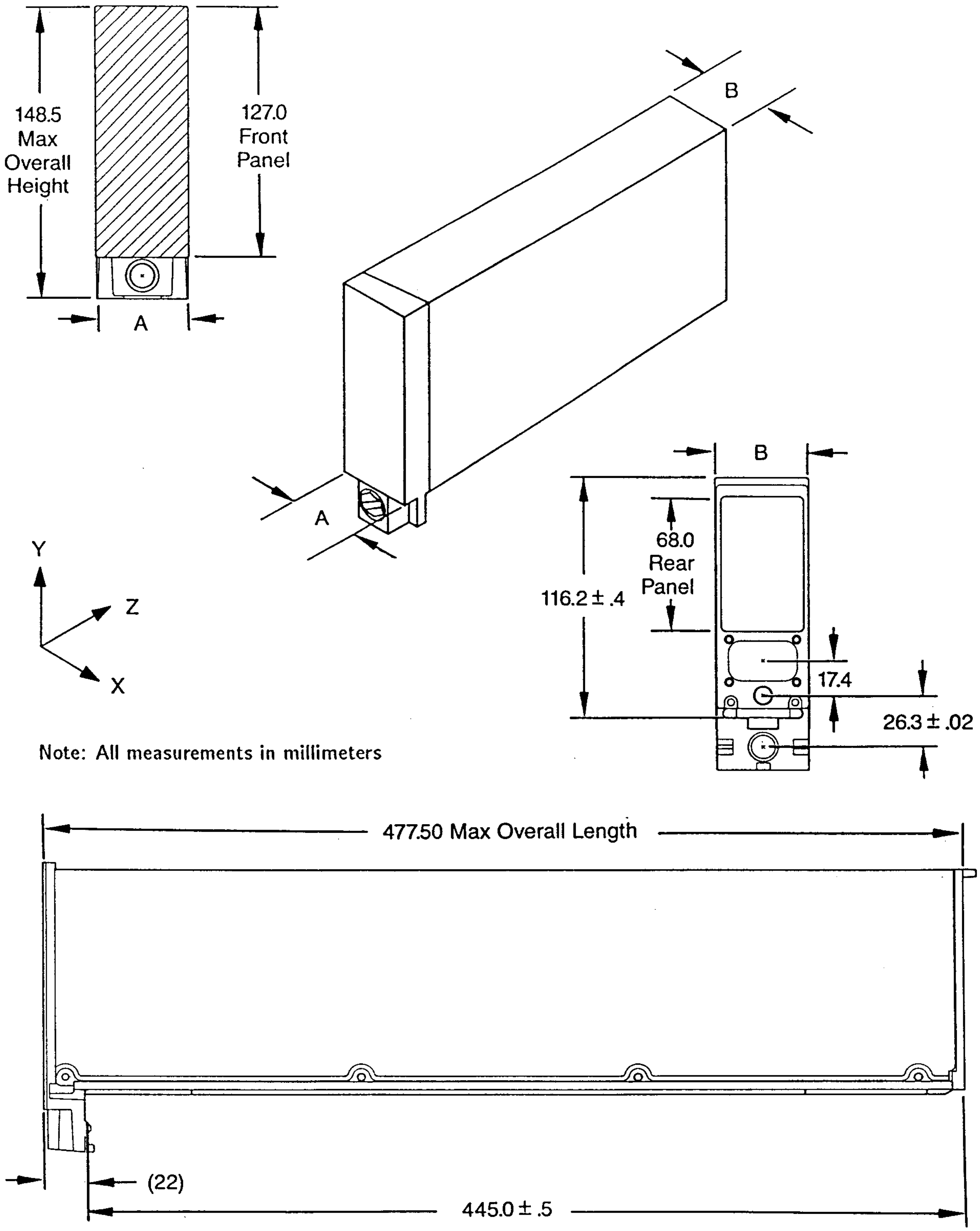
Ensuring a proper fit of any module in any mainframe requires strict adherence to a set of mechanical acceptance criteria, or more precisely, toleranced dimensional restrictions. Figure 3.1 gives the overall dimensions (with tolerances) of the four permitted sizes. Dimensions for the front panel (A) and the rear frame (B) are listed in table 3.1.

Table 3.1: Front Panel & Rear Frame Dimensions

Module Width	Front Panel (± .02) A* (mm)	Rear Frame B* (mm)
1/8	47.6	46.4
2/8	96.0	94.8
3/8	144.4	143.2
4/8	192.8	191.6

*see figure 3.1

For more detail, see appendix F, ERS (external reference specification) drawings HP Part Number 70001-90003-1, sheets one through six. The designer should study the ERS drawings for an understanding of the method and extent of tolerancing, the selection of dimensional datums, the module-to-mainframe nominal clearances, and the details of subassemblies.



Note: All measurements in millimeters

Figure 3.1: Module Envelope and Mechanical Acceptance Criteria

Module Installation/Removal from the Mainframe

Figure 3.2 shows the required guiding features on modules and mainframe. The vertical height of the mainframe guiding feature is 3 mm. The front frame opening size and the module guide entry features prevent incorrect module insertion. Guide rail features provide continuous side to side alignment that is accurate enough to ensure proper mating of the mainframe guide pin and the module guide bushing. Track "jumping" is prevented by vertical constraints and by the full-length guide-rail features on the bottom of both the mainframe and the modules.

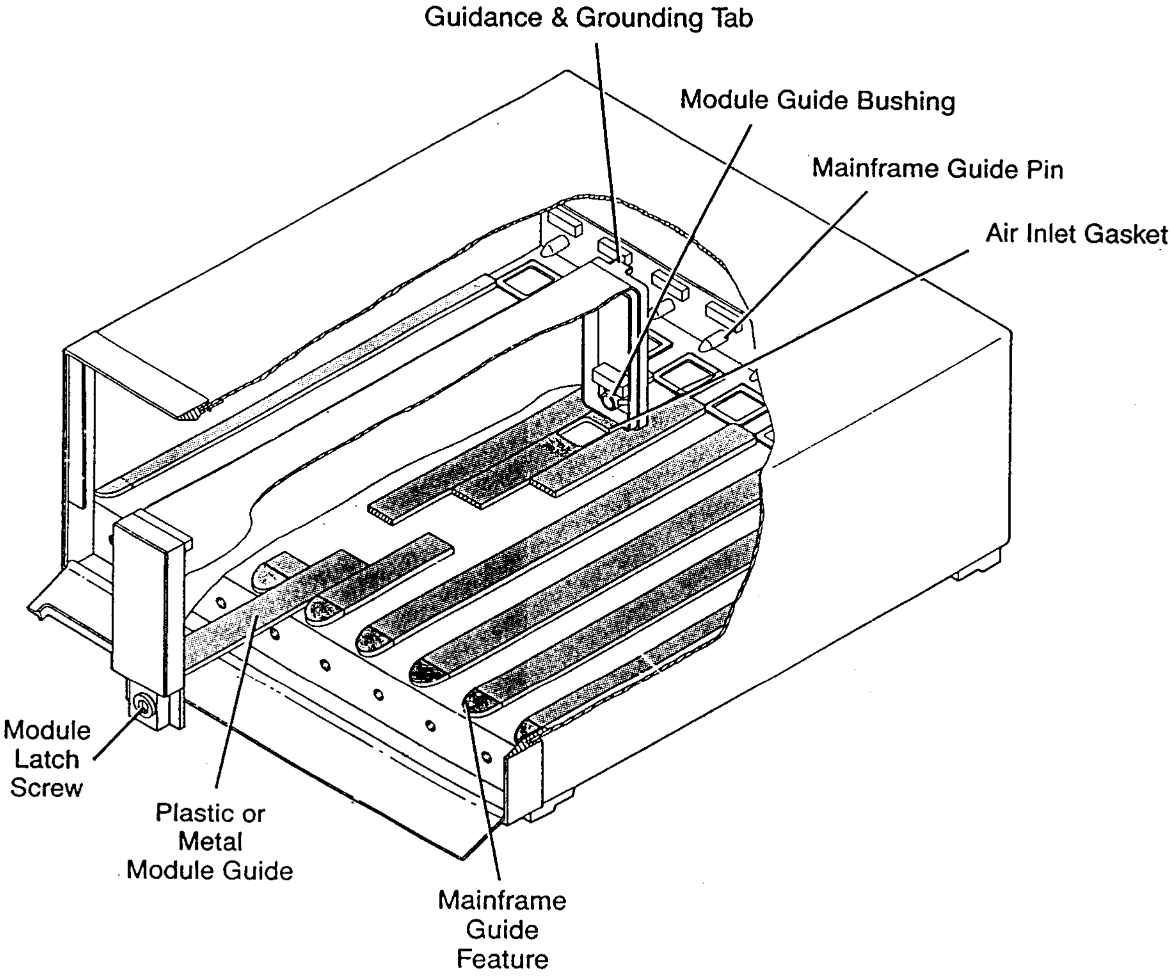


Figure 3.2: Module Guiding Features

To assure a smooth plastic-on-metal riding surface during insertion, there is a raised plastic portion at the back of the module (around the air inlet hole) and a raised plastic piece at the bottom of the mainframe front opening.

Module Latching/Retention

To secure the module in the mainframe, a female latch screw on the module mates with a spring-loaded male latch screw on the mainframe (see figure 3.3). As the user tightens the module latch screw with a $\frac{5}{16}$ inch or 8 mm hex driver (shipped with each mainframe), the mainframe latch screw is pulled forward until it bottoms out. Further tightening pulls the module into the final home position. When the module latch screw is loosened, the module is "jacked" out of the mainframe, thus disengaging the rear 50 pin module connector and providing access to the bottom of the module front frame casting which includes a feature for use as a pull handle.

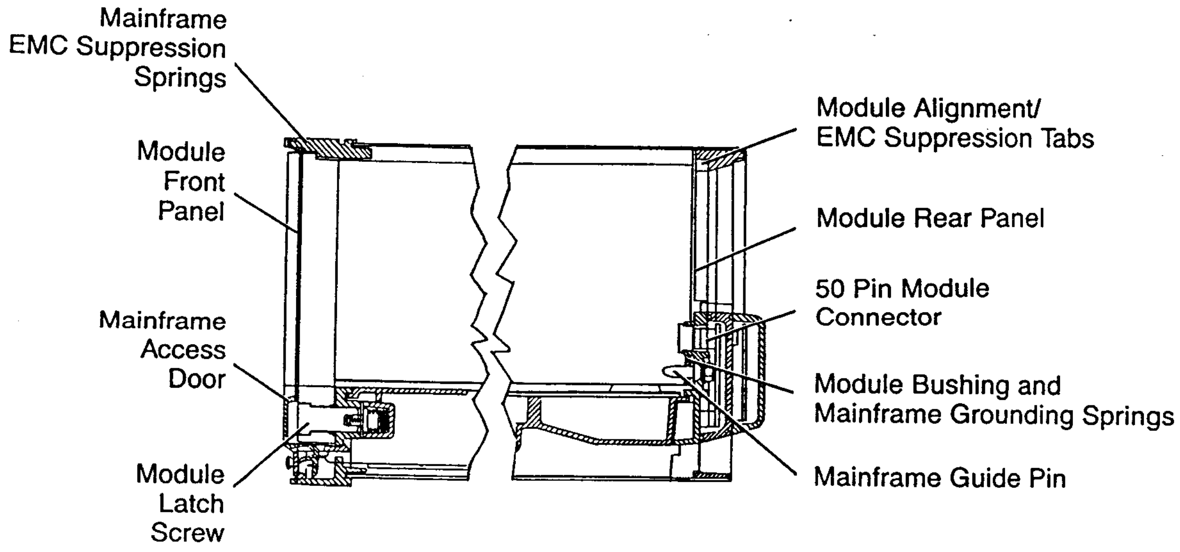


Figure 3.3: Module Latching and Structural Interfaces

Critical Reliability Requirement

4 Only one latch screw per module is allowed. Its position must be consistent with the guidelines shown in figure 3.4.

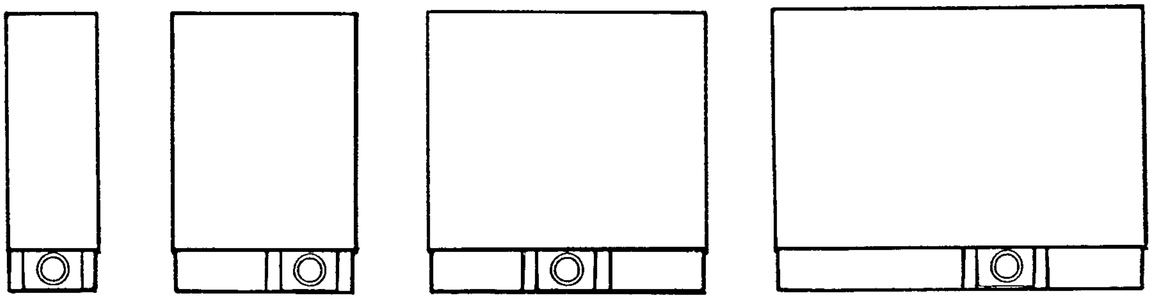


Figure 3.4: Module Latch Placement

The HP 70001A mainframe has an access door covering the latch area. The door will not close unless all module latches are fully engaged, and the system will not power up if the door is not closed. This precaution prevents connector damage that could result from either inserting or removing a module while mainframe power is on.

Module Structural Interfaces

Figure 3.3 illustrates the mainframe's module-supporting structural interfaces, which are designed according to the module mechanical environment specifications (see Structural Environment, page 24).

A tightened latch screw securely clamps the module front frame to the mainframe front frame and provides structural support for the module z-axis (use the x, y, and z axes shown in figure 3.1 as module reference axes). The latch screw also provides alignment references for all module front panels. A tongue on the bottom of the module front frame and an interlocking v-groove on the mainframe front frame work with the module latch screw to achieve x and y alignment of the module front frames. To add x-axis support to the top of the module, there is a module-to-mainframe boss-to-slot interface at the top rear of the two frames.

For additional x-axis and y-axis support and to assure accurate alignment, the mainframe mounted guide pin inserts into the guide bushing at the bottom rear of the module. This feature gives primary alignment to the module and mainframe 50-pin connectors.

A single pin to bushing interface is best, since it results in significantly less clearance between mainframe guide pin and module guide bushing—the key to minimizing vibrational gain (the vibration of a module relative to the vibration of the mainframe).

Measurement Performance Requirements

5 The number of bosses must correspond to the $\frac{1}{8}$ multiple (one boss per $\frac{1}{8}$ width). Only one boss per module is a functional locator; others act as contact points for the mainframe top ground springs.

6 Regardless of module size, only one boss provides alignment, but all bosses contact the mainframe EMC suppression springs. If the shaded areas in figure 5.3, page 56 (the boss surfaces and those areas between the 50-pin connectors) receive a coating, it must be durable, conductive, and compatible with tin (ground springs are tin plated).

Critical Reliability Requirement

7 The following are mandatory rear frame components: 50-pin module connector, guide-pin grounding spring, float hardware, and guide bushing(s). Refer to figure 3.5.

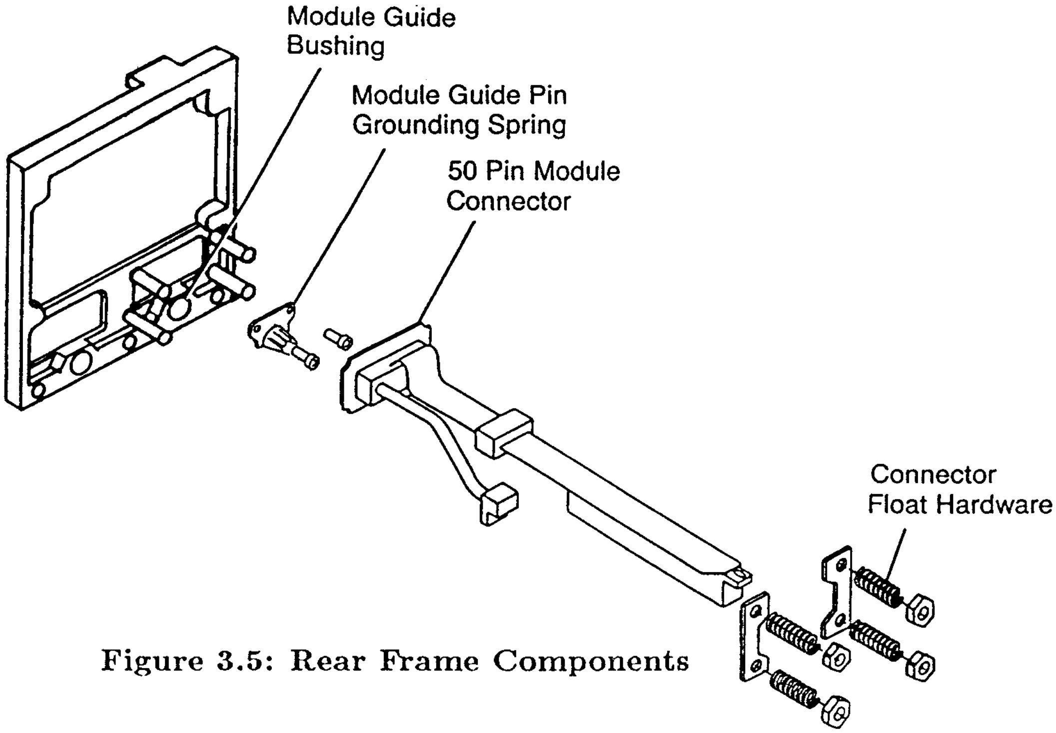


Figure 3.5: Rear Frame Components

Design Recommendation

8 The alignment pin and precision bushing design provides dynamic stability (see figure 3.2). Proper accommodation of weights greater than 5.0 kg (11.0 lbs) requires a second horizontally elongated bushing(see table 3.6).

The second bushing has two functions. It provides additional restraint to vibrational amplification in the y-axis, which experiences the greatest effects of asymmetrical loading or improperly placed masses, and it limits transmission of resonances to the mainframe structure.

Those criteria which affect dynamic performance (i.e. weight, mass distribution, inherent structural integrity of the design) should be carefully tested and optimized early in the development of modules that are $\frac{4}{8}$ width or that weigh 5.0 kg or more. In these cases, two (the maximum) alignment bushings are required. Figure 3.6 shows the required bushing placement, which must be strictly adhered to in accordance with the recommended latch placement described in Module Latching/Retention, page 20.

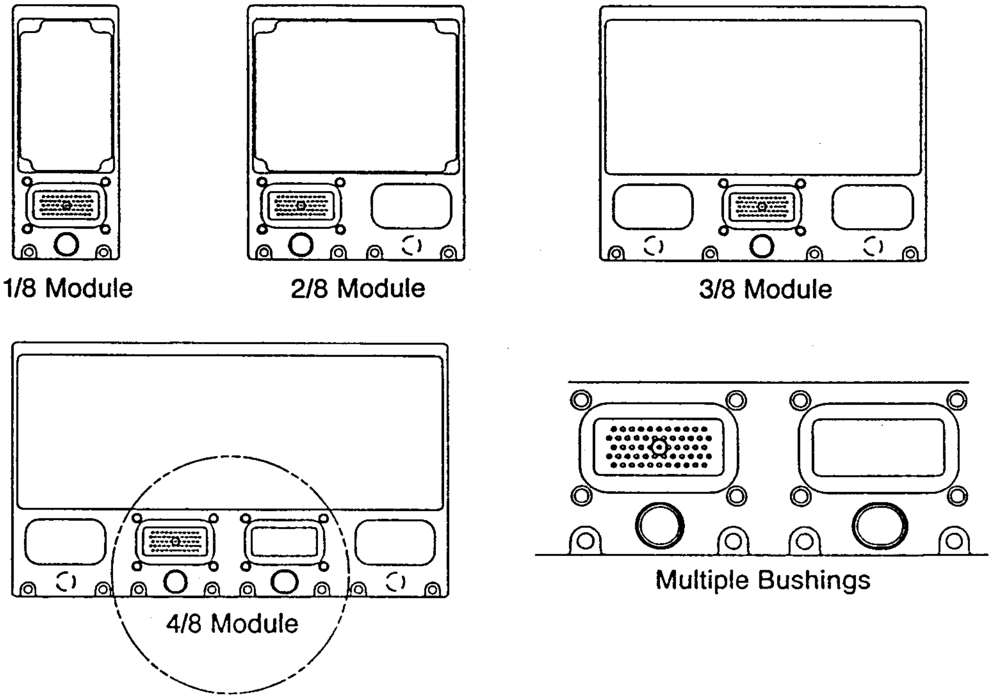


Figure 3.6: Preferred Module Bushing and Connector Placement

The required adjacent placement for guide bushings in modules greater than 5.0 kg reflects the undesirable buildup of manufacturing tolerances over longer distances. The designer must consider all appropriate manufacturing tolerances when incorporating a second guide bushing in a single module.

Structural Environment

The design of the mainframe structure and the module interfaces assures that modules receive minimal gain in vibration or shock relative to inputs to the mainframe. Tables 3.2 and 3.3 and figures 3.7 and 3.8 define the HP 70000 system environment. Table 3.4 shows the environmental limits for shock and vibration that can be experienced by modules as a result of the mainframe design.

In HP 70000 system mainframes, vibration due to the internal cooling is limited by fan vibration specifications and by the fan mounting technique. The overall acceleration limit is 0.5 m/sec^2 RMS (root mean square), measured with an accelerometer and AC voltmeter at any point on the mainframe structure. Tables 3.2 through 3.4 and figures 3.7 and 3.8 indicate the vibration environment a module may encounter.

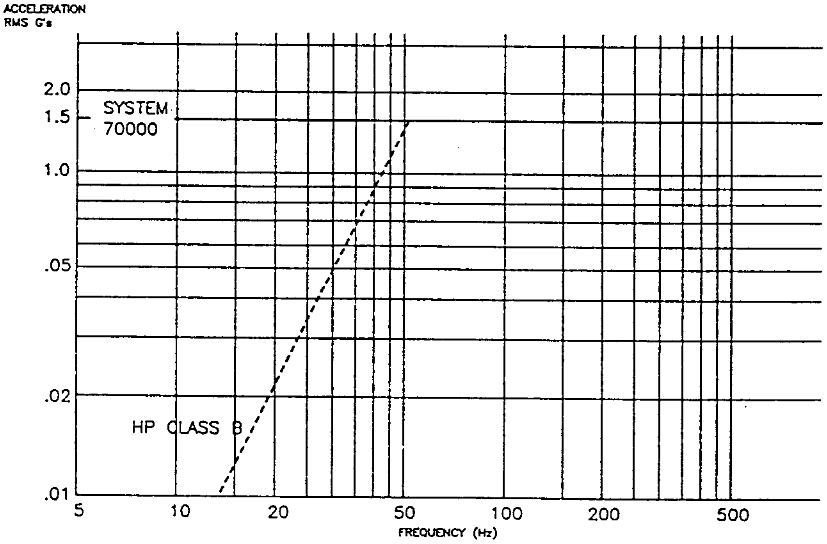


Figure 3.7: Sinusoidal Vibration Environment (Operating Survival)

Table 3.2: Mechanical Environments

Environment	HP 70000 System
Temperature	
Operating	0 to 55°C
Operating Survival	-20 to 65°C
Non-Operating	-40 to 75°C
Humidity	
Operating	5 to 95% RH
Non-Operating	55 C, 90% RH
Altitude	
Operating Temp. at 15,000 ft	55°C
Vibration - Operating Survival	
Rack Mounted	
Sinusoidal Range	5 to 500 Hz
ACC - RMS	1.50 g's
Random Range	20 to 2000 Hz
ACC - RMS	3.2 g's
Cantilever Mounted	
Sinusoidal Range	10 to 500 Hz
ACC - RMS	0.5 g's
Random Range	20 to 2000 Hz
ACC - RMS	1.0 g's
Vibration - Functional (Operate within specs)	
Sinusoidal Range	5 to 2000 Hz
ACC - RMS	0.1 g's RMS
Random Range	5 to 2000 Hz
ACC - RMS	0.5 g's RMS
Shock - Non-Operating	
Rack Mounted and Bench Top	
Pulse Shape	$\frac{1}{2}$ sine
Amplitude	30 g's peak
Duration	11 ms
Number	18

Table 3.3: Transportation Environments

Environment	**HP 70000 System**
Vibration	
Sinusoidal Sweep	
Amplitude, RMS	1.0 g's
Range	5 to 500 Hz
Time	20 min.
Sinusoidal Dwell	
Amplitude, RMS	1.0 g's
Range	at resonances
Time	10 min.
Random	
Amplitude	1.5 g's
Range	5 to 500 Hz
Time	20 min.
Shock (six faces)	
Shape	$\frac{1}{2}$ sine
Magnitude	45 g's
Duration	11 ms.
Drop Test (26 drops)	
Height	30"

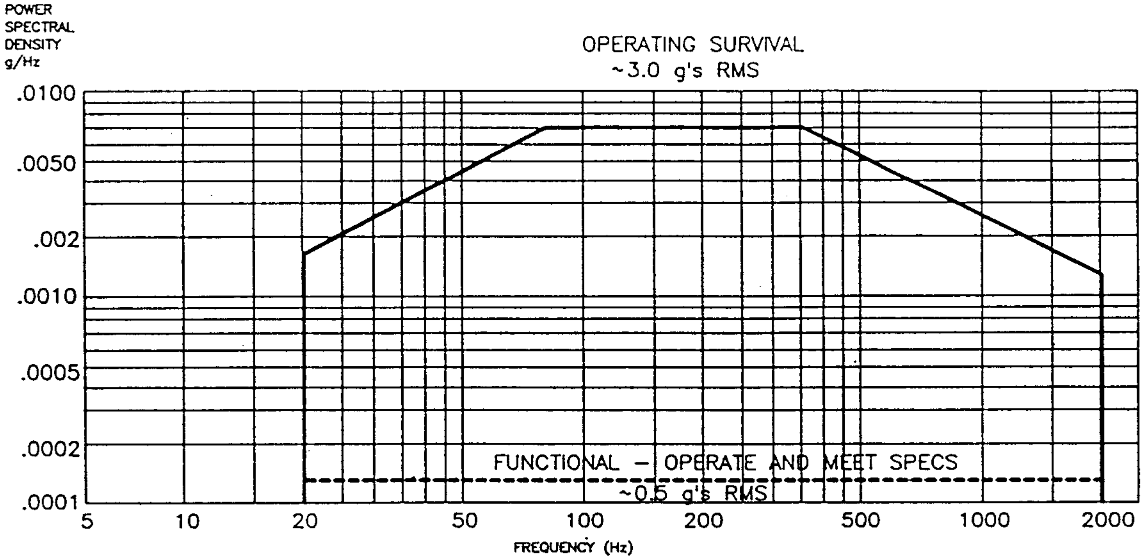


Figure 3.8: Random Vibration Environment (Operating, Survival, & Functional

Table 3.4: Module Structural Environment (Within a Mainframe)

Environment	Limits
Vibration - Operating Survival	
Sinusoidal: 10 to 500 Hz	Gain ≤6 (Acc ≤9 g's)
Random: 20 to 200 Hz	Gain ≤6 (Acc ≤18 g's)
Vibration - Functional (meet specifications)	
Sinusoidal: 5 to 2000 Hz	Gain ≤2 (Acc ≤0.2 g's)
Random: 5 to 2000 Hz	Gain ≤2 (Acc ≤1.0 g's)
Shock	
($\frac{1}{2}$ sine wave)	≤60 g's peak 6 ms

Module Weight Constraints

The design considerations discussed in this section affect static and dynamic performance of individual modules and of the mainframe.

Table 3.5, page 28, lists maximum module weights. Figure 3.3, page 20, shows suggested placement of the pin to bushing interface and the rear panel connector.

Critical Reliability Requirement

9 Two bushings are required for modules heavier than 5.0 kg, and are recommended for all $\frac{4}{8}$ width modules.

Adhering to these suggestions will optimize integral stabilization of the locating and retention systems.

Table 3.5: Maximum Allowable Module Weights

Width	Weight
one section	2.5 kg (5.5 lbs)
two section	5.0 kg (11.0 lbs)
three section	6.0 kg (13.2 lbs)*
four section	8.0 kg (17.6 lbs)*

* Requires special module design consideration for the rear structural pin interface for modules exceeding 5 kg. See Critical Reliability Requirement number 9.

When placing weight concentration within the module, the designer should also consider position of the latch screw (see figure 3.4, page 21) and proper placement of 50 pin module connector (see figure 3.6, page 23).

Design Recommendation

10 Centroids of large mass should be as low as possible in the y-axis and as close as possible to the front of the module in the z-axis. (See figure 3.1).

The weight-constraint limits listed in table 3.5 help reduce the upper limit of potential vibratory gain seen in a module, thus improving structural integrity in dynamic vibratory modes. The direct benefits are increased pin to bushing longevity, reduced cyclic loading [fatigue] on the 50-pin connector, and reduced level of vibration transmitted to sensitive components (i.e. quartz crystals, oscillators, etc.).

The instrumentation of the HP 70000 system is qualified to operate within defined environments (see table 3.2, page 25). Noncompliance with the module weight limits set forth in this manual may adversely affect the performance of both the module and the HP 70000 system.

50-Pin Module Connector

Description

The 50-pin module connector provides access to 40 kHz power, line sync, and the HP 70000 system communication buses—HP-IB and HP-MSIB. There are five rows of connector pins encased in a metal shell. The overall structure has excellent blind mating features and proven reliability. Figure 3.9 shows the connector.

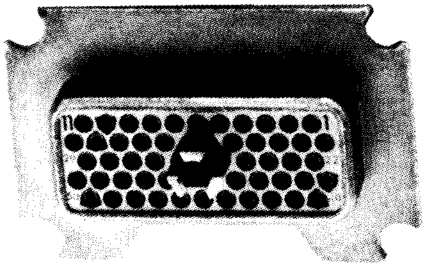


Figure 3.9: The HP 70000 50-pin Module Connector

A metallic shield across the face of the connector is part of the ESD (electrostatic discharge) protection system used to protect against possible damage caused by static discharge.

Figure 3.10 illustrates the connector pin assignments. Refer to appendix B for more complete connector electrical specification. Table 3.6 provides a summary of pin electrical functions. Available pins utilized as returns provide a controlled low impedance return path, thus helping to reduce radiated emissions.

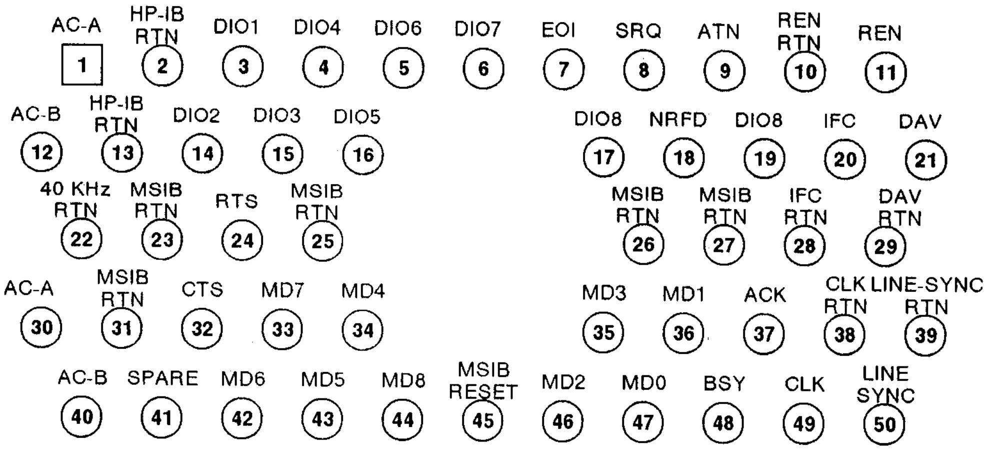


Figure 3.10: 50-pin Module Connector (View of Mating Face on Mainframe)

Table 3.6: 50-pin Module Connector

Functions	Pin Quantity
AC-A (in)	2
AC-B (out)	2
AC RTN	1
Line Sync	2
GND (chassis)	1
HP-IB	16 + 5 returns
HP-MSIB	15 + 7 returns

Design Recommendation

11 To prevent interaction, the HP-MSIB and HP-IB signal lines should be independently shielded within the module. (The 50-pin connector and cable assembly in figure 3.11, page 32, conforms to this requirement.)

Refer to the *Electromagnetic Compatibility Design Guide* and the *Electrical Design Guide* for comprehensive coverage of signal shielding.

The pin module connector assignments are shown in figure 3.10. In addition to these required assignments, the designer must understand certain electrical aspects of this connector interface.

Critical Reliability Requirement

12 In particular, LINE SYNC RETURN *must not* connect directly to ground in any module.

For a theoretical discussion of LINE SYNC and the associated optocoupler circuit, refer to the *Electrical Design Guide.*

All module connector pins should be present to guarantee a uniform mating force between the module connector and the mainframe connector. The connector manufacturer recommends uniform mating force since the connector is designed to float in the module rear frame.

Critical Reliability Requirement

13 The 50-pin module connectors are to mate only with similar connectors as specified in this manual.

Connector Float

To allow for mainframe and module positional and length tolerances, the 50-pin connector floats in the x, y, and z-axes. The z-axis connector float also helps to prevent fretting corrosion, which can result from small relative movements between two rigidly mounted connectors. The module connector is spring loaded in the z-axis to assure full engagement while allowing the z-axis float.

The following sequence provides alignment of the module and mainframe connectors:

1. The interface between the mainframe guide pin and the module guide bushing aligns the module accurately enough to allow interfacing of the tapered end of the mainframe connector alignment pin and the module connector polarizing key.
2. The connector alignment pin closely aligns the the two connector shells so that the lead-in on the polarizing keys can pull the connectors into the final alignment position.

The float on the module connector guarantees that neither the male nor female connector of the mated connector pair will carry any structural loads and that the connectors will always be fully engaged.

The 50-pin module connectors will withstand a minimum 500 cycles of insertion and still operate reliably in the environments defined in Structural Environment, page 24.

Recommended Placement

Design Recommendation

14 One 50-pin module connector per module is recommended. The use of two or more connectors is discouraged due to the risk of connector mismating or connector damage. All module sizes currently supported by Hewlett-Packard contain only one 50-pin module connector.

Figure 3.6, page 23, shows the recommended placement of the module bushing(s). Note the elongated guide bushing on $\frac{4}{8}$ modules. The elongated bushing compensates for manufacturing tolerances of two-pin/two-bushing alignment.

Available Styles

The HP 70001A system proprietary 50-pin module connector is available either assembled or unassembled. All versions use the floating hardware described under 50-Pin Module Connector, page 29.

Assembled Module Connector This version is the specified connector for the HP 70000 development kits discussed in chapter 5. It incorporates both a flex circuit terminated to a 50-pin header (printed circuit board connector) and a five pin shielded power cable terminated with a connector. The two connectors and the header are strain relieved. A ferrite core choke helps reduce radiated emissions from HP-MSIB and HPIB signals. Figure 3.11 shows this configuration. The schematic and pin designations from the assembled 50-pin module connector cable are shown in detail in figure B.2.

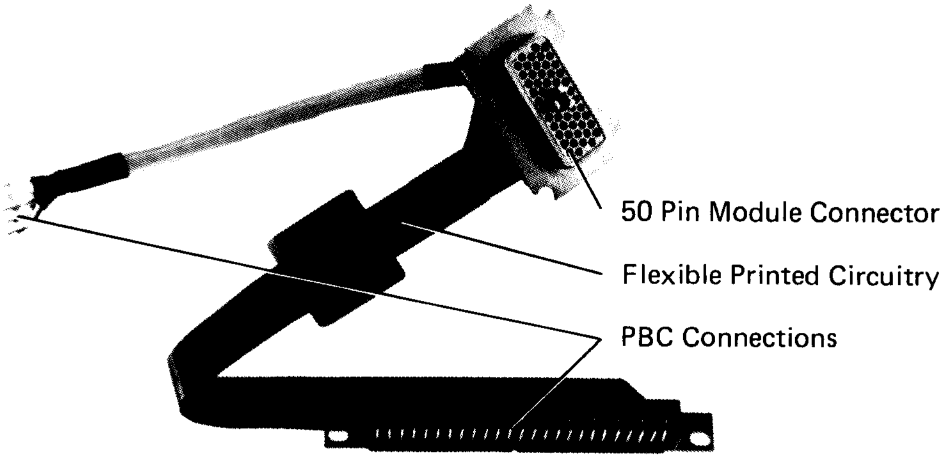


Figure 3.11: Assembled 50-pin Module Connector (HP Part Number 70000-60001)

Unassembled Module Connector Unassembled or partially assembled versions allow custom wiring configurations. Connector contacts are available in either solder or crimp termination, thus allowing a choice in assembly methods. Appendix E lists part numbers for contact parts and tools. Custom wiring configurations should allow for various module and HP 70000 system requirements as defined in the *Electromagnetic Compatibility Design Guide* and in the *Electrical Design Guide.*

The mainframe half of the 50-pin connector (the male half) is also available in either solder or crimp terminating contacts. Appendix E lists the part numbers.

Extender (Test) Module

The HP-70000 system extender module facilitates bench top operation and diagnosis of a module. A shielded cable routed through a plug-in module housing provides a 150 mm I/O extension. Figure 3.12 shows the extender module. The female connector, on the free end of the extender cable, replicates the HP-MSIB connector interface.

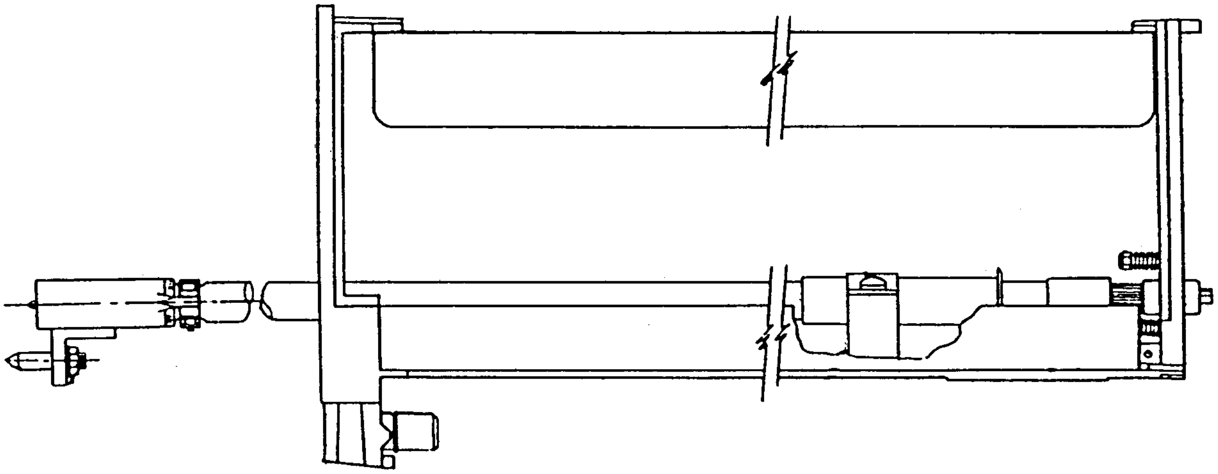


Figure 3.12: Extender Module

The extender is available only as an assembled unit, Hewlett-Packard Part Number 70001-60013. Extender features are those outlined in this manual as necessary for interchangeability and system performance (i.e. 25A safety ground around the module guide bushing, floating 50-pin module connector, grounding surfaces on front and rear frames, standard latch screw assembly). The extender cable is shielded and cable grounds are maintained, but degradation of EMC performance is to be expected when the module is operating outside of the mainframe environment.

A module operating on the extender cable does not receive forced air cooling; convective heat transfer supplies the only significant cooling action. Therefore, bench top operation on an extender cable should be without covers and in ambient temperatures not exceeding 30°C. See Module Operating Environments, page 35.

Module Back Panel Access

Figure 3.1 gives approximate dimensions of rear panel space accessible to the user and available to the designer. Guidelines in chapter 6, Industrial Design, aid in consistent rear panel layout and inter-module semi-rigid cabling. Figure 3.13 shows maximum allowable protrusion from the rear panel.

When mainframe is operating in the vertical position, the rear feet protect cables and the line cord.

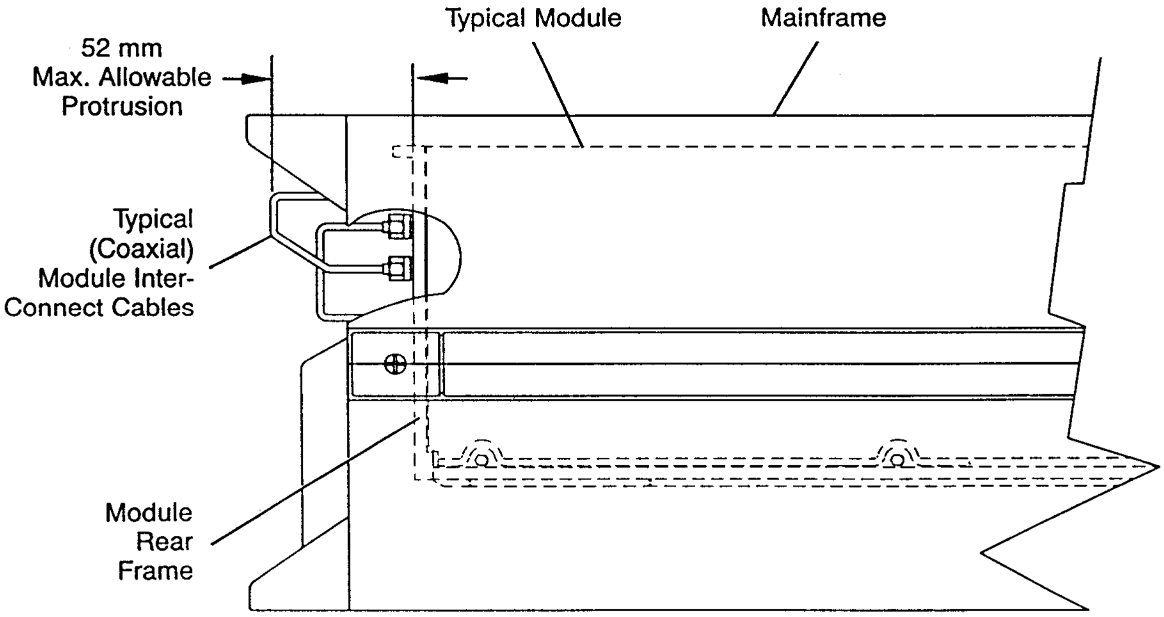


Figure 3.13: Allowable Rear Panel Protrusion

4

Airflow/Thermal Management

Cooling System Overview

The mainframe cooling system supplies cooling air to the modules. The HP 70001A mainframe cools both the integral mainframe power supply and the modules. Figure 4.1 illustrates the airflow path through the HP 70001A and the modules. The airflow volume and relatively high allowable operating back pressure (.065 inches H_2O) of the fan permit flexibility in packaging techniques.

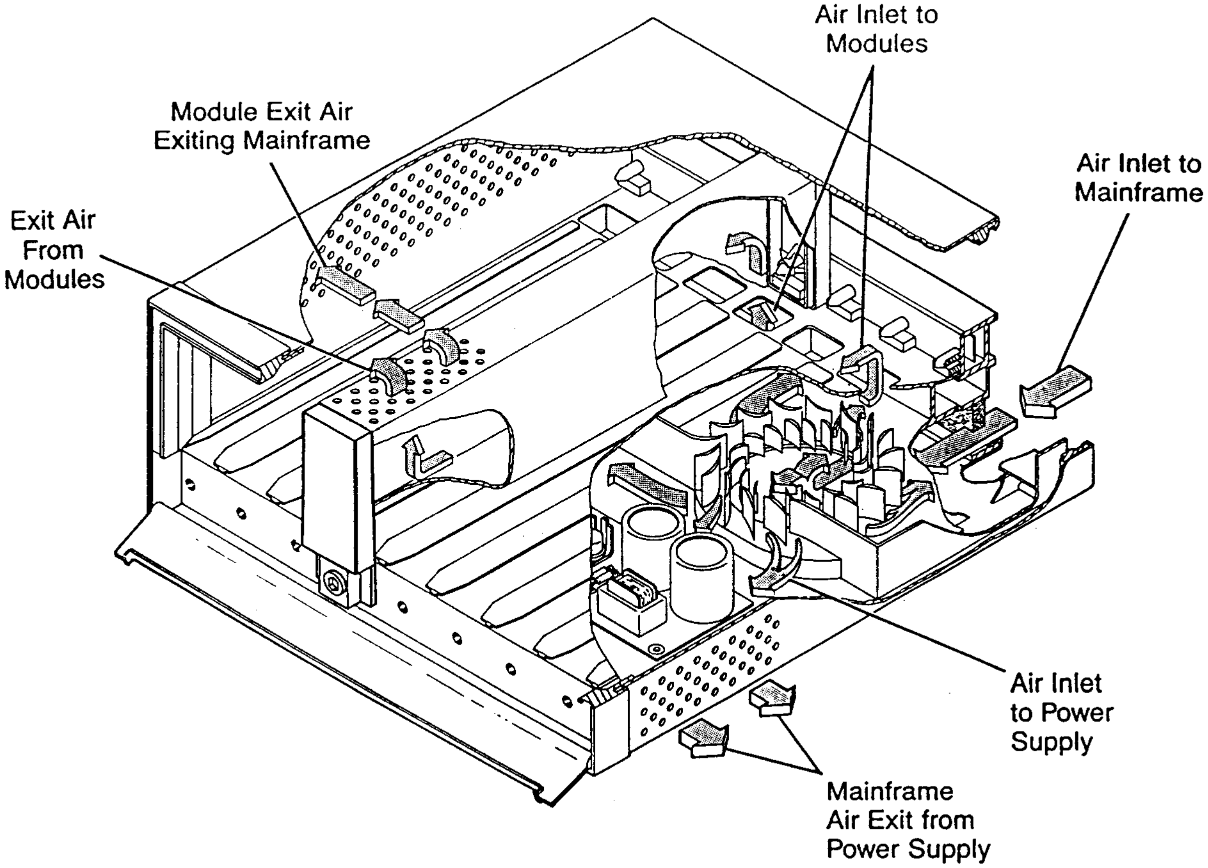
On the HP 70001A, the locations of air inlet and exit areas on the module and the mainframe are compatible with both bench top and rack applications. The air inlet area on the mainframe rear panel allows the cooling system to pull air from the rear section of a rack, which is often pressurized by a rack fan. The air passes through the modules from back-to-front and bottom-to-top (see figure 4.1), then out the sides of the mainframe, thus allowing the cooling system to exit the air in the low pressure chimneys along each side of the rack.

NOTE

Future mainframe versions may have different air delivery systems, but all will deliver the airflow as outlined in the Operating Environment section of this chapter.

Module Operating Environments

At full fan speed, regardless of the number of vacant $\frac{1}{8}$ width slots, the HP 70001A mainframe will supply a minimum 3.5 cfm per $\frac{1}{8}$ width.



The air is drawn in at the rear panel into one of two fan inlets. Then the air is forced through an air plenum to the inlet area beneath the modules, into the module air inlets at the rear of the modules, through the module, across the module's top surface, through the mainframe air plenum, and out the mainframe's side covers.

Figure 4.1: HP 70001A Mainframe Cooling System

Design Recommendation

15 At a flow rate of 3.5 cfm, the module flow resistance should be no greater than 0.065 inches H^2O. That is,

$$\Delta P \leq .065 \text{ inches } H_2O \ @ \ 3.5 \text{ cfm per } \frac{1}{8} \text{ module @ STP}$$

$$\text{or} \leq 16.2 \text{ Pa } @ \ 5.95 \ m^3/h \text{ per } \frac{1}{8} \text{ module @ STP.}$$

where, ΔP = intake pressure − exhaust pressure,
Pa = pascal, the si (international system of units) term for pressure expressed in Newtons/meter^2,
STP = standard temperature and pressure.

This airflow is assured by the operating characteristics of the cooling fans and the "tuned" exit ports on the mainframe.

1. When the HP 70001 system fan is operating at full speed
   - Normal Operating Temperature range is $T_{AMBIENT} = 0$ to +55°C and
   - Absolute Maximum Temperature range is $T_{AMBIENT} = -20$ to +65°C. Modules may not meet specifications when operating outside of the normal temperature range. The HP 70000 mainframe power supply shuts down at temperatures above 70°C
2. Without airflow (bench top operation with covers off)
   - Normal Functioning Range is $T_{AMB} \leq +30$°C. Within this ambient temperature, a module on an extender and with covers off should operate indefinitely without airflow.

The above are operational environments; the designer is accountable for managing the internal temperature rise of his/her module design. Additionally, exceeding these guidelines can result in an increased surface temperature adversely affecting thermal performance of other modules in the system.

Module Cooling Guidelines

Given the operating environments of the last section, effective cooling requires consideration of at least four mechanical design factors. They are:

1. air exit holes in module covers,
2. preferred printed circuit board orientation,
3. temperature rise and airflow, and
4. thermal measurements

and are discussed in the subsections that follow.

Air Exit Holes in Module Covers

Refer to figure 4.1. Individual component packaging design determines placement of air exit ports, which should conform to requirements set forth in figure 4.2. The figure indicates mainframe RFI spring wiping areas (zones) on the top and sides of the cover.

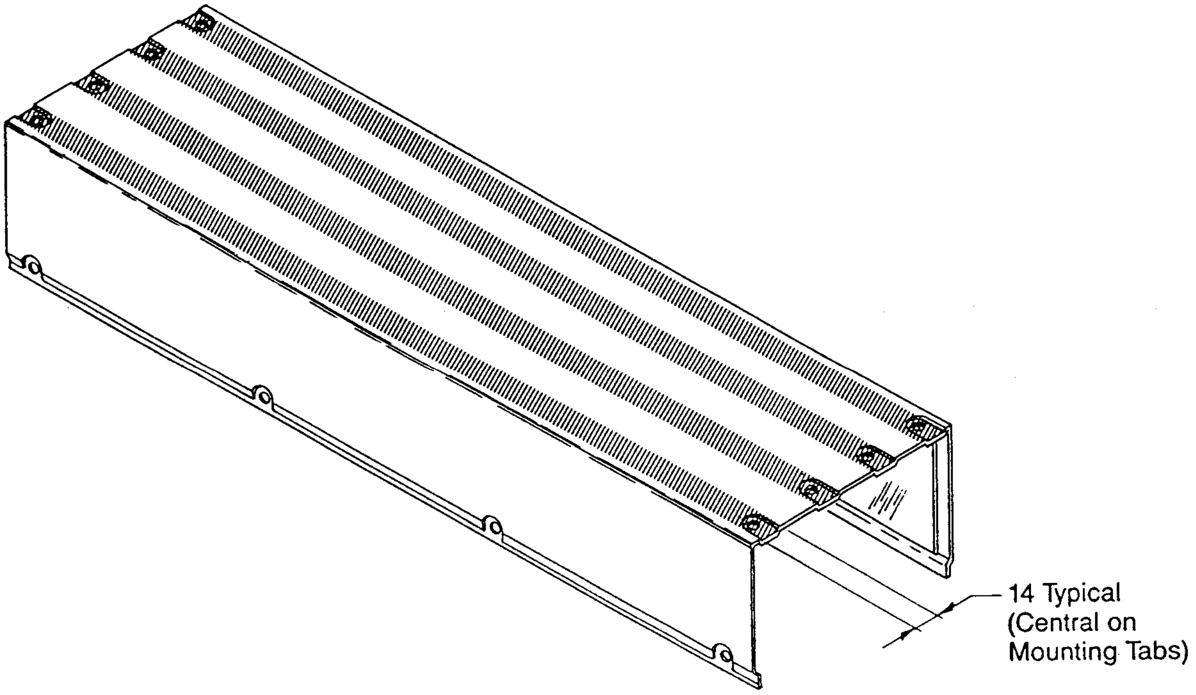


Figure 4.2: Module Cover with Typical Restriction Zones for Air Exit Ports.

Design Recommendation

16 To guarantee that repeated module removal and replacement will not damage the EMI suppression springs (see figure 3.3), the zones indicated in figure 4.2 must be free of upsets, screen printing, and perforations larger than 4.0 mm diameter.

17 Air exit ports should be located on the top of the module cover, near the front, to take advantage of natural convective currents. Air exit ports on the sides of modules are not recommended because of possible adverse heating of adjacent modules.

To allow unrestricted exhaust of heated air, total area of the exit ports should be approximately two times the inlet area (always verify compliance with maximum allowable back pressure). Optimal packaging locates thermally critical components close to but not impeding the air inlet; this practice minimizes the effects of the cooling air's thermal gradients (rise in temperature between inlet and outlet). Some standard guidelines help minimize the effects of these thermal gradients:

- Maximize air velocity over components. Velocity is the key to effective forced convective cooling.
- Use components with low power dissipation and/or lowest $\Theta_j a$ (thermal resistance between junction temperature and ambient temperature).
- Locate critical components close to an air inlet and down low because cooling air temperature increases as it flows over components. Using natural convection as the primary cooling method will amplify this effect.
- Minimize air velocity everywhere else (big flow areas).
- Coat the inside of the module cover with a high emissivity coating. (This can reduce component case temperature by up to 4°C.)
- If necessary, mount components on heat sinks to increase effective surface area, thus reducing $\Theta_j a$.

Preferred Printed Circuit Board Orientation:

Vertical printed circuit boards promote efficient convective cooling and also help reduce the effects of condensation, which can occur in some extremely humid environments.

Design Recommendation

18 For optimal cooling, vertical printed circuit board orientation is recommended (see figure 4.3).

HP 70000 design kits provide for use of a horizontal motherboard attached at relieved bosses on the module base. This allows use of vertical daughter boards or a combination of vertical boards and microelectronics packages.

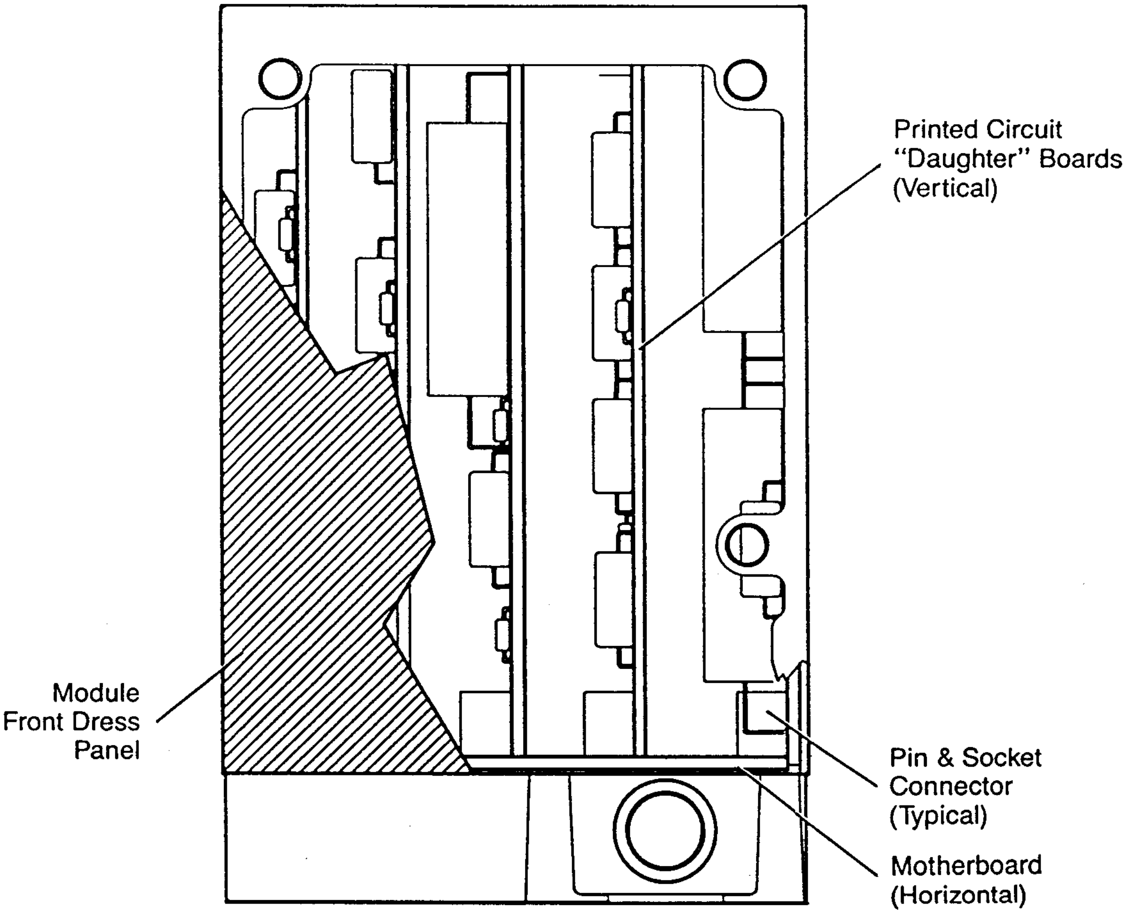


Figure 4.3: Suggested Printed Circuit Board Orientation for Optimal Cooling

Temperature Rise and Airflow:

Bulk air temperature rise is an important factor because it affects all modules, but the major concern is discrete component junction temperature. Component manufacturers often supply information relating case temperatures, T_c, and junction temperature, T_j. In the early stages of layout design, data from this relationship can help avoid thermally overstressed components, which are probably the single most important contributors to reliability problems in electronic devices. Circuit performance and long term circuit reliability are affected significantly by die temperature. Normally, both are improved by keeping the integrated circuit junction temperatures low.

Electrical power dissipated in any integrated circuit is a source of heat. This heat increases the temperature of the die relative to some reference point, normally an ambient temperature of 25°C in still air. The temperature increase depends on the amount of power dissipated in the circuit and on the net thermal resistance between the heat source and the reference point.

Junction temperature is a function of the ability of the package and the mounting system to remove heat generated in the circuit. Two basic formulas for converting power dissipation to estimated junction temperature are:

$$\begin{aligned} T_J &= T_A + P_D(\overline{\theta}_{JC} + \overline{\theta}_{CA}) \\ T_J &= T_A + P_D(\overline{\theta}_{JA}) \end{aligned}$$

where T_J = maximum junction temperature,
T_A = maximum ambient temperature,
P_D = calculated maximum power dissipation with effects of external load,
$\overline{\theta}_{JC}$ = average thermal resistance, junction to case,
$\overline{\theta}_{CA}$ = average thermal resistance, case to ambient,
$\overline{\theta}_{JA}$ = average thermal resistance, junction to ambient,
$\overline{\theta}_{JA} = \overline{\theta}_{JC} + \overline{\theta}_{CA}$.

The user can vary only two terms on the right side of the first equation—the ambient temperature and the device case to ambient thermal resistance, $\overline{\theta}_{CA}$. Table 4.1 shows typical thermal data used to establish component junction temperature, $\overline{\theta}_{JC}$. Appendix B provides integrated circuit derating information.

Thermal Measurements

Accurate definition of a module's thermal performance typically comes from four types of measurements:

1. Temperature,
2. Temperature distribution,
3. Airflow rate, and
4. Air pressure.

Table 4.1: Typical Thermal Data

Package Type	Θ_{JC} (°C/W)	Θ_{JA}(Still Air) (°C/W)	Θ_{JA}300 Ft/Min Air) (°C/W)
24-Lead Dip			
Ceramic	15 to 20	45 to 55[1]	30 to 40
Plastic		80 to 100	60 to 70
40-Lead Dip			
Ceramic	12 to 17	40 to 50[1]	25 to 35
Plastic		40 to 60	30 to 40
68-Lead Plastic Chip Carrier			
J-Bend		35 to 40[1]	25 to 30
Ceramic Pin-Grid Array			
(Cavity Up)			
100 to 144 Leads	6 to 10	20 to 25[2]	15 to 20
Ceramic Pin-Grid Array			
(Cavity Down)			
155 Leads	3 to 6	15 to 20[3]	10 to 15
299 Leads	3 to 6	10 to 15[3]	6 to 10
Plastic Pin-Grid Array			
(Cavity Up)			
100 to 144 Leads	8 to 12	25 to 30[3]	20 to 25

1. Die Size is 200 MIL^2
2. Die Size is 380 MIL^2
3. Die Size is 573 MIL^2

A variety of measurement methods are available to provide data about temperature and temperature distribution:

- Thermal transducers (thermocouples)

  Thermal transducers can monitor temperature rise on specific components or in particular areas. This technique produces quick, accurate, useful results. To optimize thermocouple placement, the designer should refer to component data sheets for thermal limitations and power dissipation information. Proper use of thermocouples is imperative to assure accurate results. Figure 4.4 shows suggested mounting methods for thermocouples.
- Thermistors

  Thermistors are semiconductor devices whose electrical resistance decreases as temperature increases. They can thus detect temperature differentials.
- RTD (resistive thermal device)
- Bulb thermometer
- Temperature sensitive crayons, paints, and labels
- Liquid crystals
- Infrared thermometers and imagers

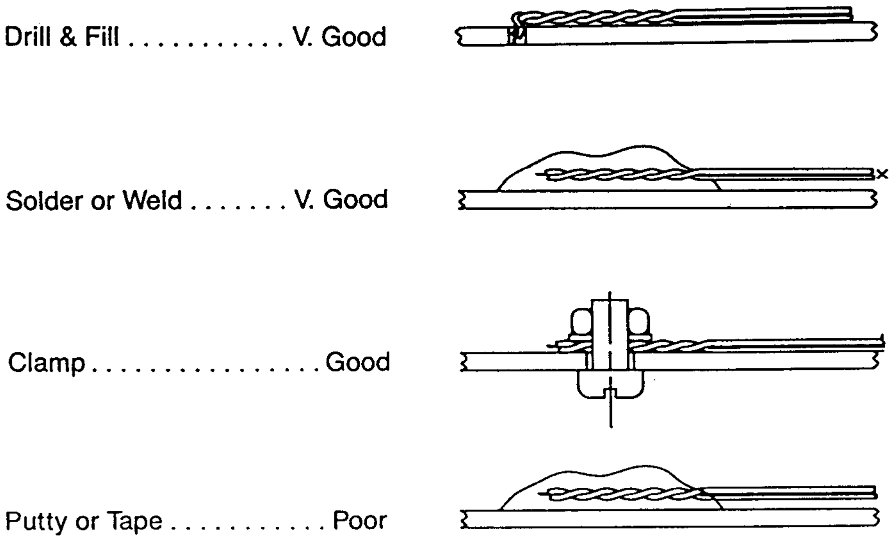


Figure 4.4: Mounting Methods for Thermocouples

Airflow and air pressure measurements will identify problems with interior density as well as flow stagnation areas. A calibrated flow chamber (see figure 4.5) allows complete characterization of the module and produces a graphical comparison between airflow and back pressure (pressure drop). The characterization data is useful in computations of system airflow capabilities.

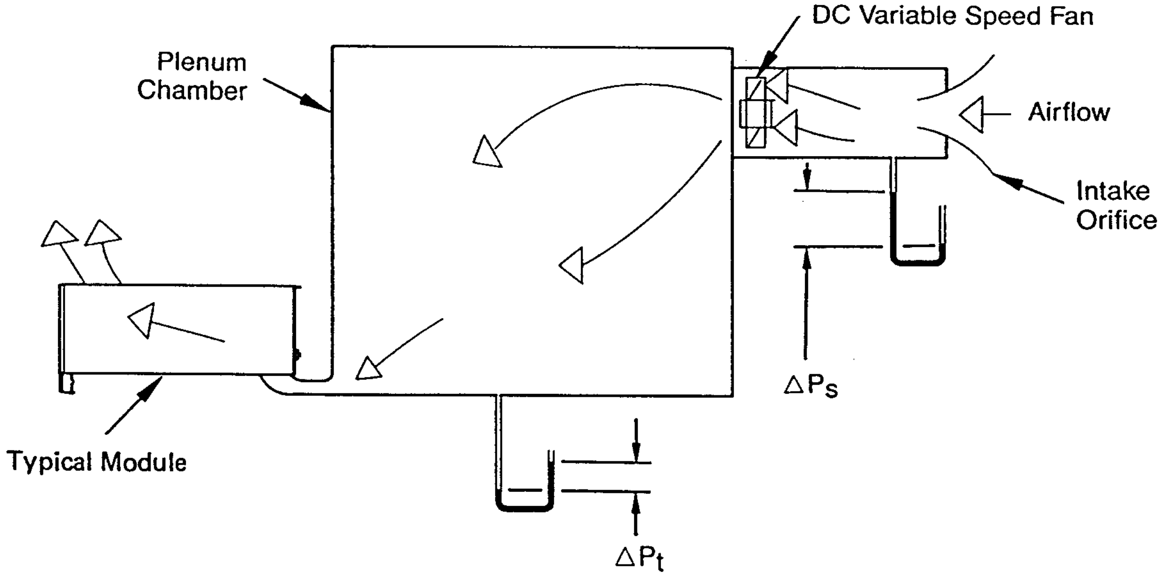


Figure 4.5: Calibrated Flow Chamber

Bench top methods of air measurement are also useful:

- Air pressure
  1. Water manometer
  2. Water manometer with pitot tube
- Air velocity: the following methods detect direction and magnitude of airflow.
  1. Vane anemometer
  2. Hot wire anemometer
- Air Directionality
  1. Yarn on a Q-tip will often provide useful relative data on airflow magnitude and directions.

A Thermal Management Primer

The management and removal of heat from a module or any other containment requires a blend of thermodynamic theory, common sense, and analysis (testing). Numerous factors affect thermal performance; no formula will accurately predict results. This section is an abridged discussion of these factors—it is *not* a comprehensive study of thermodynamics. The bibliography lists texts that describe and define heat transfer methods; the designer is encouraged to refer to these texts often throughout the design process.

A summation of the following three heat transfer actions provides an estimate of total effect.

1. Convection heat transfer
2. Thermal Conduction
3. Radiation heat transfer

The following subsections discuss the actions.

Convection Heat Transfer

Convection heat transfer, natural and forced, is the primary contributor to thermal management in module design. Natural convection (free air) of a properly engineered enclosure can remove the majority of the unwanted heat from an isolated body. Forced convection (e.g. fans), when compared with natural convection, can yield a two to ten times improvement in heat transfer.

Design Recommendation

19 This formula estimates forced air convective cooling requirements for modules in an HP 70001A mainframe.

$$A = 1.72 \times \frac{P}{\Delta T}$$

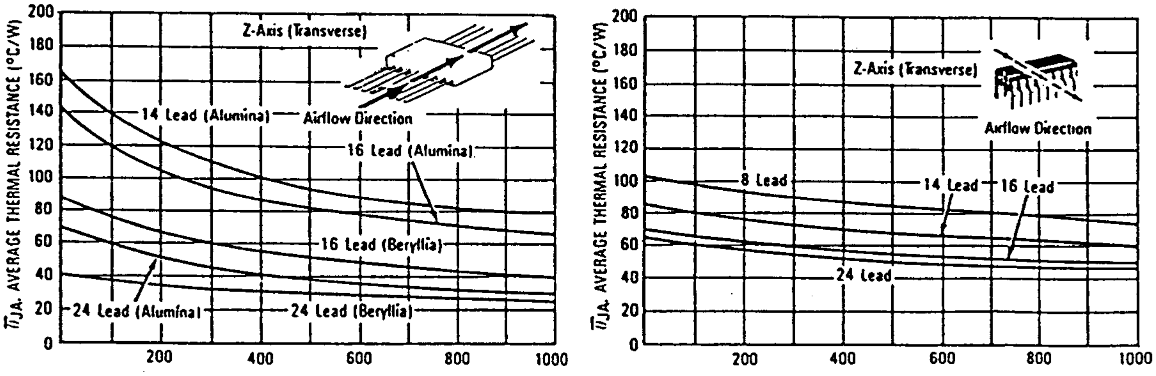
where, A = airflow in cfm,
ΔT = maximum temperature rise °C, and
P = total dissipated power in watts.

The effect on $\overline{\theta}_{JA}$ (due to a decrease in $\overline{\theta}_{CA}$) of air flow over a typical integrated circuit package is shown graphically in ambient temperature derating curves supplied by integrated circuit manufacturers. This air flow reduces the thermal resistance of the package, thereby permitting a corresponding increase in power dissipation without exceeding the maximum permissible operating junction temperature. The extent of the derating is governed by the type, style, and power levels of the specific integrated circuit package.

The following example calculates the maximum junction temperature for a 16 lead ceramic integrated circuit. Assume 195 mW as maximum total power dissipation for the integrated circuit, including its load. Also assume an air flow of 500 linear feet per minute. Figure 4.6 shows that $\overline{\theta}_{JA}$ is 50°C/W. With a T_A of 25°C, the following maximum junction temperature results:

$$\begin{aligned} T_J &= P_D(\overline{\theta}_{JA}) + T_A \\ &= (0.195W) \times (50^\circ C/W) + 25^\circ C \\ &= 34.8^\circ C \end{aligned}$$

In this example, the integrated circuit junction temperature is 9.8°C above ambient. The designer should keep in mind that the majority of heat transfer in an integrated circuit occurs first through the base and the leads to the printed circuit board and then to the surrounding air.



Airflow Versus Thermal Resistance (Ceramic Flat Package)

Airflow Versus Thermal Resistance (Plastic Dual-In-Line Package)

Figure 4.6: Typical Airflow Versus Thermal Resistance

Thermal Conduction

Heat transfer by conduction is a passive action. Energy (heat) flows from the high temperature region to the low temperature region. The heat transfer rate is proportional to the temperature difference. This transfer allows heat dissipation from conductive paths, which can be heat sinks, housings, printed circuit boards, conductive buses, etc. Thermal conductivity of the material governs the contribution of conduction to total heat transfer.

In brief, heat transfer by thermal conduction is a function of the following factors:

1. Temperature difference,
2. Thermal conductivity, and
3. Cross sectional area in the direction of heat flow.

Fins, heat sinks, and printed circuit boards provide the majority of conduction heat transfer in module designs. An example at the end of this section provides a finned heat-sink thermal-design example.

Multilayer printed circuit boards with ground planes provide good thermal paths. Countersinking mounting holes for low power devices allows the package bottom to contact the power plane, and thermal paste between the package and the power plane would further improve thermal conductivity.

Printed channeling is a useful technique for conduction of heat away from the packages when the devices are soldered into a printed circuit board. Refer to figure 4.7. The channels should terminate into channel strips at each side or the rear of a plug-in type printed circuit board. The heat can then be removed from the circuit board, or board slide rack, by means of wipers (e.g. module base or cover) that come into thermal contact with the edge channels.

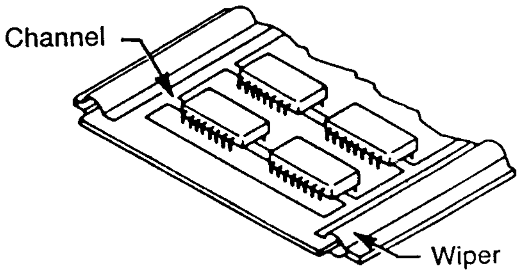


Figure 4.7: Channel/wiper Heat Sinking on Double Layer Board

Radiation Heat Transfer

Radiation heat transfer does not rely on conduction to dissipate heat. Heat radiates passively from the subject to the cooler surroundings, and is usually not the primary method of cooling in designs utilizing forced air cooling such as the HP 70000 system.

The formula for total heat transferred by radiation heat transfer is:

$$Q_r = q_r \epsilon S_r$$

where,
Q_r = total heat transferred by radiation
q_r = heat transferred/unit area by perfect radiator (watts/cm^2),
ϵ = emissivity of the subject surface, and
S_r = effective radiating area of the subject surface

The module designer can change Q_r significantly by effecting a change in ϵ and/or S_r; in other words, changing the surface material greatly effects emissivity. Appendix B includes a table of emissivities for materials common in electronic assemblies. Surface treatments (chromate conversion, anodizing, painting, etc) can improve the relatively poor emittance of bright aluminum or other such materials. Any organic paint will improve surface emissivity to better than .85, and there are some special paints that provide .95 emissivity. The color of the paint is unimportant.

Thermal Design Example, Finned Heat Sink

A TO-3 power transistor is to mount to an aluminum heat sink as shown in figure 4.8. Given a power dissipation of 10 watts and a 0.025 mm thickness of heat sink compound between the transistor base and the heat sink, calculate the temperature differential between the transistor and the base of the farthest fin.

When power dissipation is 25 watts, how much hotter than the base of the farthest fin will the transistor be? If the temperature at the base of the farthest fin is 50°C and the junction-to-case thermal resistance of the transistor is 1.52°C/watt, what is the temperature of the transistor junction when power dissipation is 25 watts? These simple computations allow the designer to estimate thermal performance of individual circuits, and, where appropriate, verify compliance with the circuit manufacturer's thermal limits. The solution is found on page 50.

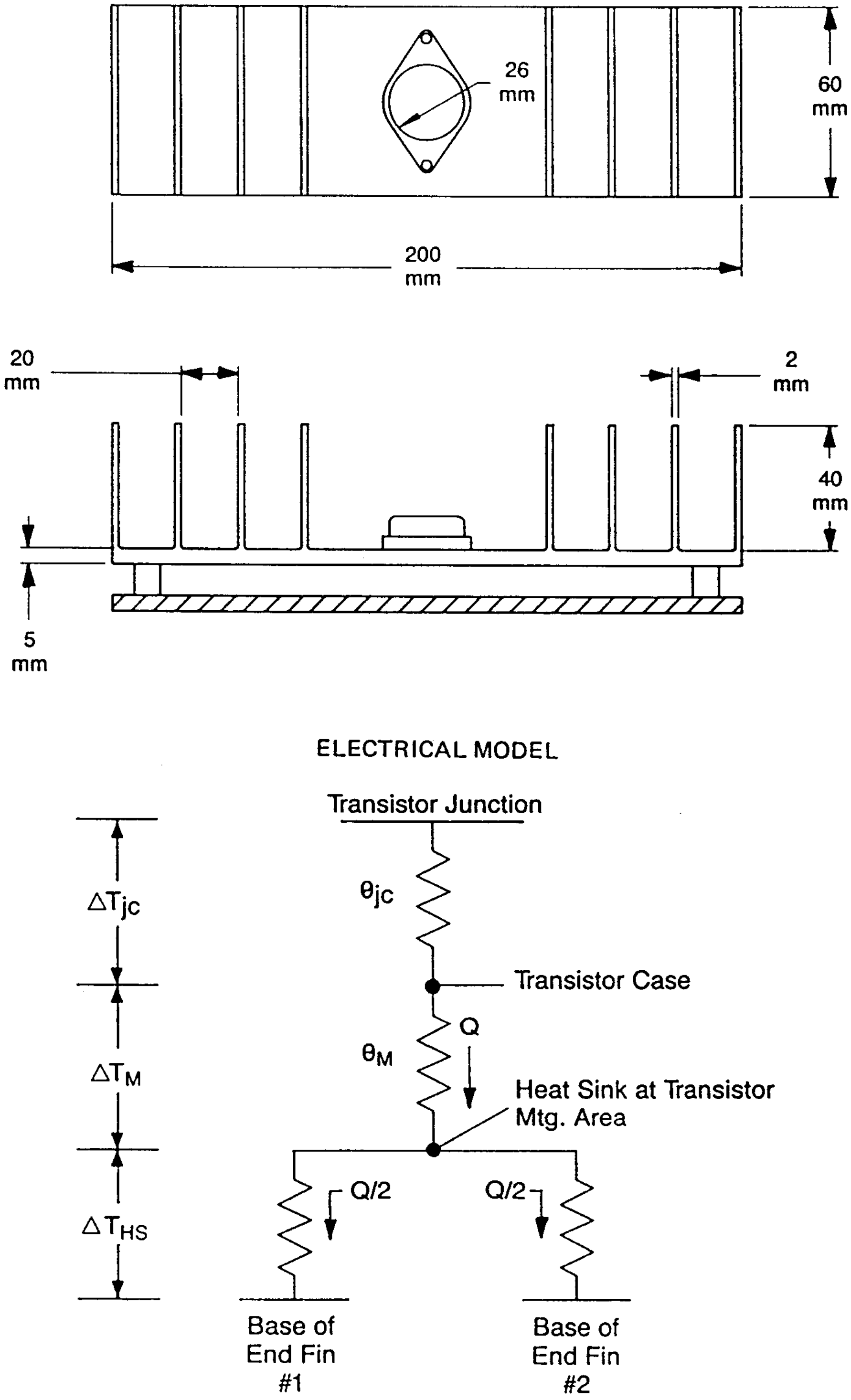


Figure 4.8: Power Transistor Mounted on Finned Heat Sink

SOLUTION (Thermal Design Example, page 48):

$$\Delta T_T = \Delta T_M + \Delta T_{HS}$$

where,
ΔT_T = total temperature difference,
ΔT_M = mounting temperature difference, and
ΔT_{HS} = heat-sink temperature difference, transistor to end.

1. Determine Θ for mounting interface. Change all dimensions to centimeters.

$$\Theta M = \frac{L}{ka} = \frac{0.0025}{0.004\pi(2.6/2)^2} = 0.12^\circ\text{C/watt}$$

where, k = 0.004 watts/cm°C.

2. Determine ΔT for mounting interface.

$$\begin{aligned}\Delta T_M = Q\Theta_M &= 10 \times 0.12 = 1.2^\circ\text{C for 10 watts}\\ &= 25 \times 0.12 = 3^\circ\text{C for 25 watts}\end{aligned}$$

3. Determine Θ for heat sink base from transistor to base of farthest fin.

   Since diameter of the transistor is almost the same as the conductive width of the heat sink, assume that the transistor heat is entering the heat sink uniformly across the heat sink center line. Since the heat sink is also symmetrical, 1/2 of the heat will flow towards each end.

$$\Theta_{HS} = \frac{L}{ka} = \frac{10}{2.165 \times 6 \times 0.5} = 1.54^\circ\text{C/watt}$$

where, k = 2.165 watts/cm°C.

4. Determine ΔT for heat sink base from transistor to base of farthest fin. Refer to figure 4.8.

$$\begin{aligned}\Delta T_{HS} = Q\Theta_{HS} &= \frac{10}{2} \times 1.54 = 7.7^\circ\text{C for 10 watts}\\ &= \frac{25}{2} \times 1.54 = 19.3^\circ\text{C for 25 watts}\end{aligned}$$

5. Determine ΔT from transistor case to farthest fin base.

$$\begin{aligned}\Delta T_T &= \Delta T_M + \Delta T_{HS} = 1.2^\circ\text{C} + 7.7^\circ\text{C} = 8.9^\circ\text{C for 10 watts}\\ &= 3^\circ\text{C} + 19.3^\circ\text{C} = 22.3^\circ\text{C for 25 watts}\end{aligned}$$

6. Determine temperature of transistor junction.

$$\begin{aligned} T_J &= T_{FB} + \Delta T_{HS} + \Delta T_M + \Delta_M + T_{JTC} \\ &= 50^\circ\mathrm{C} + 19.3^\circ\mathrm{C} + 3^\circ\mathrm{C} + (25 \times 1.52)^\circ\mathrm{C} \\ &= 110.3^\circ\mathrm{C} \end{aligned}$$

where, T_{FN} = fin base, and
T_{JTC} = transistor junction to case

5

Module Design Kit Application

This chapter discusses a series of module parts kits for $\frac{1}{8}$ to $\frac{4}{8}$ width modules. Module parts kits provide flexible, proven designs with tooled, quality parts. The adaptable, integral kit parts are suited to a wide variety of design constraints and engineering needs. The kits ease module design by ensuring adherence to the design specifications listed in various sections of this design guide. Contact your local Hewlett-Packard representative for availability and pricing information. Figure 5.1 shows major chassis components of the module parts kit. Refer also to appendix E for a listing of available Hewlett-Packard parts.

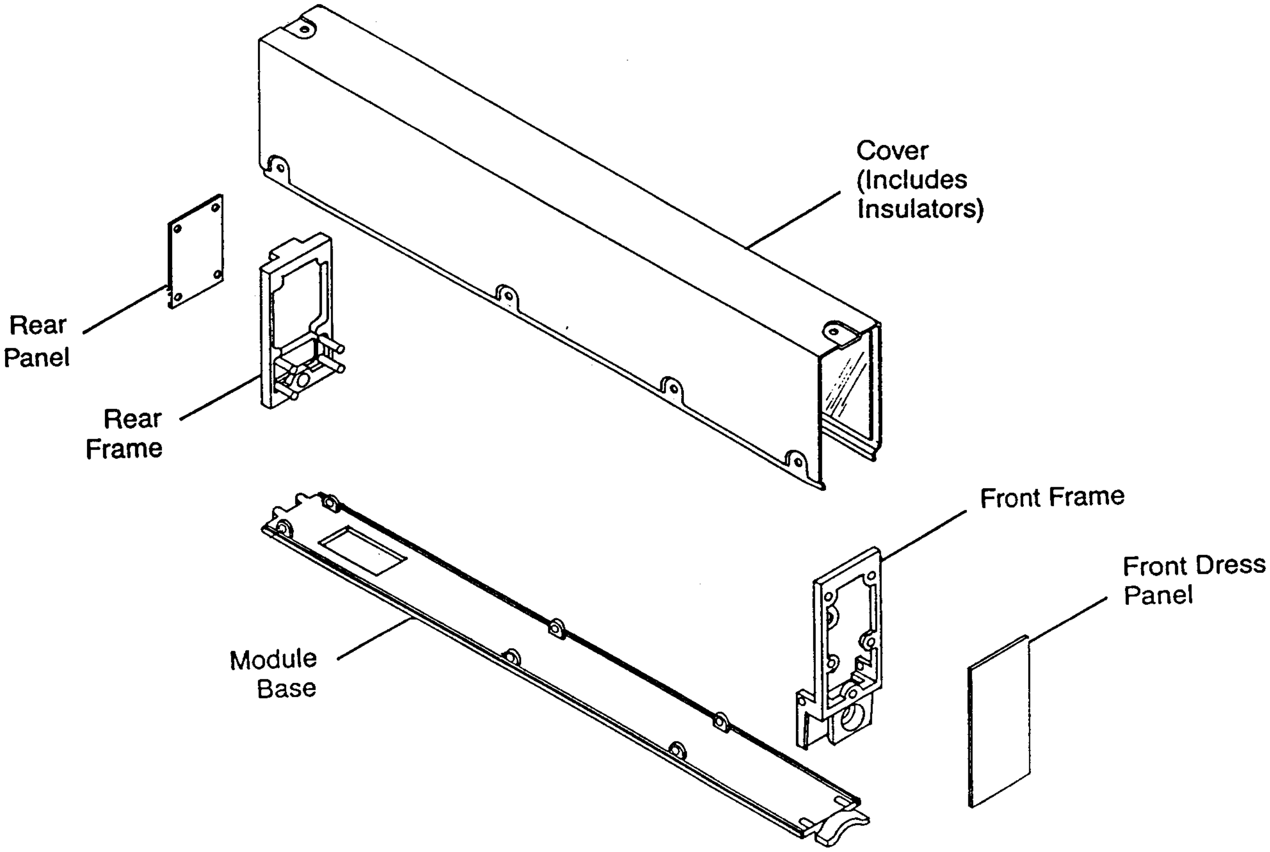


Figure 5.1: Module Parts Kit: Typical Major Chassis Components

Appendix F provides engineering drawings of the module kit parts. Some general design related observations follow:

- To allow daughterboard (see figure 5.7, page 61) interchange, all modules conform to the same vertical height specifications.
- To ensure an optimal solution for a given application, the designer should study the motherboard layout and support features (see figure 5.6, page 60).
- The kits comply with the ERS drawings referred to in appendix F. Though the kit illustrations omit some of the ERS drawing details (front/rear panel details, top cover air exhaust hole pattern, etc.), the designer must provide for these in accordance with information in related chapters.
- The development kit designs use only metric threaded hardware.

Front Frame

Some front frame related observations follow:

- The zero datum on the front frame tongue feature (see figure 5.2) is the basis for most of the z-axis dimensional specifications on the ERS drawings.
- The frame provides attachment points for the top cover.
- Long life threaded stainless steel inserts at mounting points assure suitability for developmental and breadboard applications

Front frames are open on $\frac{1}{8}$ and $\frac{2}{8}$ modules; wider modules have solid, two millimeter thick walls. Engineering drawings in appendix F indicate areas of the solid wall frame that may be optionally machined away to satisfy a given application. Open frames on $\frac{1}{8}$ and $\frac{2}{8}$ modules allow flexible panel design, connector placement, and status board layout. The solid wall provides structural integrity when the front dress panel alone is inadequate. The wall does not affect front dress panel design or usage; the attachment bosses that accept the dress panel are part of the outer frame. Front frames supplied in the module development kits have a protective chromate coating, providing a moderately durable surface finish. Verification of its performance in a given design is suggested.

Rear Frame

The $\frac{1}{8}$, $\frac{2}{8}$ and $\frac{3}{8}$ modules weighing less than 5 kg have a single guide bushing. Modules exceeding 5 kg (11 lbs) mass may require additional such as shown in figure 3.6, page 23, in the form of an elongated guide bushing adjacent to a

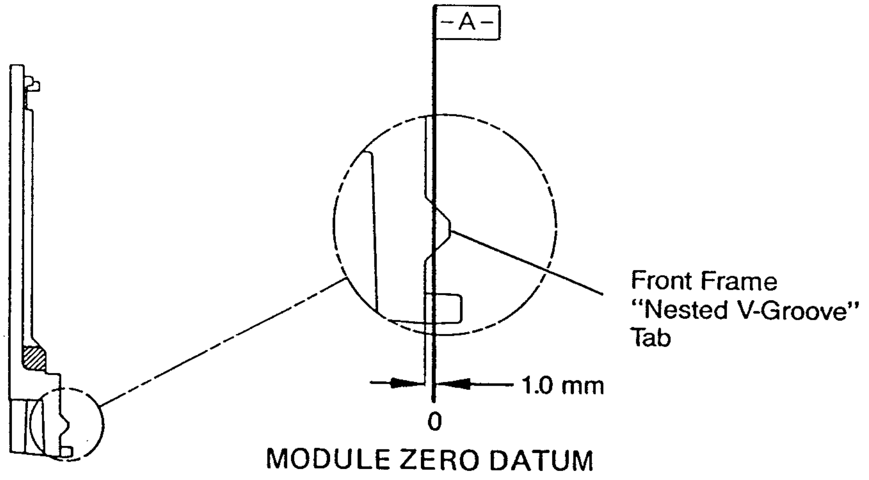


Figure 5.2: Module Front Frame Showing V-groove/Tongue Grounding Feature and Zero Datum

standard module guide bushing. This elongated bushing must provide restraint sufficient to allow compliance with the operating environment specifications listed in Structural Environment, page 24.

The upper portion of the rear frame is open on $\frac{1}{8}$ and $\frac{2}{8}$ modules; wider modules have a solid, two millimeter thick wall. Engineering drawings in appendix F show those areas of the solid wall frame that can be machined away to satisfy a given application. Either design accommodates a one millimeter thick aluminum dress panel. Optionally, the solid design can utilize an adhesive label instead of a dress panel.

Indexing bosses and metric hardware position and attach the frame to the module base. The top cover attaches via metric threaded inserts pressed into a tab (see ERS dwg 70001-90003).

The back of the tab acts as an alignment and EMC grounding detail. The presence of all bosses assures mechanical integrity and improves EMC performance. Rear frame coating should be non-reactive with the EMI suppression spring material (tin). Therefore, tin is the preferred plating (see figure 5.3).

Electronegativity difference (cell potential) indicates the tendency to produce corrosive salts (to oxidize), which are generally nonconductive. Refer to appendix B for data about electronegativity factors and cell potential. To ensure stable performance over time, use mating materials with a small

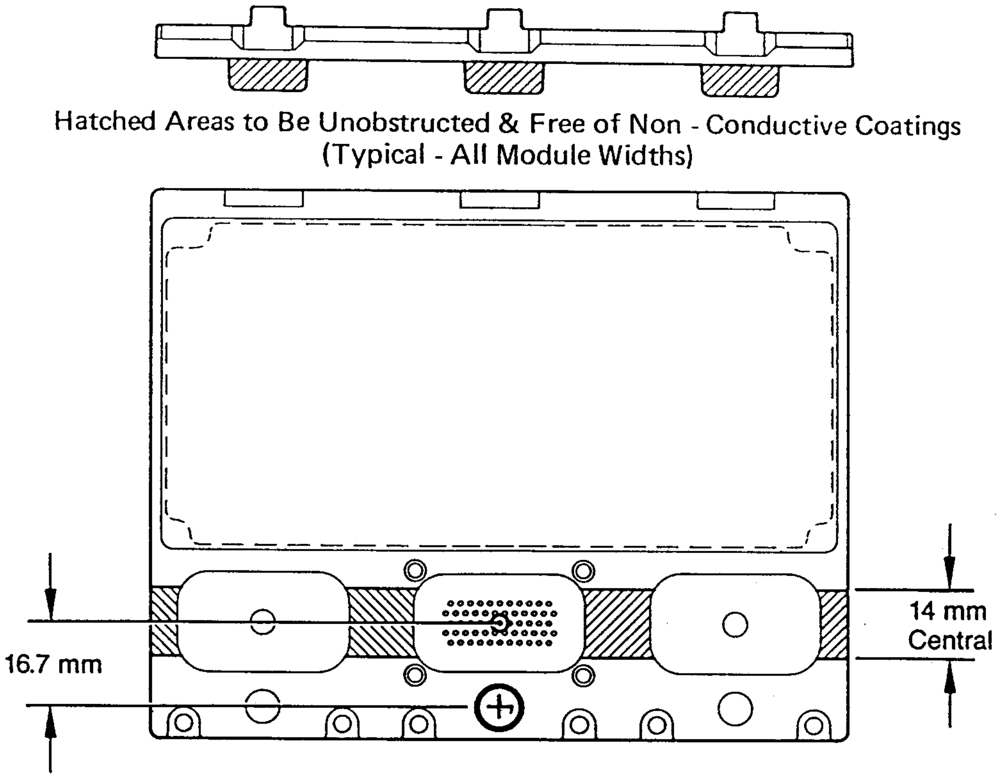


Figure 5.3: Rear Frame Restricted Areas for RFI Springs

electronegativity difference relative to the tin plated EMC springs. For instance, a rear panel coated with tin would result in zero cell potential, a coating of gold results in a cell potential of 1.82 V, and a bare aluminum surface results in a difference of 1.53 V. Thus, a tin coating would be ideal while gold would be more likely to corrode at the contact area than bare aluminum would be.

Base

The module base provides the following:

- A solid foundation for a printed circuit motherboard or other large discrete components.
- The module's main longitudinal structural component.
- Mounting points for the module cover.
- A full length cover locating groove that also facilitates an interlock feature.

The interlock feature (see figure 5.4) provides an indirect route for radiation to escape and provides a better level of EMC shielding than a simple butt or lap joint. Above approximately 30 MHz, the level of EMC protection provided by the interlock groove begins to diminish. Where possible, it is generally prudent to suppress signals at their source. For additional EMC information, refer to the HP 70000 Module Measurement System *Electromagnetic Compatibility Design Guide* and the *Electrical Design Guide.*

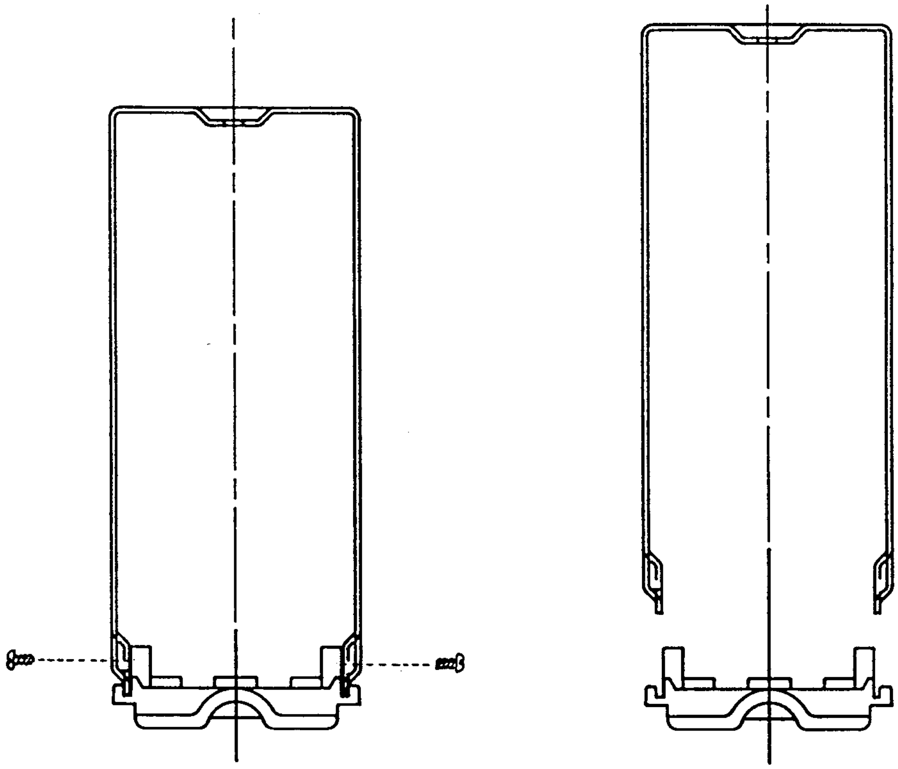


Figure 5.4: Module Base Cover Locating Groove and Interlock Feature

Some base related observations follow:

- Threaded steel inserts at mounting points help provide long life.
- For $\frac{4}{8}$ modules, an optional but recommended z-axis stiffening device (rib) adds vibration dampening and reduces bending moments. Components can be mounted on this stiffening rib by the addition of necessary mounting features. For example, figure 5.5 depicts an engineered die cast stiffening rib for a weight sensitive application, but less expensive solutions (i.e. plastic, formed sheet metal, extrusion) can provide similar structural benefits.

Engineering constraints of a particular design will determine the need for the stiffening rib. If needed, the details of the stiffening rib must be tied closely to the internal layout.

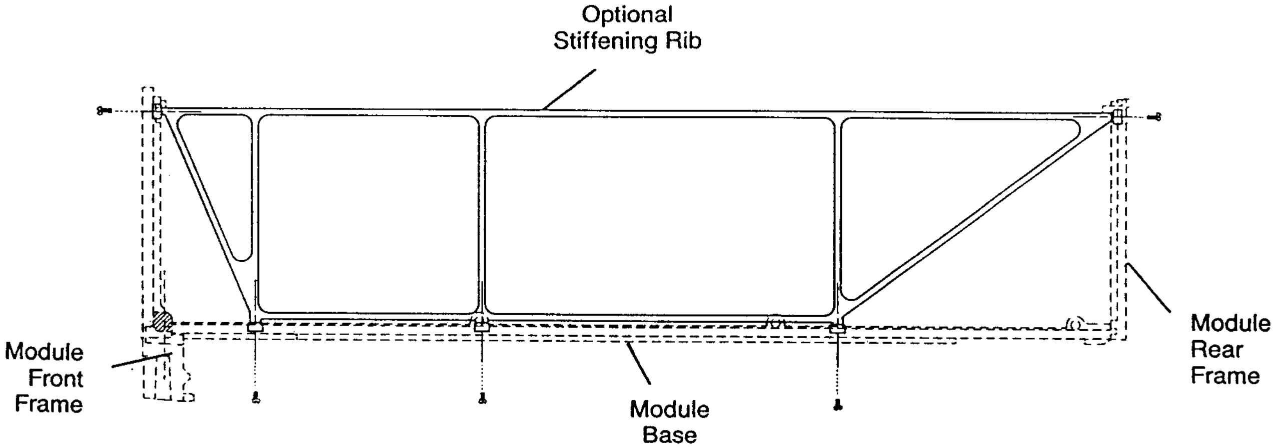


Figure 5.5: Wide Module Stiffening Rib

- All module kit base parts are aluminum with a clear chromate conversion coating to inhibit corrosion. The designer should consider cell potential when choosing mating materials (see appendix B and chapter 7).
- To allow for adequate airflow, there is an air inlet at every $\frac{1}{8}$ width interval (e.g. a $\frac{3}{8}$ module requires three inlets).

Rear Panel

The sheet aluminum rear panel is attached with screws inserted through clearance holes into threaded bosses on the frame. The rear panel is optional on $\frac{3}{8}$ and $\frac{4}{8}$ width modules, because their solid wall subpanel can be either bare or covered with an adhesive label.

Before laying out the rear panel, consider the guidelines presented in chapter 6 to assure optimal placement of connectors, graphics, etc.

Front Dress Panels

Front panels that are 1.6 mm thick and mounted on front frames specified in this document will satisfy the overall module length specification as presented in appendix F drawings.

Front frame clearance bosses and female threaded standoffs provide front panel initial positioning and retention. Final positioning (to satisfy ERS guidelines) can be accomplished by simple assembly fixturing. The bosses have a 2° draft (largest diameter at front surface) to aid in assembly and a 45°×0.4 mm deep chamfer to provide clearance for the weldment present at the base (weld point) of the standoff.

Top Cover

The module parts kits use a one piece cover. Custom design is acceptable if the design does not adversely affect the module's structural integrity. The covers supplied with the development kits are aluminum, but specific requirements may dictate a substitute (e.g. nickel alloys for added magnetic shielding, ductile steel to accommodate certain stamping details). Screw head recesses allow the cover to accommodate related hardware while maintaining compliance with the module envelope specification (refer to figure 3.1, page 18). A 0.5 mm thick adhesive insulating panel is permanently affixed to the two inside vertical walls of the cover. This helps protect against accidental contact between the cover and printed circuit board circuitry.

Printed Circuit Board Guidelines

Printed circuit boards are not included in module development kits due to the uniqueness of designs. This section shows suggested maximum board outlines for the development kits. The guidelines illustrated in this section show suggested details and features which may not be applicable for all designs. The guidelines are to be used as initial development guidelines only. Appendix F contains unabridged drawings for the printed circuit boards outlined in this section.

Motherboard (Horizontal)

The suggested motherboard for use in HP 70000 development kits is a 1.6 mm thick board that adheres to the graphic guidelines shown in figure 5.6, page 60 and appendix F drawings. The final placement of support bosses and the required stability of the motherboard/daughterboard system dictate motherboard thickness. The dimensions shown in figure 5.6 are recommended maximum board size; specific engineering requirements may require alterations of the geometry.

The $\frac{1}{8}$ width motherboard design provided in appendix F typifies features useful with other module widths. For the other widths, the designer should extrapolate the given features. The motherboard is for use with the mechanical fastening details (mounting boss, locations, cover boss clearance, etc.) that are part of current HP 70000 development kits.

	$\frac{1}{8}$ Width	$\frac{2}{8}$ Width	$\frac{3}{8}$ Width	$\frac{4}{8}$ Width
X =	39 mm	87 mm	136 mm	184 mm

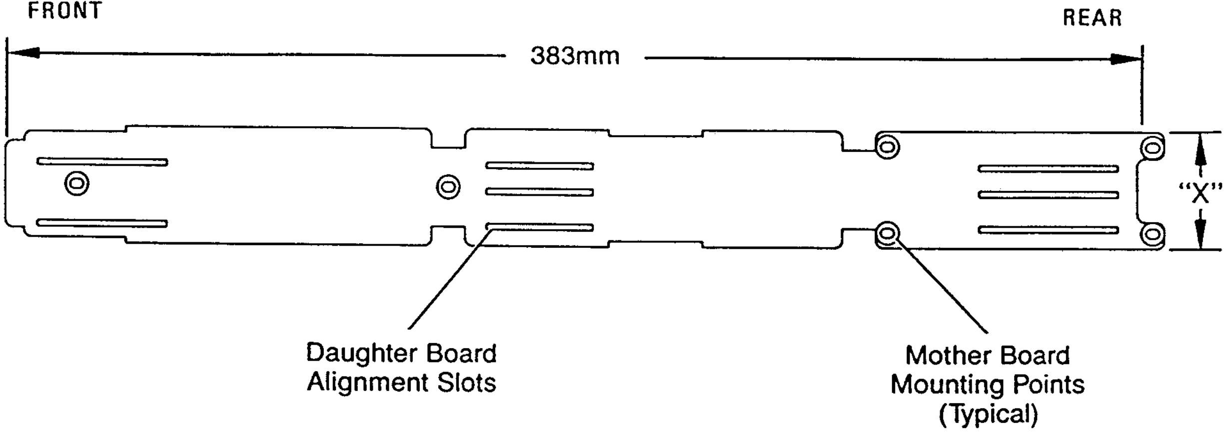


Figure 5.6: Recommended Motherboard Widths

Daughter Board (Vertical)

Figure 5.7, page 61, shows the recommended maximum printed circuit daughterboard size and layout for use in HP 70000 development kits. This is a maximum envelope, and certain considerations will restrain these dimensions somewhat (component height of neighboring boards, clearance for removal, etc.)—smaller sizes are acceptable if engineering design constraints are met. A single printed circuit board will yield approximately 4800 square centimeters (74 square inches). The number of boards per module is governed only by the maximum allowable module width as outlined in the ERS Drawings chapter.

The tabs on the bottom of the daughterboard allow mating with matching slots on the motherboard, thus contributing to printed circuit board stability and mating connector longevity. (A specific design will determine the need for this tab-to-slot interlocking feature.) Also shown are the approximate positions for connector placement. Ultimately, the only requirement for placement is consistency with the motherboard mating connectors and printed circuit board removal. The designer should be aware of the mandatory rear frame components and their impact on daughter board outlines.

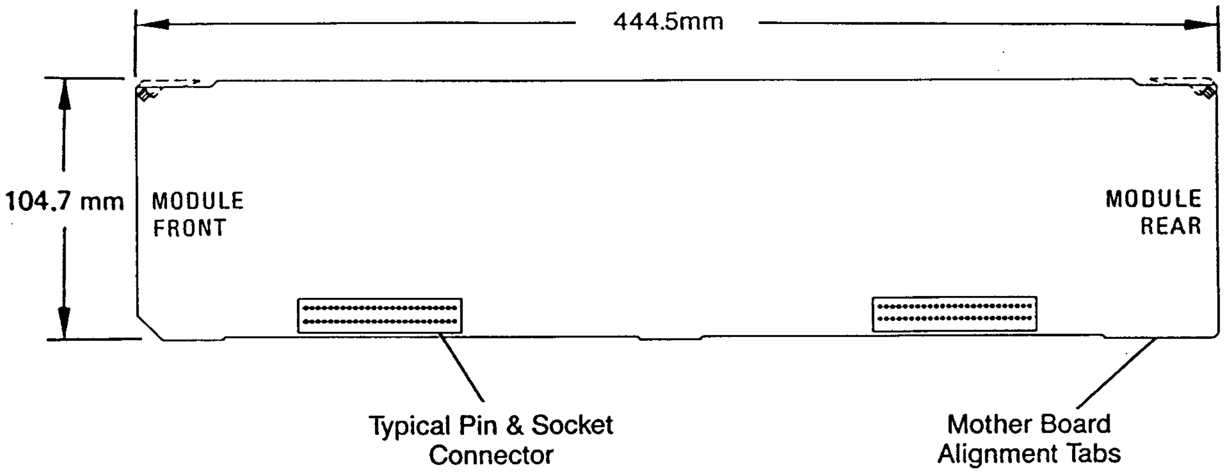
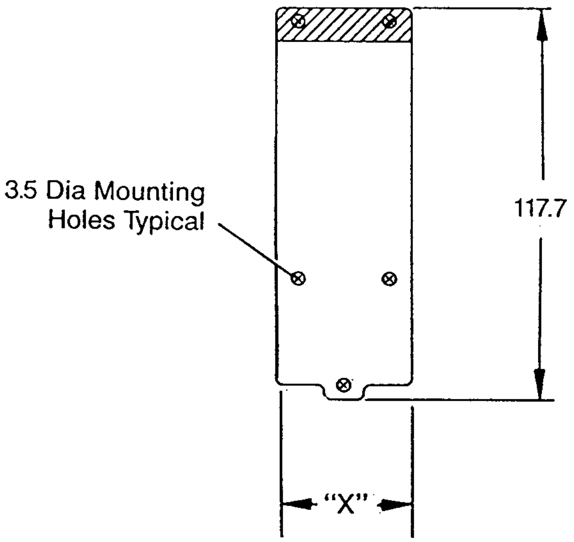


Figure 5.7: Daughter Board Layout

Front Panel Status Board

Many designs will require front panel printed circuit boards (front panel key illumination, status lights, annunciators, front panel switch mounting, etc.). Chapter 6, Industrial Design, contains information about recommended printed circuit boards, and front panel annunciators. Figure 5.8, page 62 shows maximum dimensions for standard applications: This layout is compatible with the HP 70000 system but may not be optimized for universal application—for example, incorporation of a card guide for the vertical printed circuit boards might require a height reduction, as indicated by the crosshatched area in the figure 5.8 layout. The recommended status board thickness of 2.5 mm (.093 inch) allows use of the same screw (metric 3.0 × 0.6) used in the status board, front panel, and front frame assembly. A more standard printed circuit board thickness (1.6 mm/.063 in) can be substituted if provisions are made for a proportionately shorter M-3 screw in attaching the status board to the front panel.



	$\frac{1}{8}$ Width	$\frac{2}{8}$ Width	$\frac{3}{8}$ Width	$\frac{4}{8}$ Width
X =	39 mm	87 mm	136 mm	184 mm

Figure 5.8: Recommended Front Panel Status Board Sizes

Module Insertion Guide Feature

The module guide provides two functions:

- Rough alignment of a module during insertion into the mainframe.

  To ensure correct alignment, the typical design should include at least one guide. Guides can be an integral part of the base or a secondary mechanically attached part. If using attached guides, select materials that minimize corrosive products (see appendix B for electronegativity data).

  A single (integral) guide will provide module guidance; however, multiple guides incorporated into the base can add significantly to the rigidity of the base and of the module.

- A means for improving module dynamic stability.

  The development kits provide a symmetrical, sturdy, solid cross section, aluminum base that is designed within the process constraints of aluminum die casting. By choosing different base materials and cross-sectional design, the designer can accommodate special applications—such as modules wider than $\frac{3}{8}$ and layouts with heavy, asymmetrically placed components.

Air Inlet Gasket

The provided plastic air inlet gasket attached to the module base provides a non-metallic raised bearing surface during module insertion and removal. The gasket also serves as an air transition seal between the mainframe plenum and the module. Modules use one gasket per $\frac{1}{8}$ module width, i.e. a $\frac{3}{8}$ module requires three gaskets—one per air inlet relief. The mainframe half of the air gasket is spring loaded to guarantee a reasonable air seal with the module over the full range of manufacturing assembly tolerances in the module air inlet gasket/base assembly.

Critical Reliability Requirement

20 The use of the air inlet gaskets on the module base is required. Their elimination can result in an improper mechanical mating (jamming) of the module in a mainframe.

Air transition seals help ensure delivery of the cooling air at the specified maximum back pressure (3.5 cfm per standard module width @ 0.065 inches H_2O).

6

Industrial Design

This chapter contains complete dimensioning and labeling information for front and rear panels, top cover, safety, graphics, and color. This data supports consistent system appearance, function, and standard inter-modular cabling.

Product Consistency Requirement

21 To maintain consistent human interface and system continuity (e.g. annunciator placement, color, panel sizes), the designer must comply with specifications presented in this chapter.

Front Panel

Sizes

The panel sizes shown in figure 6.1 conform to the module volume specifications set forth in figure 3.1, page 18.

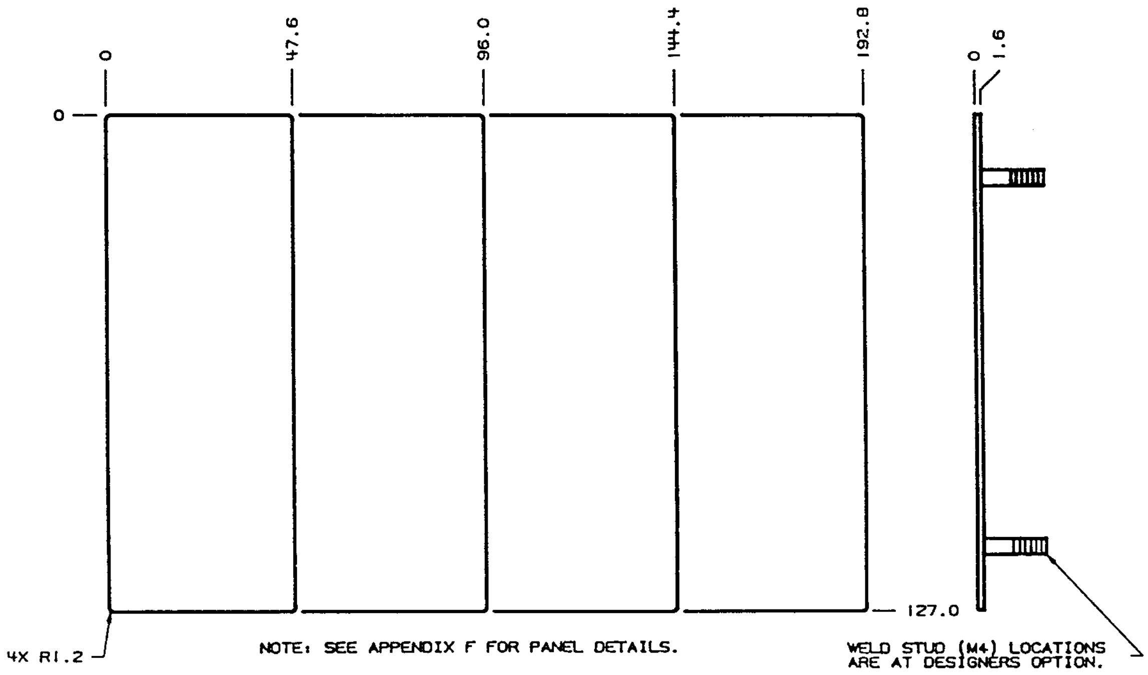


Figure 6.1: Module Front Panel Sizes

Component Layout

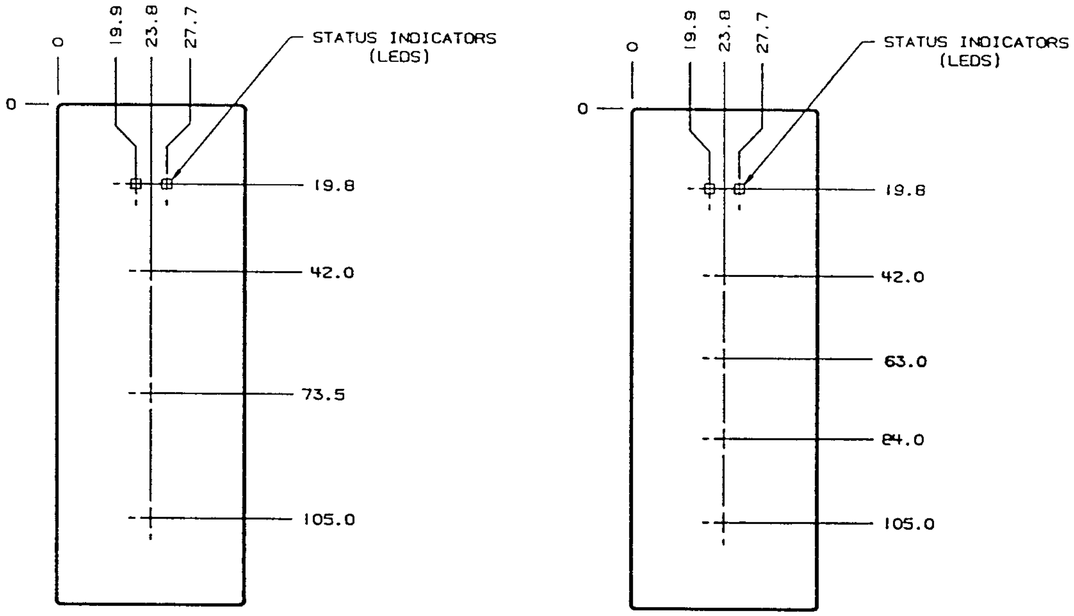
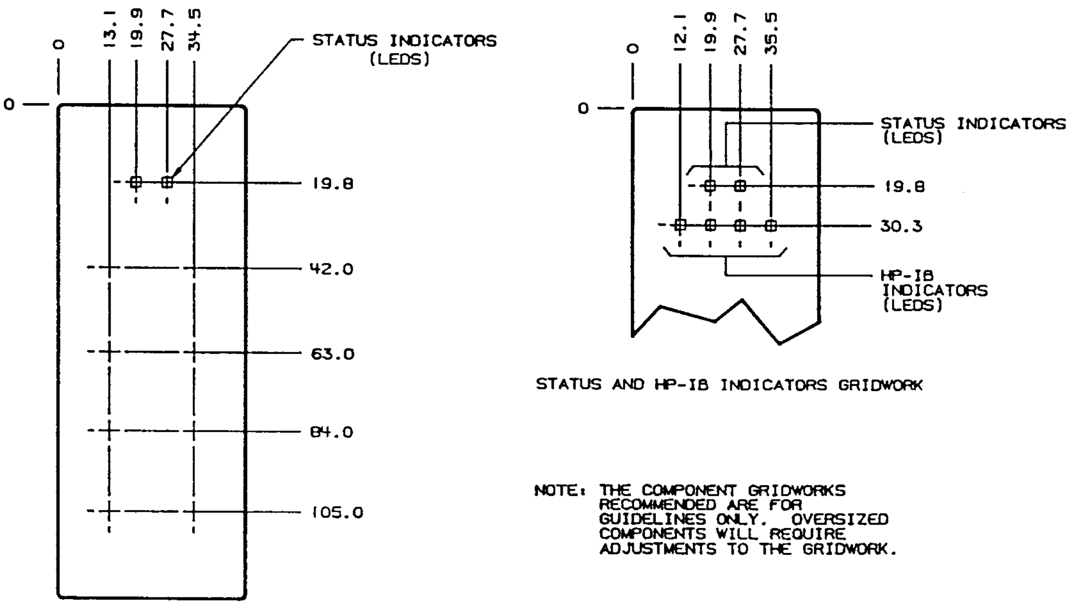


Figure 6.2: Front Panel 3 & 4 Component Gridwork, 1/8 Module



STATUS AND HP-IB INDICATORS GRIDWORK

NOTE: THE COMPONENT GRIDWORKS RECOMMENDED ARE FOR GUIDELINES ONLY. OVERSIZED COMPONENTS WILL REQUIRE ADJUSTMENTS TO THE GRIDWORK.

Figure 6.3: Front Panel 8 Component Gridwork, 1/8 Module

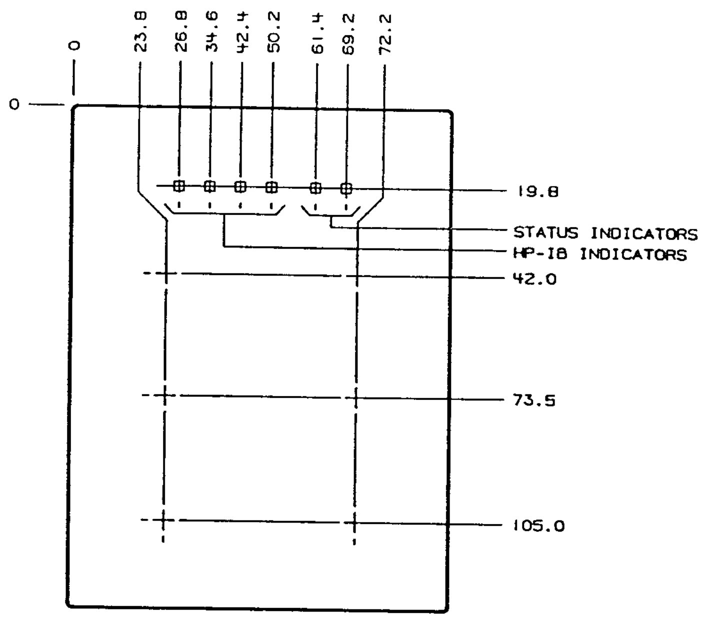


Figure 6.4: Front Panel 6 Component Gridwork, 2/8 Module

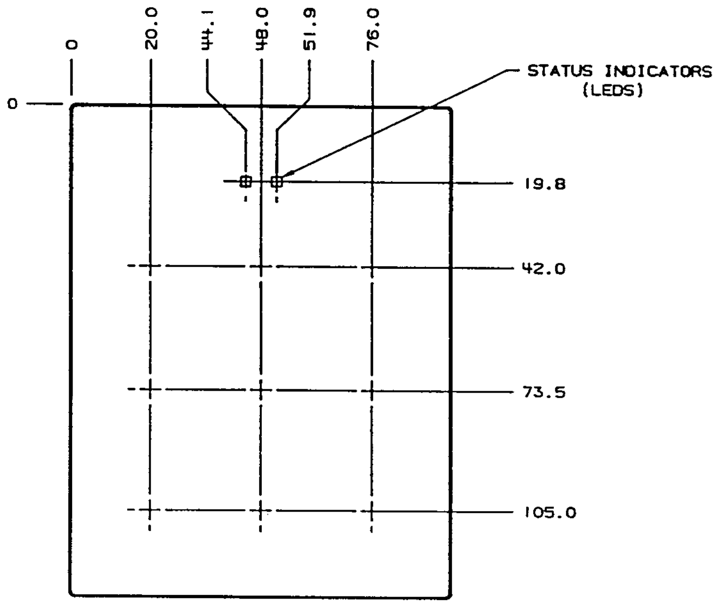


Figure 6.5: Front Panel 9 Component Gridwork, 2/8 Module

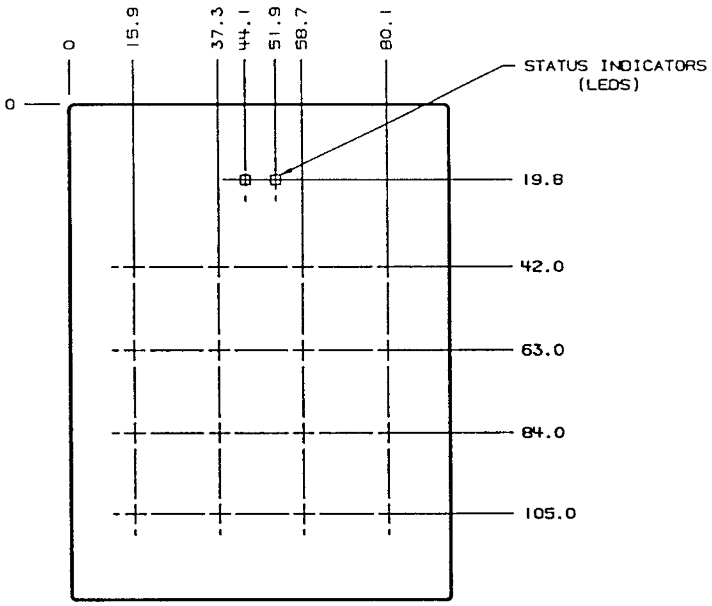


Figure 6.6: Front Panel 16 Component Gridwork, 2/8 Module

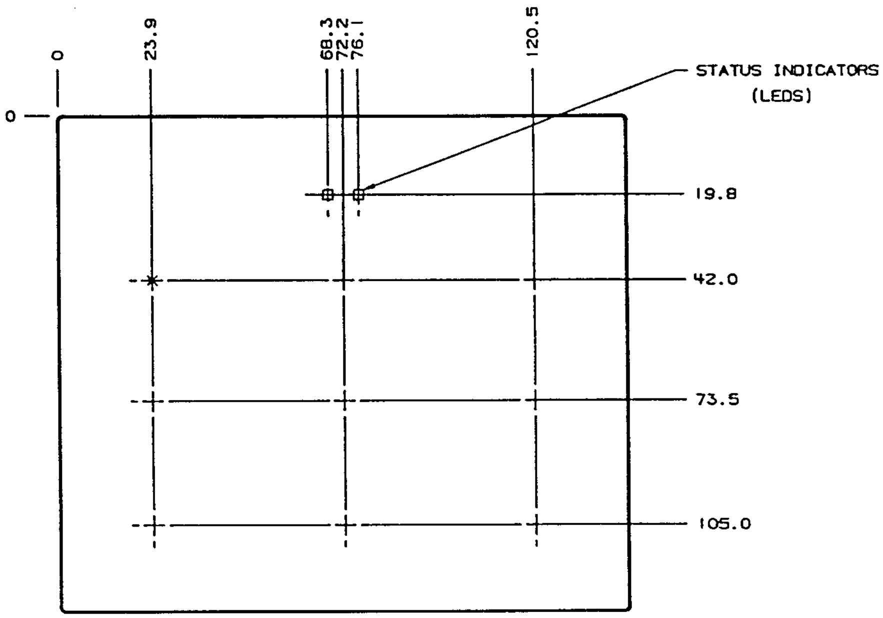


Figure 6.7: Front Panel 9 Component Gridwork, 3/8 Module

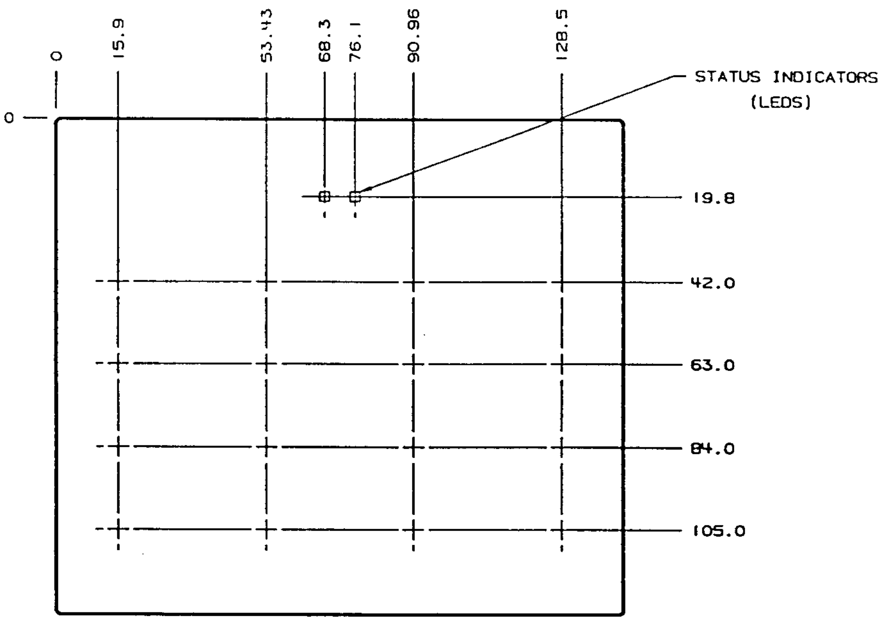


Figure 6.8: Front Panel 16 Component Gridwork, 3/8 Module

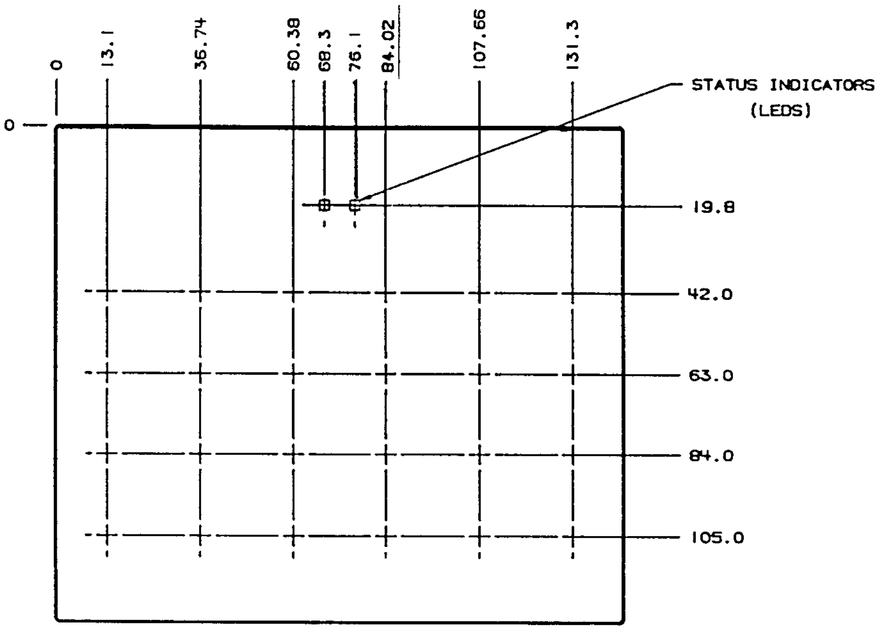


Figure 6.9: Front Panel 24 Component Gridwork, 3/8 Module

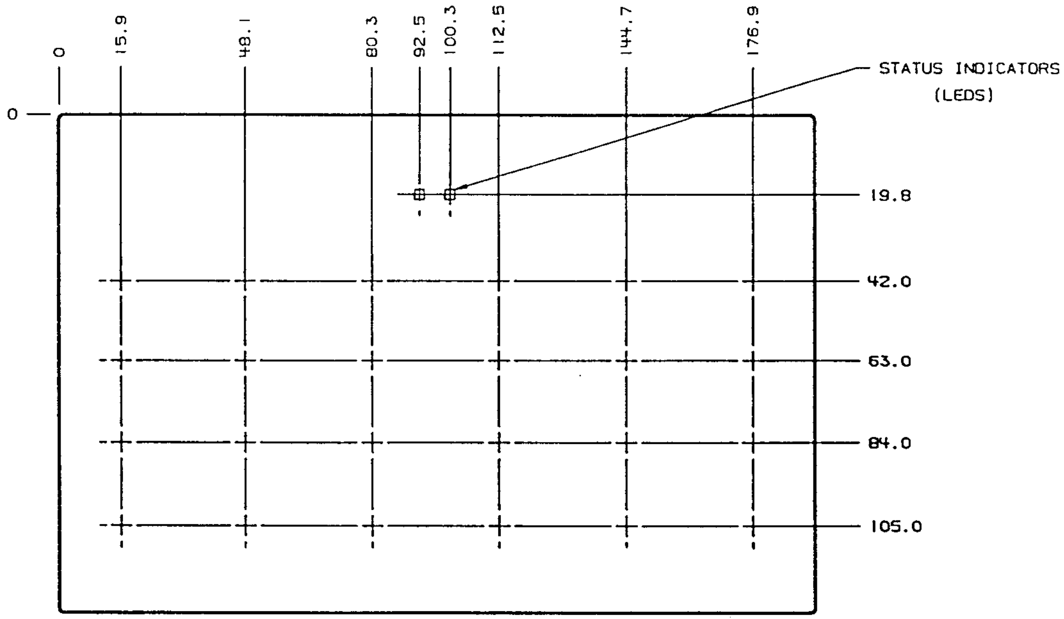


Figure 6.10: Front Panel 24 Component Gridwork, 4/8 Module

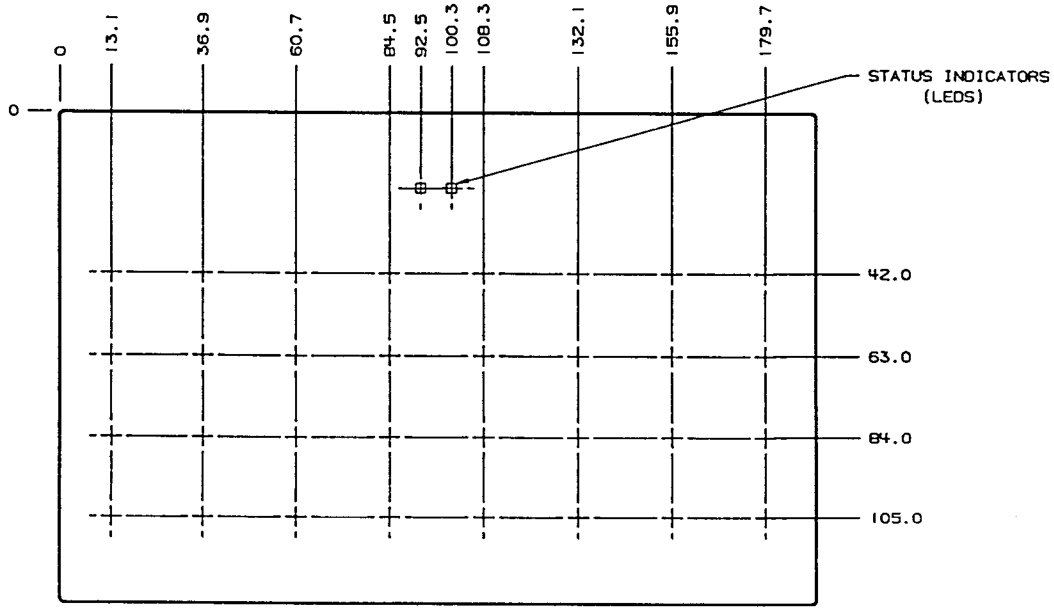


Figure 6.11: Front Panel 32 Component Gridwork, 4/8 Module

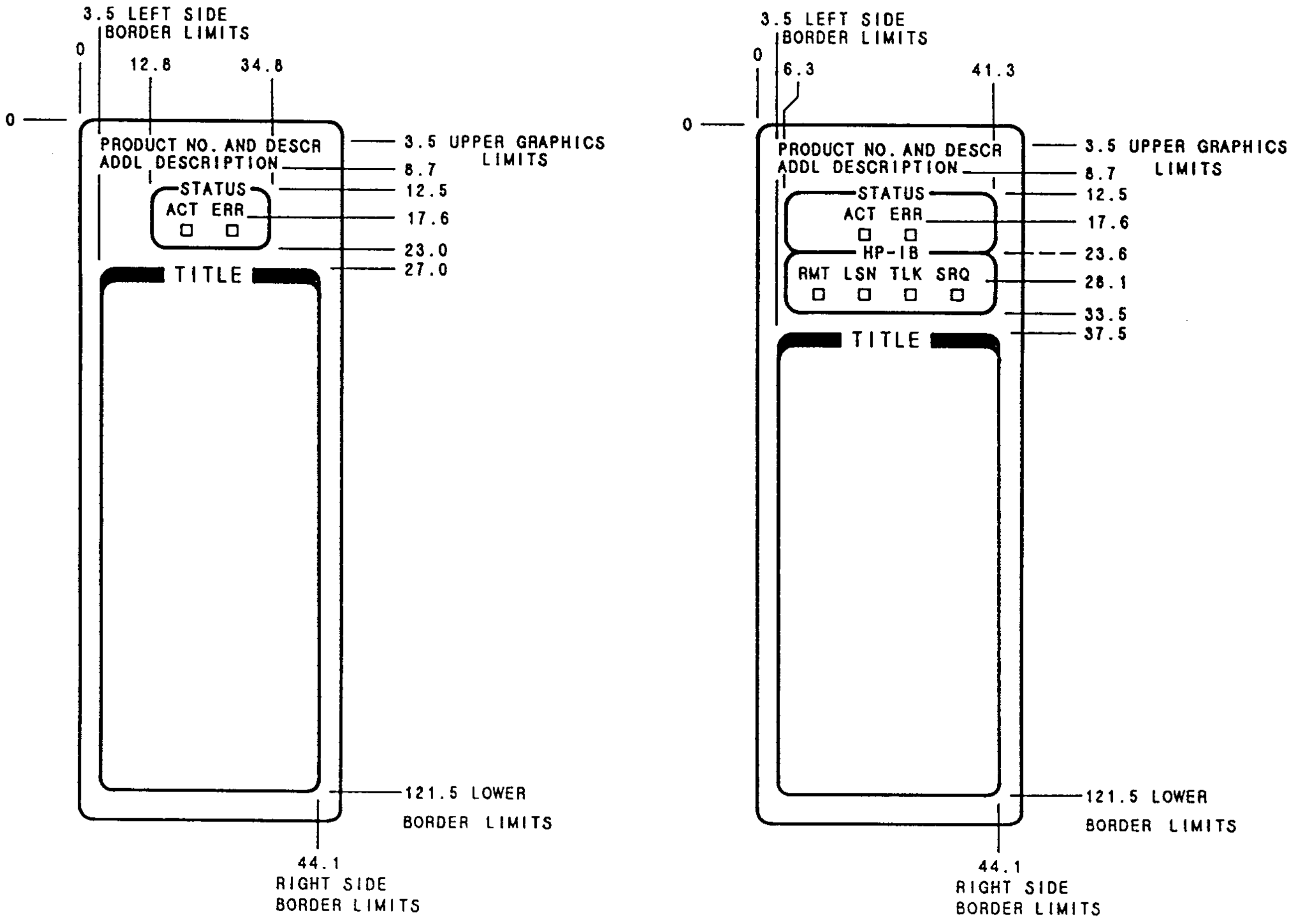


Figure 6.12: Front Panel Graphics Positioning, 1/8 Module

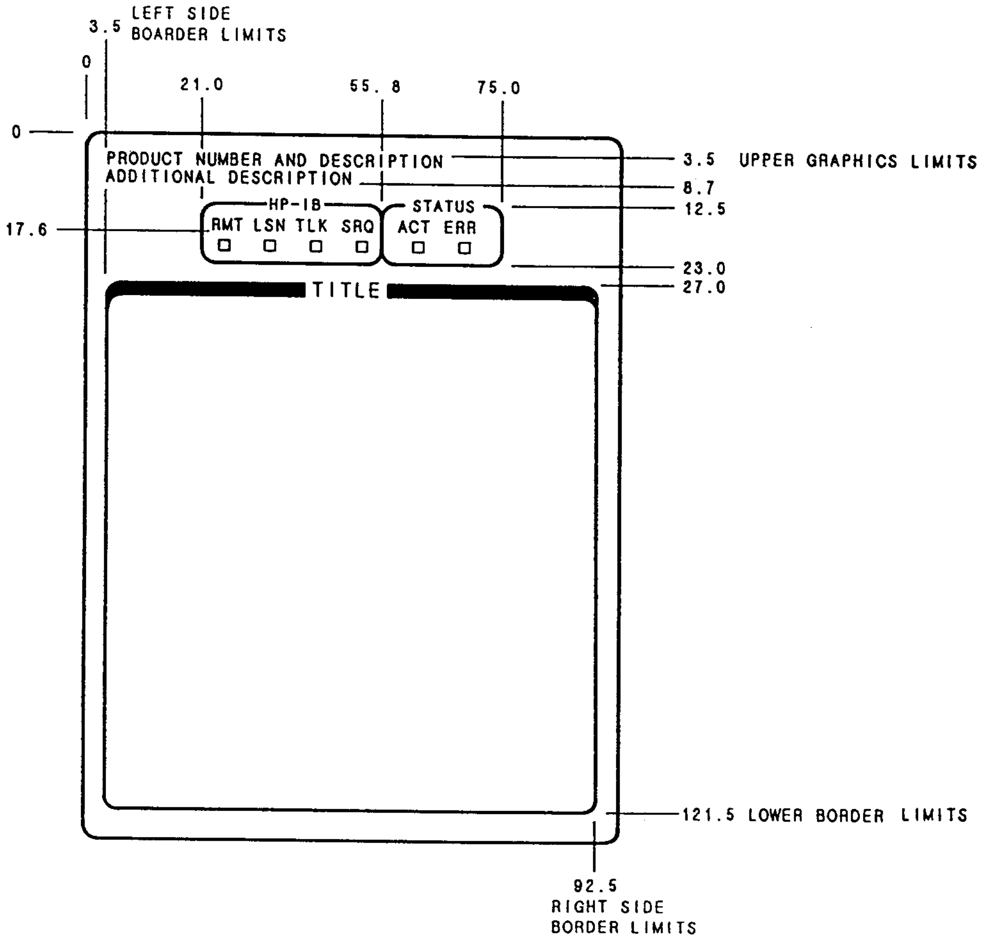


Figure 6.13: Front Panel Graphics Positioning, 2/8 Module

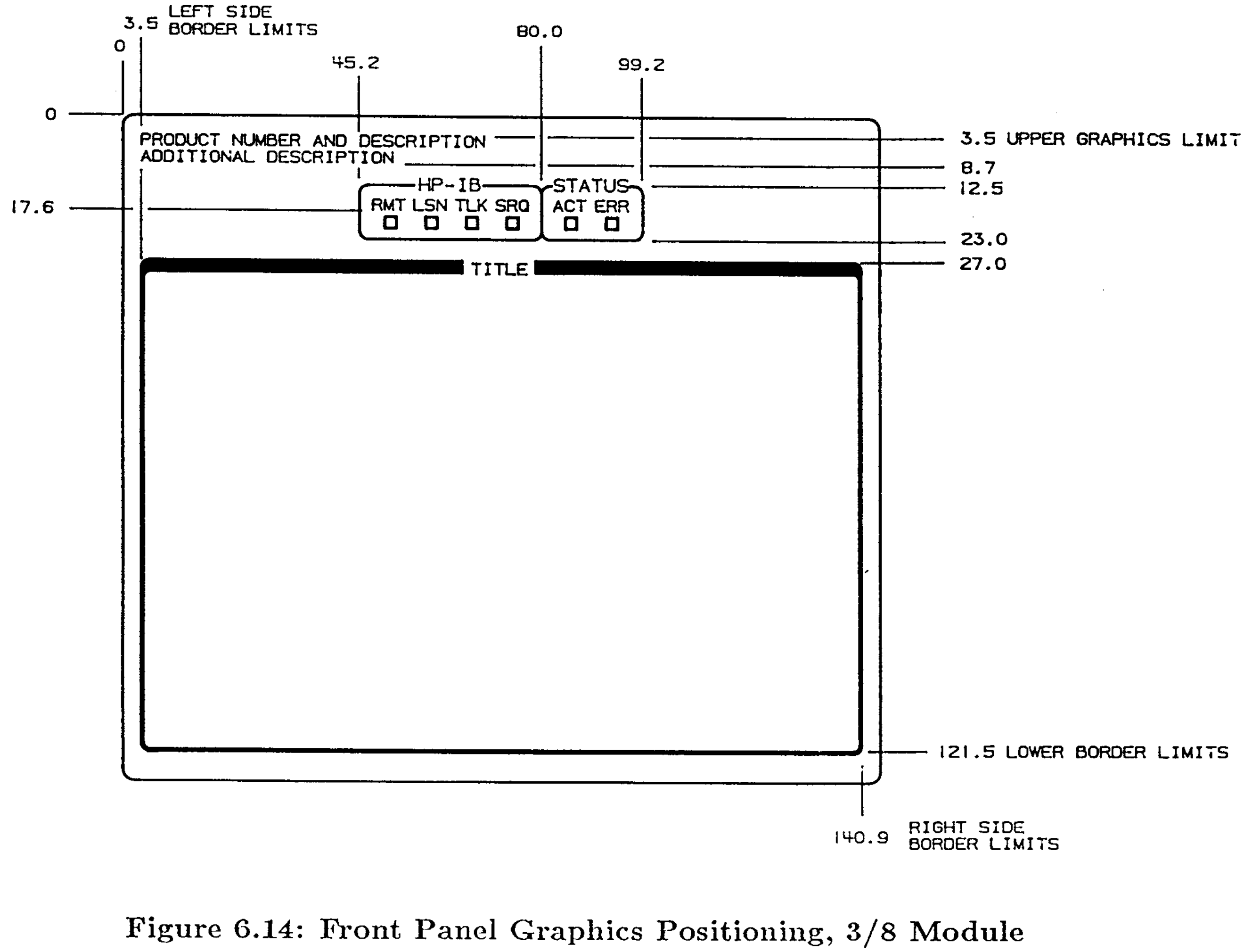


Figure 6.14: Front Panel Graphics Positioning, 3/8 Module

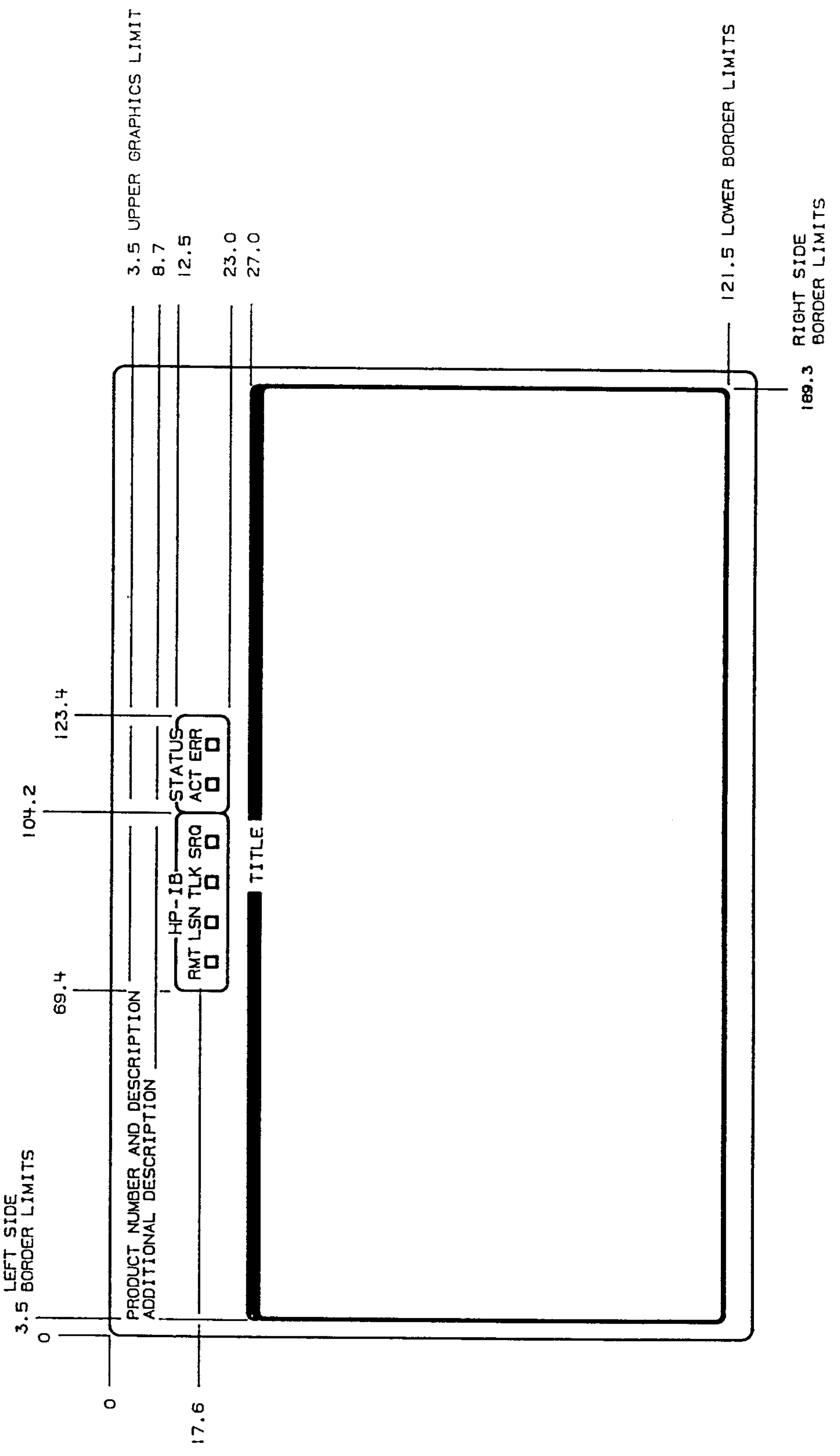


Figure 6.15: Front Panel Graphics Positioning, 4/8 Module

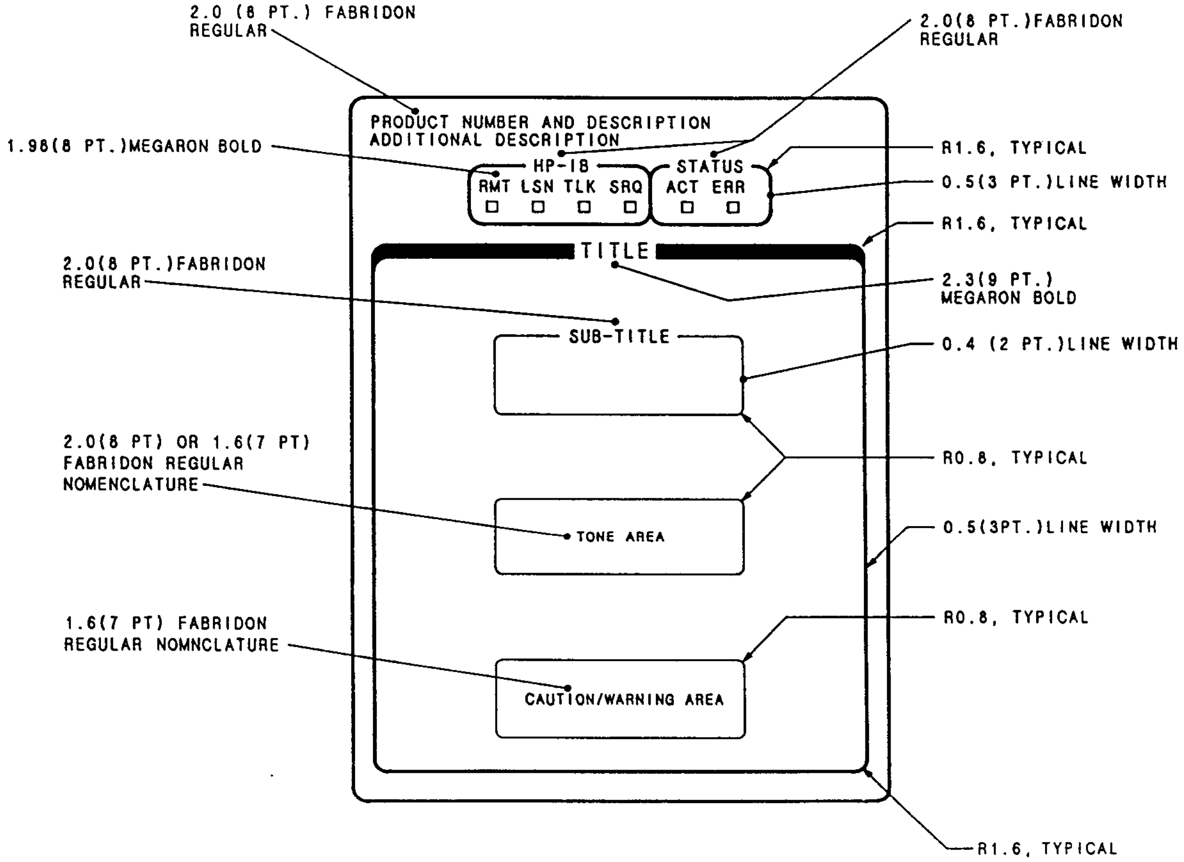


Figure 6.16: Front Panel Typeface Sizes and Graphics Dimensions

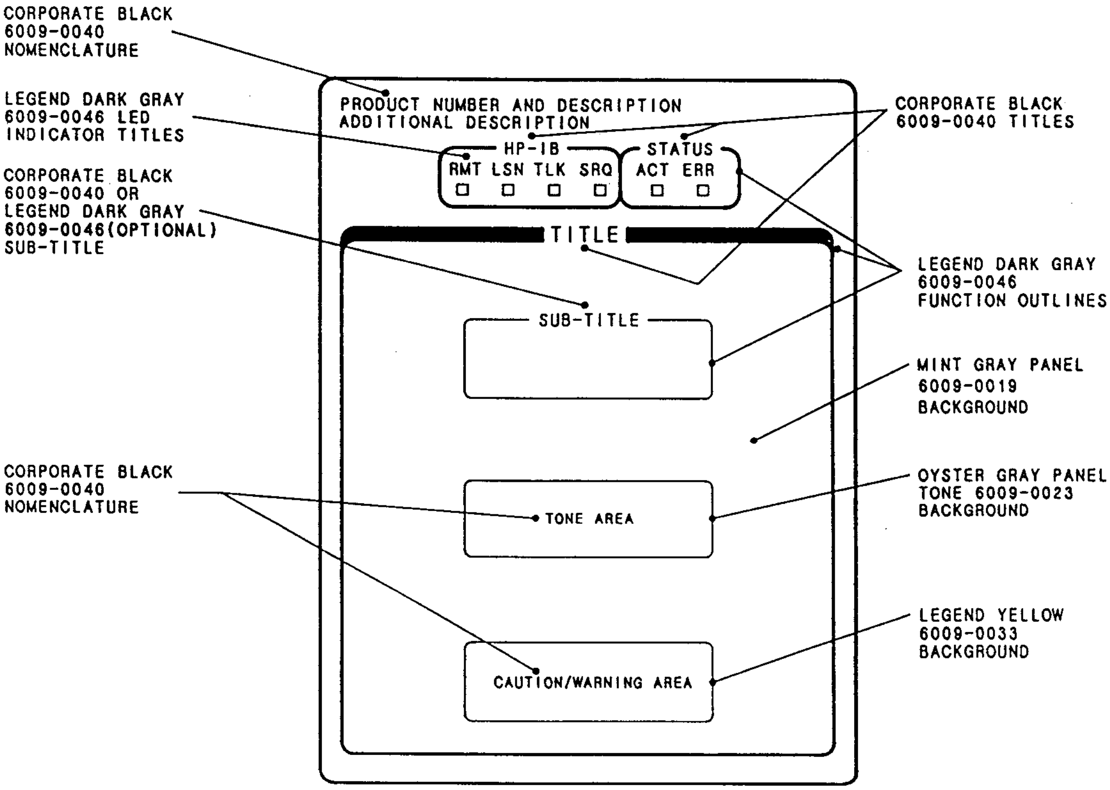


Figure 6.17: Front Panel Graphics Colors

Indicators

Table 6.1: Front Panel Indicators/Applications/Part Nos.

Indicator Application	LED Color	LED Part No. *
SELF TEST OVEN COLD PLL ERROR UNLEVELED ERR (Status)	Red	1990-1129
RF EXTERNAL REF RMT (HP-IB) LSN (HP-IB) TLK (HP-IB) SRQ (HP-IB)	Yellow	1990-1130
MEASURE ACT (Status)	Green	1990-1131

* LEDs available individually through HP Corporate Parts Center. See also appendix E.

Notes:

(a) Indicator Color Parameters:

RED:	Caution/Warning applications.
YELLOW:	General/Normal operations.
GREEN:	Activated/On applications.

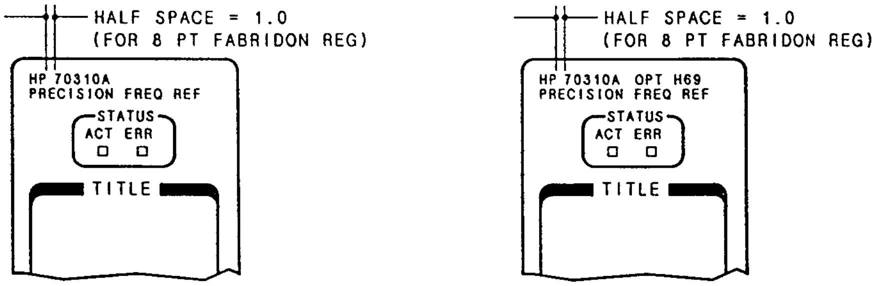
(b) The recommended LED light bar is to be mounted so that its top/illuminated surface is parallel to, and positioned 0.4 ±0.4mm from, the backside of the front panel when fully assembled. (The position of the light bar is important to assure consistent light projection and viewing angle range.) Panel hole size: 2.2 mm X 2.2 mm.

(c) For consistent brightness, power requirements differ for the three colors. The following table lists the recommended voltages (V_F) and currents (I_F) for the LEDs.

LED	V_F	I_F	Resistance *	Power * Required
Red	1.83V	3.17 mA	1 k-ohms	0.016W
Yellow	2.01V	6.64 mA	450 ohms	0.033W
Green	1.96V	6.76 mA	450 ohms	0.034W

* Assumes a 5V source.

For modules produced by Hewlett-Packard, all module model numbers should be preceded by the uppercase letters "HP". Half a letterspace should be placed between "HP" and the model number. For option designations on modules, the recommended format is "HP XXXXXA OPT XXX". The same format should also be indicated on the rear panel identification block.



Notes:

(a) See figures 6.12 through 6.15 for front panel product identity graphics positioning information.

(b) The rear panel model number designation should also be preceded by "HP" uppercase letters.

Figure 6.18: Module Front Panel Product Identification

SERIAL NUMBER BLANK LABEL

PART NUMBER: 5180-2350
DRAWING NO.: A-5180-2350-1
B-5180-2350-2

OPTION NUMBER BLANK LABEL

PART NUMBER: 5180-2351
DRAWING NO.: A-5180-2351-1
B-5180-2351-2

Note: These labels are positioned into recessed features on the module front die castings. The serial label is to be located to the front right side of the module latch with the nomenclature reading vertically from the bottom up. The option label is to be located to the front left side of the module latch with the nomenclature reading vertically from the bottom up. Refer to ERS drawings listed in appendix F.

Figure 6.19: Hewlett-Packard Serial & Option Labels

Rear Panel
Sizes

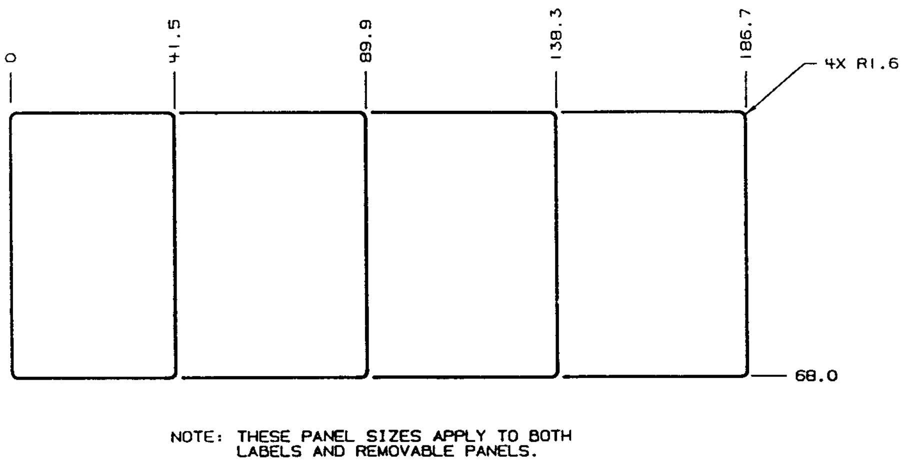


Figure 6.20: Module Rear Panel Sizes

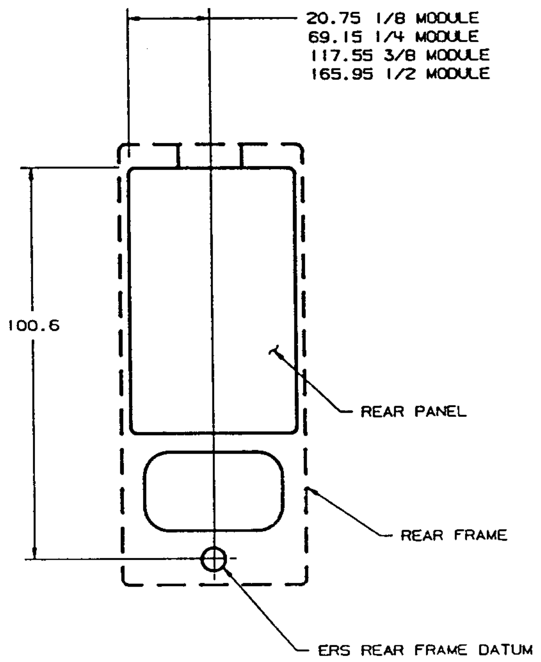


Figure 6.21: Rear Panel ERS Datum References

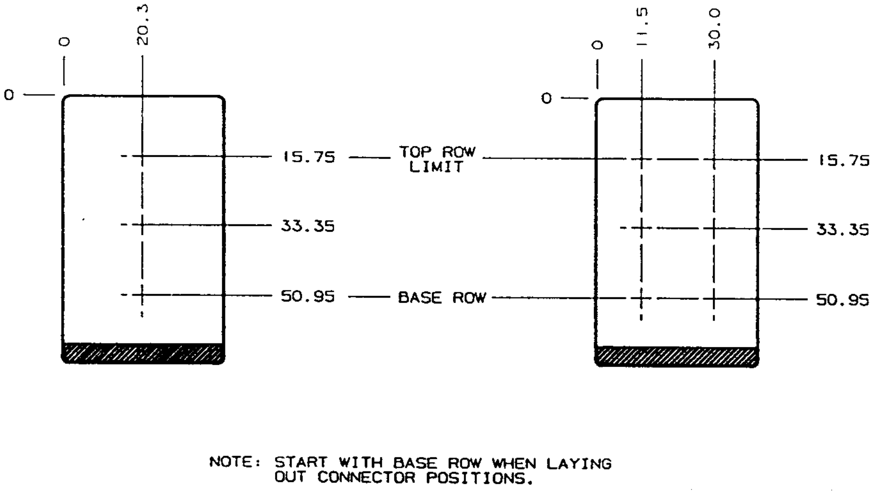


Figure 6.22: Rear Panel 3 & 6 Component Gridwork, 1/8 Module

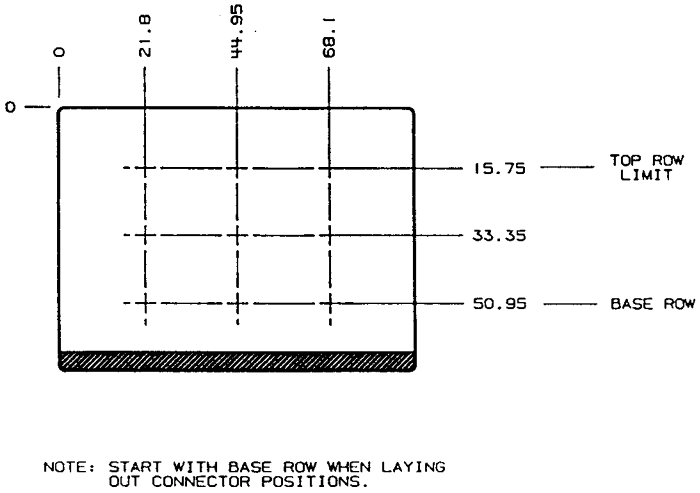
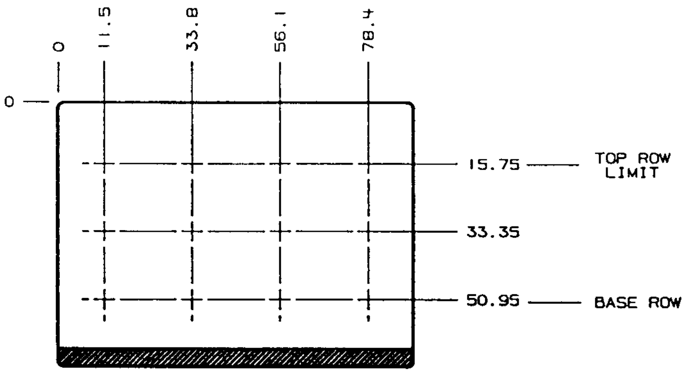
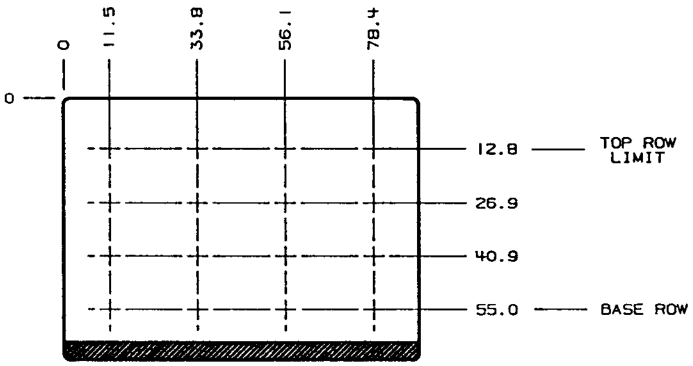


Figure 6.23: Rear Panel 3 to 9 Component Gridwork, 2/8 Module



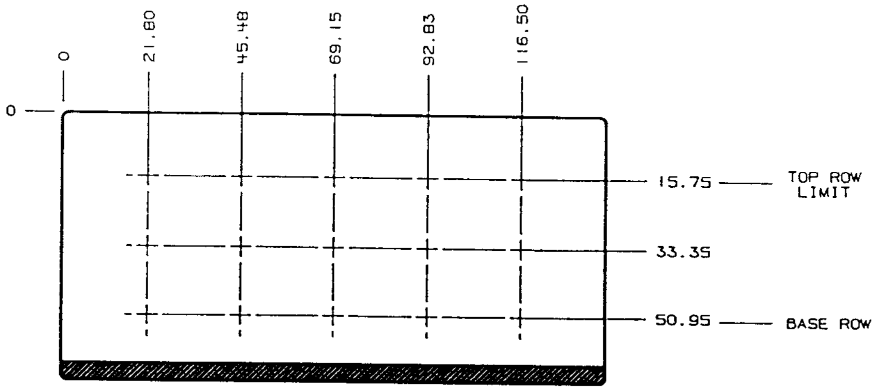
NOTE: START WITH BASE ROW WHEN LAYING OUT CONNECTOR POSITIONS.

Figure 6.24: Rear Panel 4 to 12 Component Gridwork, 2/8 Module



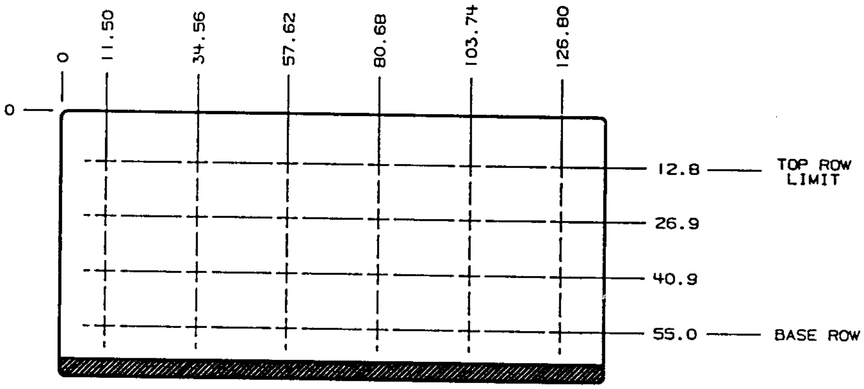
NOTE: START WITH BASE ROW WHEN LAYING OUT CONNECTOR POSITIONS.

Figure 6.25: Rear Panel 4 to 16 Component Gridwork, 2/8 Module



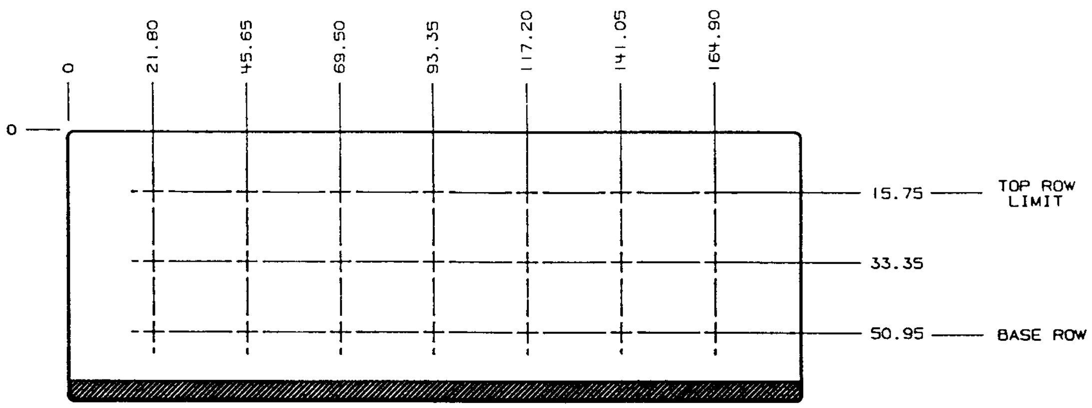
NOTE: START WITH BASE ROW WHEN LAYING OUT CONNECTOR POSITIONS.

Figure 6.26: Rear Panel 5 to 15 Component Gridwork, 3/8 Module



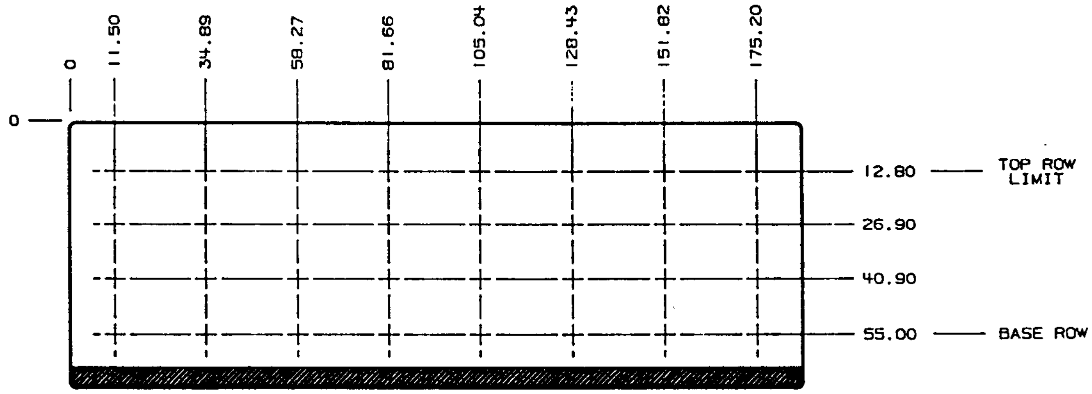
NOTE: START WITH BASE ROW WHEN LAYING OUT CONNECTOR POSITIONS.

SMA/SMB Connectors Only
Figure 6.27: Rear Panel 6 to 24 Component Gridwork, 3/8 Module



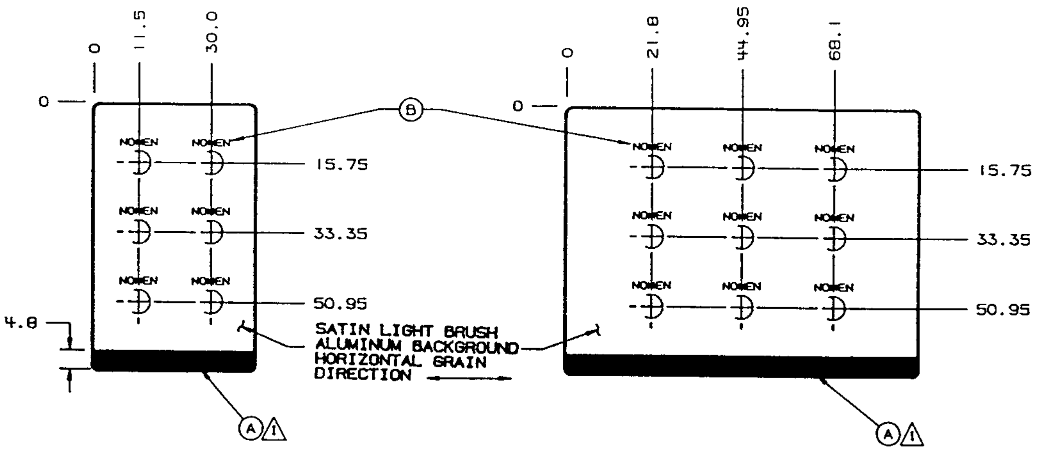
NOTE: START WITH BASE ROW WHEN LAYING
OUT CONNECTOR POSITIONS.

Figure 6.28: Rear Panel 7 to 21 Component Gridwork, 4/8 Module



NOTE: START WITH BASE ROW WHEN LAYING
OUT CONNECTOR POSITIONS.

SMA/SMB Connectors Only
Figure 6.29: Rear Panel 8 to 32 Component Gridwork, 4/8 Module



Ⓐ MODEL NUMBER IDENTIFICATION BLOCK CENTER MODEL NUMBER (8PT MEGARON BOLD DROP OUT) ON BLACK FIELD (6009-0040).

△ THIS IDENTIFICATION BLOCK WILL BE ON ALL MODULE REAR PANELS USING THE SAME COLOR AND FORMAT. (SEE EXAMPLES IN APPENDIX A).

Ⓑ CONNECTOR NOMENCLATURE TO BE CORP. BLACK (6009-0040) (8PT AND 9PT MEGARON BOLD).

Figure 6.30: Rear Panel Typeface Sizes and Graphics Dimensions

Interconnect Cables (LO only)

The Local Oscillator (LO) signal is widely used in the HP 70000 System. For this reason a set of 14 standard LO semi-rigid cables is available to interconnect modules which use this signal. SMA is the standard interconnection convention. Figure 6.31 indicates the required placement of LO signal lines on any module. This information is for LO cabling only and supersedes standard rear panel layouts shown previously.

The set of 14 cables is actually two sets of seven cables, the first set to take "LO out" from one module to the "LO in" of another module located to the right of the first module in the mainframe. The second set of cables carries the signal to the left. (Left and right are as viewed from the rear of the mainframe and modules). Cable lengths from $\frac{1}{8}$ to $\frac{7}{8}$ module to LO spacing are available in each set. The use of these cables allows "cascading" of LO signals between modules. Their offset design allows clearance for cable removal and replacement. Their Hewlett Packard part number is provided in table 6.2. All designers need to be aware of the presence of these cables in the HP 70000 system, even if not used with a given module. See figure 3.13, page 34, for information on allowable protrusion of cabling from the module rear panel.

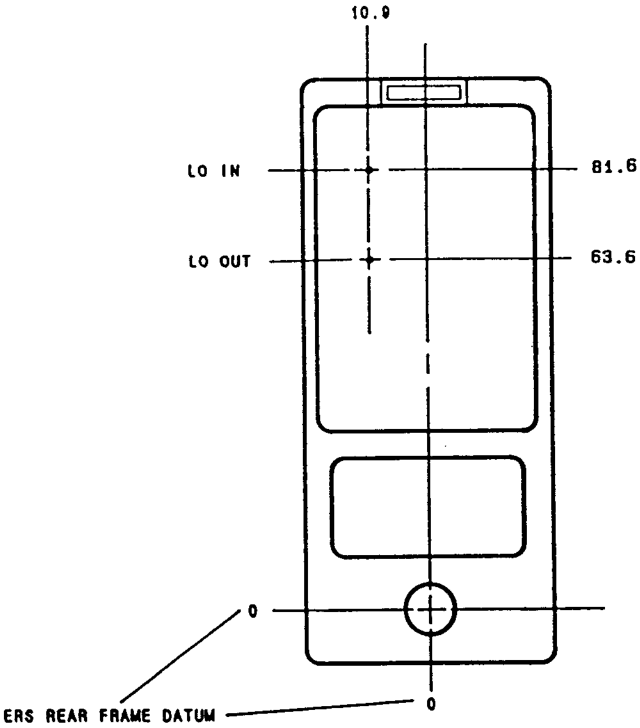


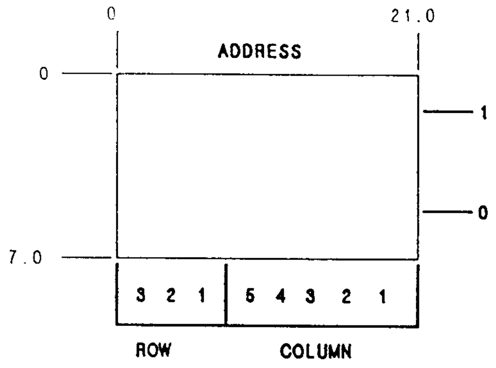
Figure 6.31: Rear Panel Module LO Interconnection Placement

Table 6.2: Rear Panel Standard LO Interconnect Cables

Module Spacing	Hewlett Packard Part Number	
	Right to Left	Left to Right
1/8	5021-5448	5021-5491
2/8	5021-5449	5021-5492
3/8	5021-5450	5021-5493
4/8	5021-5451	5021-5494
5/8	5021-5452	5021-5495
6/8	5021-5453	5021-5496
7/8	5021-5454	5021-5497
Family Drawing: C-5955-8987-1 & C-5958-4245-1		

Cover

Graphics



MODULE ADDRESS (8 POSITION)
PANEL OPENING AND GRAPHICS.

FOR SWITCH:
USE HP PART #3101-2094 OR
EQUIVALENT

Figure 6.32: Module Cover System Address Graphics

For modules which contain a mix of both metric and inch hardware, the caution note in figure 6.33 should be applied on the module cover. It should be located where it is highly visible. Make sure it is clear of the area where the mainframe grounding fingers abrade the cover when the module is inserted or removed.

CAUTION
METRIC & INCH HARDWARE
CONSULT SERVICE MANUAL

Figure 6.33: Module Cover Metric and Inch Caution Label

7

EMC Shielding

This chapter describes EMC shielding methodology that has proven effective in Hewlett-Packard module designs, and it provides an overview of suggested EMC testing procedures. In addition to this chapter's general guidelines, the designer should refer to the detailed discussion in the HP 70000 Modular Measurement System *Electromagnetic Compatibility Design Guide.*

EMC shielding of individual modules is essential to the electrical performance and emission-level compliance of the module and of other modules in the system. The module kit parts provided by Hewlett-Packard are general purpose solutions which alone provide moderate shielding up to approximately 30 MHz, considerable design flexibility, and ease of fabrication and assembly. These kits provide an excellent basis for RF and microwave applications. Those applications are likely to require some level of additional internal shielding. Additionally, a specific design problem may require kit alterations or custom enclosure design.

Chapter 3, Module Mechanical Interface, describes several features of the HP 70000 system which contribute to effective EMC shielding. Latching and locating details contribute significantly to RFI suppression and safety grounding. Other mainframe and module features contribute to the longevity and integrity of the system RFI performance. All currently produced mainframes and the module development kits include all of these features, and their inclusion in all new design is mandatory.

Mainframe EMC Grounding

Electrically conductive preformed-springs at several places in the mainframe provide an environment which helps to reduce EMI radiation and susceptibility. The springs (beryllium-copper with tin-nickel plating) are captive in the mainframe, hidden from view, and able to withstand more than 500 module-insertion cycles. Appendix F contains parts drawings for RFI springs.

Note

The need to maintain good electrical contact restricts module design flexibility in EMC spring contact-areas.

The mainframe has four primary RFI spring-contact grounds: at the top of the front and rear frames to interface with the top of module frames (see figure 3.3, page 20), and a set of upset-leaf springs on each side of each module's 50-pin connector(s). These four grounds are RFI control grounds, not safety grounds. Additionally, on the front inside surface on each side of the mainframe, there are two sets of springs to make contact with the modules in the two end slots only. The set of upset-leaf springs around the 50-pin-connector contact the module rear panel in the areas indicated in figure 7.1.

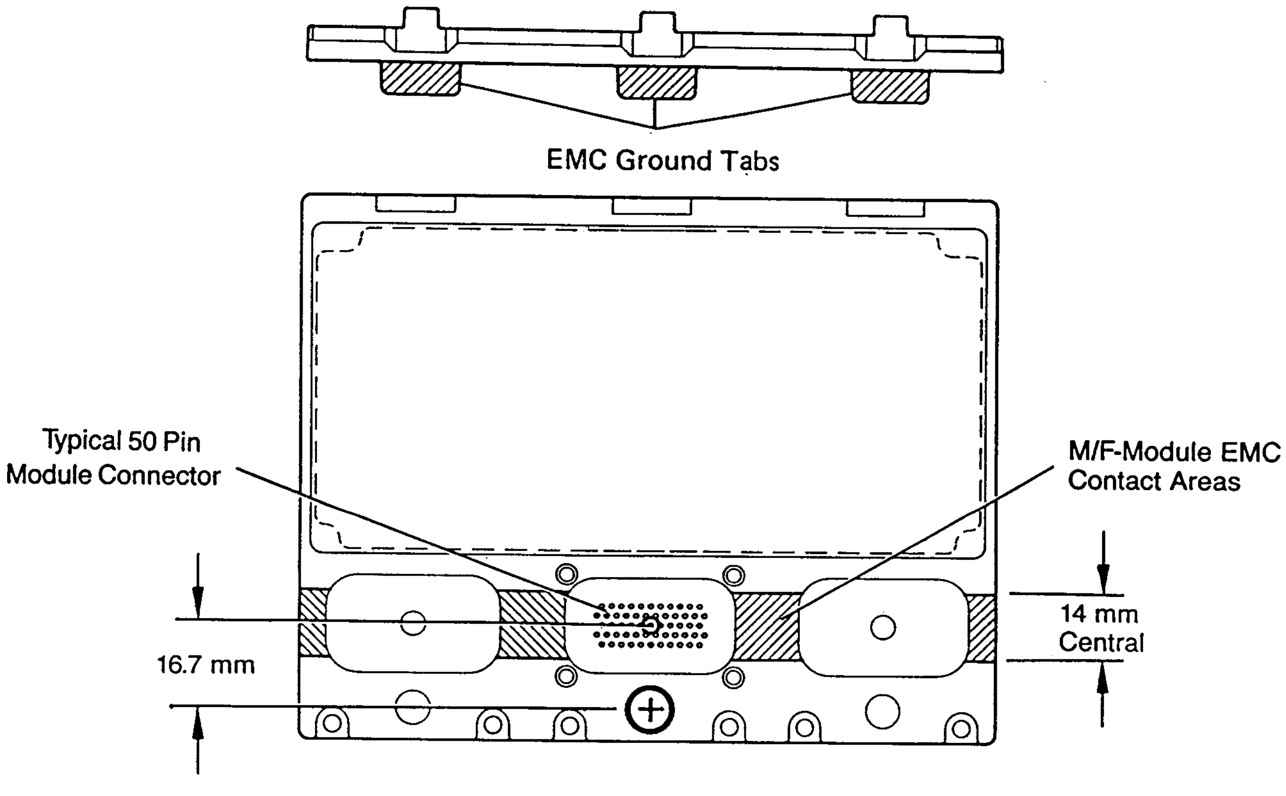


Figure 7.1: Typical Module Rear Frame Ground Spring Contact Areas

Module-to-module cabling should be done with caution. External ground loops (such as module to external devices) and ground return currents should be minimized and avoided when possible. The designer can often (especially at 40 kHz) achieve a significant reduction of ground loop currents by slipping a small toroid core such as the TDK H5C2 T3-6-1.5 (Hewlett-Packard Part Number 9170-1369) over a coaxial cable.

Module Shielding

The module mechanical-designs and their electrical interfaces allow the HP 70000 system to meet instrument EMC specifications. To preserve the system specifications, all module designs should conform to the specifications found in the *Electromagnetic Compatibility Design Guide.* In a modular system, unwanted interaction can exist between modules or between mainframe power supply and modules. The following subsections discuss effective shielding techniques that the designer should investigate.

Printed Circuit Board-Hosted Component Shielding (Source-Shielding)

The most efficient and desirable shielding techniques involve localized-shielding of any printed circuit board's mounted components that are strong emitters of radiation, or are highly sensitive to emissions and selective containment of radiation close to or at the source. The result is more repeatable and consistent electromagnetic performance. Cooperation between the mechanical and electrical engineers on a project can aid the development process by allowing thorough evaluations of pc-board layouts and circuit shielding.

An electromagnetic wave has an H (magnetic) field and an E (electric) field. High current flow creates an H field; high voltage creates an E field. The ratio E/H is Z_W (impedance), which determines energy reflection when a wave encounters a barrier (enclosure)—a large impedance mismatch causes a large energy reflection.

A metal's conductivity and its impedance are inversely related; therefore, most H field energy is absorbed, most E field energy is reflected. The energy that does cross a boundary causes current flow. Because of skin effect, current flow is not uniform throughout a conductor. The following equation indicates current distribution:

$$J = J_o e^{-x/\delta}$$

where,
J = current density,
J_o = surface current density,
x = distance from surface, and
δ = skin depth.

The skin-effect concept affects enclosure thickness design. Every skin depth of penetration attenuates electromagnetic fields by $1/e$. The minimum effective shield has a thickness of 1.2 skin depths, providing about 10 dB of attenuation. Normal shielding range is 20 to 80 dB. Shields that provide 80 to 120 dB attenuation are excellent. It is difficult to economically build and install shields more effective than this 120 dB figure.

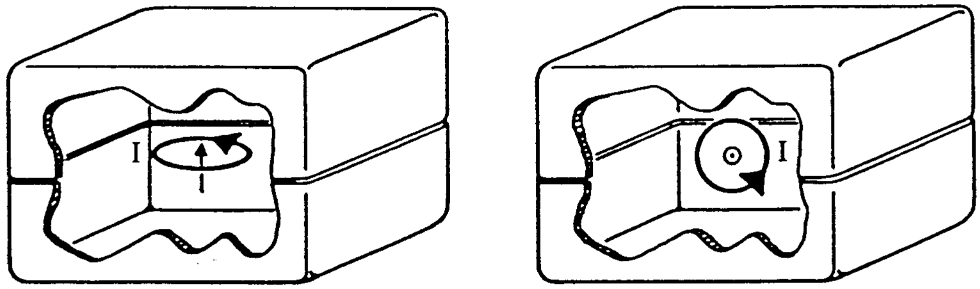
One method of determining overall shielding effectiveness is to add the reflection, absorption, and re-reflection losses for the shield. This allows the designer to combine the effects of source shielding and exterior enclosure shielding—for example, assuming a continuous sheet of conductive material, the following equation expresses the shielding effectiveness (S) in dB.

$$S = A + B + R$$

where, A = absorptive loss,
B = reflective loss, and
R = multiple reflections.

Analytic calculation of shielding effectiveness of an actual design can be difficult and unnecessary. Some of the factors that influence effectiveness are material and design, type of field, distance from the source, and shield discontinuities (high contact impedance). At frequencies greater than one megahertz, shield discontinuities can have the most influence on absorptive shielding effectiveness. Shield openings or holes provide a path for electromagnetic radiation. To minimize losses, openings larger than $\lambda/20$ for commercial devices and $\lambda/50$ for military systems should be avoided. (Because EMI is usually broadband, λ should be the highest frequency in the bandwidth.)

In designing shields, it should be kept in mind that shields with seams which are parallel to the circuit current flow are generally more effective than shields with other seam orientations (see figure 7.2). This is because the circuit current will induce a parallel current in the shield which will radiate less if it does not have to cross a seam.



Recommended
Parallel Circuit Currents

Not Recommended
Perpendicular Circuit Currents

Figure 7.2: Importance of Seam Orientation in Magnetic Shielding

Optimizing Printed Circuit Board Layout

The printed circuit board designer should be well versed in, or should consult an electrical engineer well versed in, printed circuit board layout for EMC optimization (placement of circuits to minimize coupling, placement of printed circuit board layers, importance of nearby magnetic devices, etc.) In addition to defining EMC performance limits of a given layout, the printed circuit board layout contributes significantly to total module shielding effectiveness. The mechanical designer might not design the printed-circuit boards, but attention paid to related EMC considerations can assist the electrical development process. Interactive mechanical and electrical development will help assure a successful and efficient EMC shielding plan. Because of the poor predictability of EMC performance of a module, and because of the difficulty of making major layout changes late in the development cycle, the mechanical designer should help evaluate EMC considerations in the early stages of development. To facilitate electromechanical interaction evaluations, the designer can wire-wrap circuits and breadboard the analog circuits in final electrical configurations, then test them in a module.

Contact Resistance and Seam Design

Contact resistance and seam design are important concerns. Contact resistance across seams must be kept low. Consider the following factors:

- Pressure
- Material
- Surface Area
- Corrosion (non-conductive salts)

Contact resistance is usually a strong function of applied pressure; therefore, the shield's mechanical design must guarantee that adequate pressure exists even with worst case dimensions on all mating parts. Figure 7.3 shows the variation of contact resistance with applied pressure for many metallic joints; the vertical axis is proportional to the achieved shielding effectiveness. Operation on the flat portion of the curve is best to avoid large contact resistance variations with small pressure changes. This practice improves the repeatability of shielding and thus reduces test and adjustment times. Early conductivity testing is highly recommended because the resulting data will ensure more accurate and expeditious development cycles.

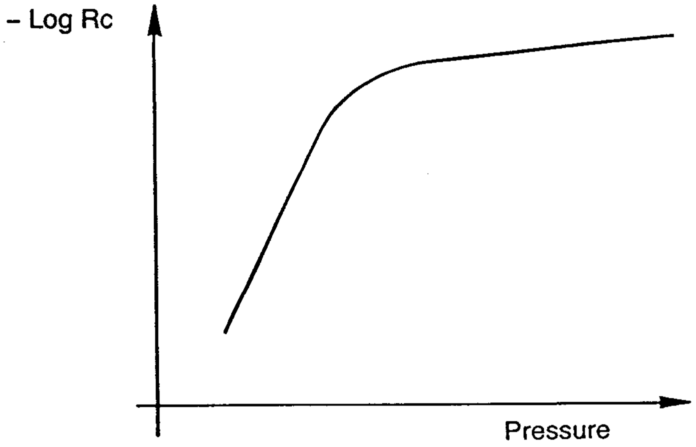


Figure 7.3: Contact Resistance vs Applied Pressure

Surface corrosion and their associated non-conductive salts also contribute to high contact resistance. Whenever possible avoid placing dissimilar metals in intimate contact because such contacts produce galvanic cells—the larger the cell potential, the greater the likelihood of corrosion. If dissimilar metal contact is unavoidable, the metals should have a small electronegativity cell potential (see appendix B for electronegativity data). Any shield design, regardless of metal system, should be tested for shielding degradation under high temperature and high humidity conditions.

Increasing contact surface area at the seams while maintaining a proportionate clamp pressure (see figure 7.4) can significantly reduce transfer impedance. In addition, contact areas should have a moderate amount of surface roughness to guarantee at least microscopic points of contact. The "Better" butt joint in figure 7.4 is utilized in the cover-to-base interface detail in the HP 70000 development kits (see figure 5.4, page 57)

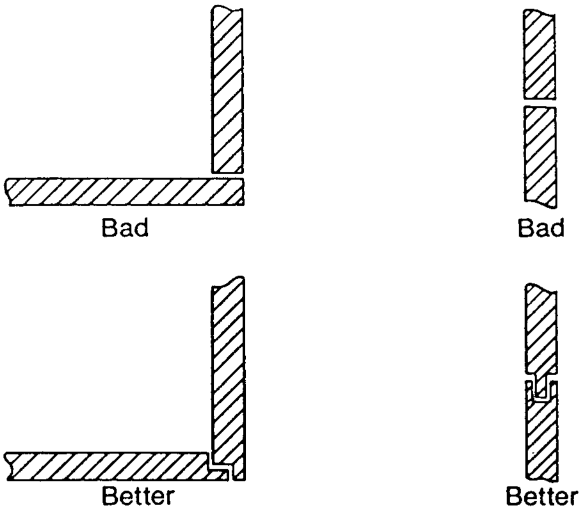


Figure 7.4: Optimizing Surface Areas at the Seams

Given a fixed clamping force, increasing seam surface-area will decrease contact pressure.

EMC Testing Guidelines

Successful EMC design is verifiable only through testing and often requires iterations. To be of value to circuit and enclosure designers, an EMC test procedure must provide useful data in a repeatable, straightforward manner. This section discusses recommended, general purpose test procedures that require minimal setup but are flexible enough to accommodate a variety of test conditions. Test procedures and/or hardware are designer's choice, of course, but the procedures outlined here have proved useful for developmental work at Hewlett-Packard.

Swept Broadband Measurements

Swept broadband shielding evaluations minimize test times, and improve overall measurement quality. This data can be useful in modifying the design to reduce module to module interaction. Measurements with a single-frequency tuned-receiver would require a greater amount of time and would produce incomplete results—for example, narrowband emissions from high-Q shielding defects that can easily be missed in a single-frequency tuned measurement are easily uncovered with this swept system. Figure 7.5 shows a typical swept measurement.

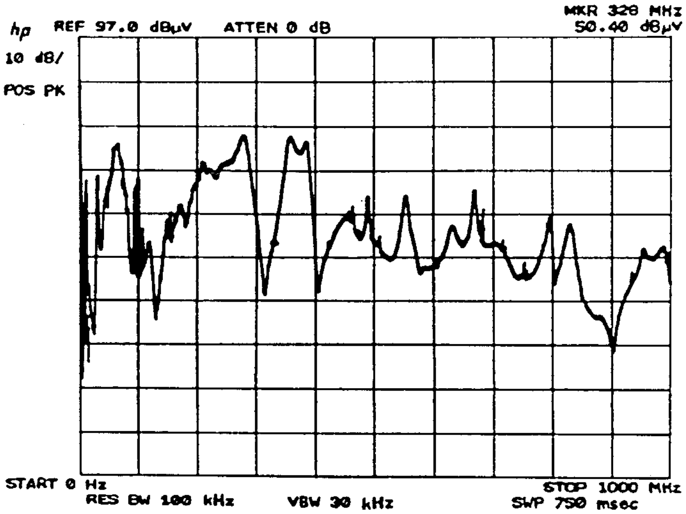


Figure 7.5: Example of Swept Broadband Shielding Effectiveness.

A tracking generator eliminates the need for multiple analyzer sweeps of certain types of circuitry. For instance, proper relative amplitude measurements can be tricky to perform on digital circuitry and swept LOs. This is because the amount of energy radiated from digital circuitry varies as a function of time and clocking rates, and radiation is only measured from a sweeping LO when the radiating frequency matches the input frequency of the swept analyzer.

Typical Measurement System

Spectrum-analyzer based systems provide versatility when measuring shielding effectiveness of circuit enclosures and cabling. Just changing the transducer adapts the system to various test conditions: bench top, screen room, site test area, etc. Figure 7.6 is a block diagram of a concise measurement system that produces repeatable data.

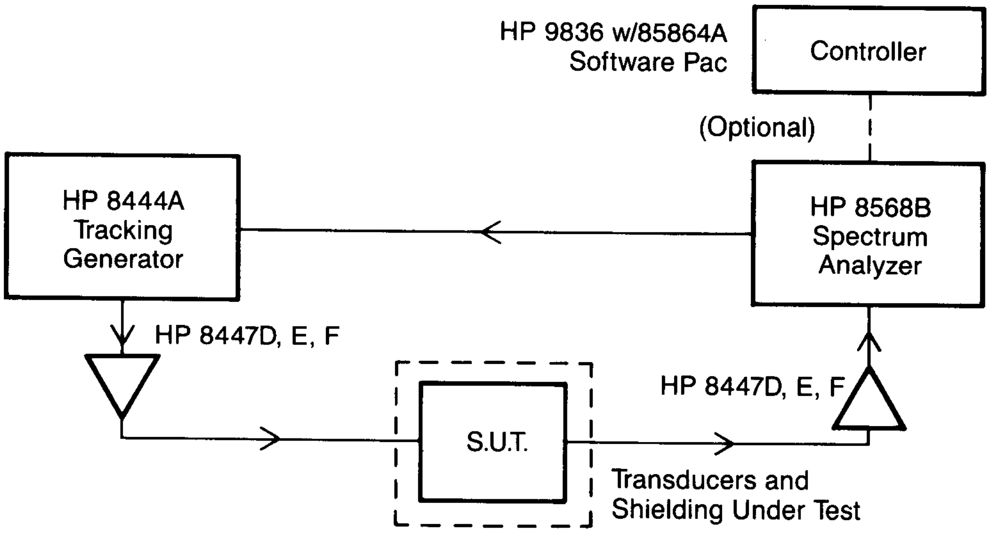


Figure 7.6: A Typical Shielding Effectiveness Measurement System

The HP 11940A & 11941A Close-Field Probes

A bench top method for quick, non-destructive radiation testing is a valuable aid to the mechanical designer. This localized testing requires a smaller antenna. The HP 11940A Close-Field Probes, for instance, are hand-held magnetic field antennas designed for this kind of application in environments from 9 kHz to 1GHz. The 11940A is calibrated for use from 30 MHz to 1 GHz. The 11941A is calibrated for used from 9 kHz to 30 MHz.

The HP 11940A and 11941A also serve to locate radiating sources in electronic equipment and to map localized field strengths. The probe gathers amplitude and frequency information, and that makes possible generation of suspect frequency lists before an open-area test, thereby reducing test time. Figure 7.7, illustrates the probe and a sample frequency plot.

Transmitting Test Antenna

Figure 7.8 diagrams a broadband, microstrip transmitting-antenna to be placed inside the module. It works in conjunction with the test setup in figure 7.6. It is

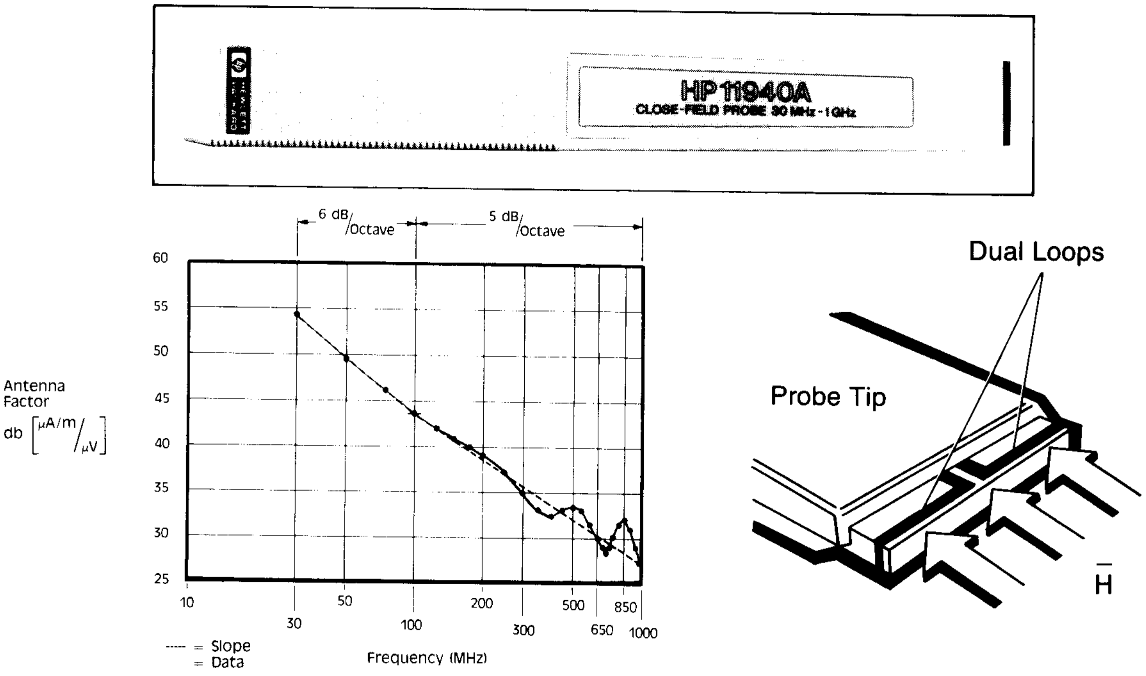


Figure 7.7: The HP 11940A Close-Field Probe and Frequency Plot

inexpensive and easy to fabricate in a variety of shapes. Input characteristics are stable over the entire operating range of the tracking generator.

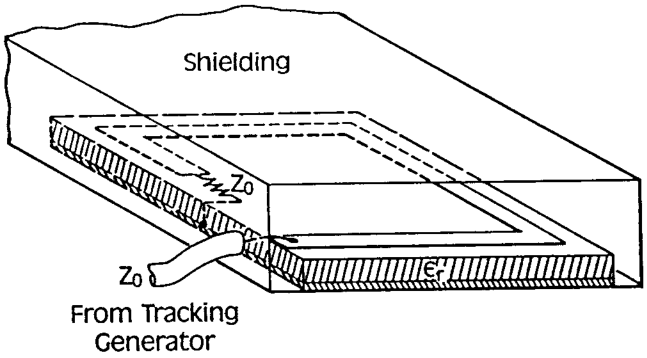


Figure 7.8: Microstrip Transmitting Antenna

The recommended broadband transmitting structure is a 50 ohm microstrip trace terminated in its characteristic impedance. Microstrip design curves are readily available. Here are some design considerations:

- Low dielectric-constant material and long line lengths maximize radiation.
- Low radiation efficiency is the major tradeoff for the broadband operation.
- Measurement repeatability requires care in antenna placement relative to the shield in question.
- It is necessary to have the shield of the coaxial input connector well grounded to the shielding enclosure under test.

8

Safety Requirements

IEC Rating

All module designs should satisfy the IEC-348 specification, *Safety requirements for electronic measuring apparatus* (1978). Compliance with IEC-348 is in keeping with HP 70000 system goals, and some European markets (e.g. France, UK, Germany) *require* this compliance. The HP 70000 system products designed and manufactured by Hewlett-Packard meet or exceed IEC-348 at the system level. It is the responsibility of individual designers to assure that their specific module design and manufacture comply with IEC-348 requirements, thus guaranteeing that the system which includes this module also complies with IEC-348.

UL Ratings

Since the HP 70000 system is intended for *non-household* use, it has not been submitted for UL testing. However, UL 1244 guidelines are incorporated in the design wherever applicable.

Safety Markings

Hewlett-Packard policy requires that those who use or service Hewlett-Packard equipment must be clearly warned of potentially hazardous conditions. To be consistent and to avoid ambiguity within the HP 70000 system, we recommend a compatible system of safety warnings and symbols. See appendix C for examples of Hewlett-Packard safety warnings and symbols.

A

Compatibility Requirements

All of the compatiblity requirements are listed below with page reference of where they appear in the document.

Critical Reliability Requirements

1. Each module *must* contain dedicated fire protection—fuse or circuit-breaker. This is required because load current conditions damaging to a module may be well below the protective limits of the mainframe. (Page 13.)
2. The module has a carefully engineered low impedance safety grounding interface. It is a connection from the bottom of the module rear frame casting through the mainframe support pin to the mainframe rear casting, as shown in figure 2.1. This ground connection must be preserved to help ensure operator safety. (Page 14.)

Design Recommendation

3. The maximum recommended module width is $\frac{3}{8}$. Although $\frac{4}{8}$ modules are allowed they are not recommended because of special constraints on the guide pin/bushing interface which require thorough engineering evaluation. (Page 17.)

Critical Reliability Requirement

4. Only one latch screw per module is allowed, and its position must be consistent with the guidelines shown in figure 3.4. (Page 21.)

Measurement Performance Requirement

5. The number of bosses must correspond to the $\frac{1}{8}$ multiple (one boss per $\frac{1}{8}$ width). Only *one* boss per module is a functional locator; others act as contact points for the mainframe top ground springs. (Page 22.)

Measurement Performance Requirement

6 Regardless of module size, only one boss provides alignment, but all bosses contact the mainframe EMC suppression springs. If the shaded areas in figure 5.3 , page 56 (the boss surfaces and those areas between the 50-pin connectors) receive a coating, it must be durable, conductive, and compatible with tin (ground springs are tin plated). (Page 22.)

Critical Reliability Requirement

7 The following are mandatory rear-frame components: 50-pin module connector, guide-pin grounding spring, float hardware, and guide bushing(s). Refer to figure 3.5. (Page 22.)

Design Recommendation

8 The alignment-pin and precision-bushing design provides dynamic stability (see figure 3.2). Proper accomodation of weights greater than 5.0 kg (11.0 lbs) require a second horizontally elongated bushing(see table 3.6). (Page 23.)

Critical Reliability Requirement

9 Two bushings are required for modules heavier than 5.0 kg, and are recommended for all $\frac{4}{8}$ width modules. (Page 28.)

Design Recommendations

10 Centroids of large mass should be as low as possible in the y-axis and as close as possible to the front of the module in the z-axis. (See figure 3.1.) (Page 28.)

11 To prevent interaction, the HP-MSIB and HP-IB signal lines should be independently shielded within the module. (The 50-pin connector and cable assembly in figure 3.11, page 32, conforms to this requirement.) (Page 30.)

Critical Reliability Requirements

12 In particular, LINE SYNC RETURN *must not* connect directly to ground in any module. (Page 31.)

13 The 50-pin module connectors are to mate only with similar connectors as specified in this manual. (Page 31.)

Design Recommendations

14 One 50-pin module connector per module is recommended. The use of two or connectors is discouraged due to the risk of connector mismating or connector damage. All module sizes currently supported by Hewlett-Packard contain only one 50-pin module connector. (Page 32.)

15 At a flow rate of 3.5 cfm, the module flow resistance should be no greater than 0.065 inches H^2O. That is,

$$\begin{aligned} \Delta P &\le .065 \text{ inches } H_2O \text{ @ } 3.5 \text{ cfm per } \frac{1}{8} \text{ module @ STP} \\ \text{or} &\le 16.2 \text{ Pa @ } 5.95 \text{ m}^3/\text{h per } \frac{1}{8} \text{ module @ STP.} \end{aligned}$$

where, ΔP = intake pressure − exhaust pressure,
Pa = pascal, the si (international system of units) term for pressure expressed in Newtons/meter^2,
STP= standard temperature and pressure. (Page 37.)

16 To guarantee that repeated module removal and replacement will not damage the EMI suppression springs (see figure 3.3), the zones indicated in figure 4.2 must be free of upsets, screen printing, and perforations larger than 4.0 mm diameter. (Page 39.)

17 Air-exit ports should be located on the top of the module cover, near the front, to take advantage of natural convective currents. Air exit ports on the sides of modules are not recommended because of possible adverse heating of adjacent modules. (Page 39.)

18 For optimal cooling, vertical printed circuit board orientation is recommended (see figure 4.3). (Page 39.)

Design Recommendation

19 This formula estimates forced air convective cooling requirements for modules in an HP 70001A mainframe.

$$A = 1.72 \times \frac{P}{\Delta T}$$

where, A = airflow in cfm,
ΔT= maximum temperature rise °C, and
P = total dissipated power in watts. (Page 45.)

Critical Reliability Requirement

20 The use of the air inlet gaskets on the module base is required. Their elimination can result in an improper mechanical mating (jamming) of the module in a mainframe.

Air transition seals help ensure delivery of the cooling air at the specified maximum back-pressure (3.5 cfm per standard module width @ 0.065 inches H_2O). (Page 63.)

Product Consistency Requirement

21 To maintain consistent human interface and system continuity (e.g. annunciator placement, color, panel sizes), the designer must comply with specifications presented in this chapter. (Page 65.)

B

Tables

Integrated Circuit Derating

Thermally overstressed components are probably the single most important contributor to reliability problems in electronic devices[1]. The information in the following table is a design guideline; it is always necessary to verify compliance with manufacturers maximum temperatures by means of a complete thermal analysis.

Table B.1: Integrated Circuit Derating

Type	Recommended Practice	Do Not Exceed
BIPOLAR DIGITAL SSI/MSI	TO 85^oC T_{JUNCTION} TO 65% MAX*, LOAD	120^oC T_{JUNCTION} 85% MAX*, LOAD 85% MAX, FREQUENCY
BIPOLAR DIGITAL LSI LINEAR	TO 65^oC T_{JUNCTION} TO 65% MAX*, LOAD TO 65% MAX*, VOLTAGE**	85^oC T_{JUNCTION} 85% MAX*, LOAD 85% MAX*, VOLTAGE
MOS DIGITAL & LINEAR	TO 50^oC T_{JUNCTION} TO 50% MAX*, CURRENT TO 50% MAX*, VOLTAGE**	70^oC T_{JUNCTION} 70% MAX*, CURRENT 70% MAX*, VOLTAGE

* of 25^{o}C Rating
** LINEAR

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[1] RE: HP application note no. 263

Thermal Conductivity

The following table provides the thermal conductivity and expansion of material commonly used in electronic equipment.

Table B.2: Thermal Conductivity and Expansion

Material	Thermal Conductivity (Watts/cm°C)	Thermal * Expansion μm/m per °C)
Metals		
Aluminum, die cast	0.994	20.9
Aluminum, extruded	2.088-2.165	23.4
Aluminum, sheet	1.382	23.2
Beryllium	1.772	12.0
Beryllium Copper	1.063	16.7
Brass (70% copper - 30% zinc)	1.220	20.5
Copper	3.937	16.6
Gold	2.913	14.2
Iron	0.669	12.0
Kovar	0.165	5.2
Lead	0.343	29.0
Magnesium	1.575	25.0
Molybdenum	1.299	5.0
Monel	0.197	14.5
Nickel	0.906	13.0
Silver	4.173	19.0
Stainless Steel 321	0.146	16.2
Stainless Steel 410	0.240	10.3
Steel, Low Carbon	0.669	15.1
Tin	0.630	20.0
Titanium	0.157	8.5
Tungsten	1.969	4.5
Zinc	1.024	35.0
Semiconductors		
Gallium Arsenide	0.591	6.8
Silicon (pure)	1.457	3.0
Silicon (doped to resistivity of .0025 ohm cm)	0.984	

* From CRC Handbook of Chemistry and Physics, and other industry sources.

Table B.2 Continued

Material	Thermal Conductivity (Watts/cm°C)	Thermal * Expansion μm/m per °C)
Insulators		
Still Air	0.0003	
Alumina (99.5%)	0.276	7.7
Alumina (85%)	0.118	5.6
Beryllia (99.5%)	1.969	7.5
Beryllia (97%)	1.575	
Beryllia (95%)	1.161	
Boron Nitride (hot pressed)	0.394	7.7
Diamond	6.299	3.2
Epoxy	0.002	60.0
Thermally conducting epoxy	0.008	
Glass	0.008	8-12.8
"Heat Sink Compound" (metal oxide loaded epoxy)	0.004	
Mica	0.007	8-25
Mylar	0.002	
Phenolic	0.002	20-40
Silicone Grease	0.002	
Silicone Rubber	0.002	1200
Teflon	0.002	100
FR-4 G-10 Printed Circuit Board (Bare)	0.003	

* From CRC Handbook of Chemistry and Physics, and other industry sources.

Panel Annotation Abbreviations

This section provides example abbreviations for words and phrases that commonly appear on the front and/or rear panel(s) of HP 70000 system modules.

Table B.3: Panel Abbreviations

Abbreviation	Definition
1st	FIRST
2nd	SECOND (not time)
AC	ALTERNATING CURRENT
ACT	ACTIVE
ADJ	ADJUST
ADRSD	ADDRESSED
ADRS	ADDRESS
ALC	AUTOMATIC LEVEL CONTROL
ALT	ALTERNATE
AMP, A	AMPERE
AM	AMPLITUDE MODULATION
AMPL	AMPLIFIER
AMPTD	AMPLITUDE
ASTIG	ASTIGMATISM
ATTEN	ATTENUATION
AUTO	ATUOMATIC
AUX	AUXILIARY
AVG	AVERAGE
BAL	BALANCE
BAT	BATTERY (electrical)
BKSP	BACK SPACE
BL	BASELINE
BW	BANDWIDTH
CAL	CALIBRATE
CF	CENTER FREQUENCY
CHAN, CH	CHANNEL
COHER	COHERENCE
CONFIG	CONFIGURATION
CONT	CONTINUOUS
CONV	CONVERTER
CW	CONTINUOUS WAVE
dBm	DECIBEL REFERRED TO 1 MILLIWATT
DC	DIRECT CURRENT
DECR	DECREASE
DEMOD	DEMODULATOR
DFI	DISCRETE FAULT INDICATOR
DGTL	DIGITAL
DIV	DIVISION

Table B.3 Continued

Abbreviation	Definition
DSPL, DSP	DISPLAY (use DSP only if space is limited)
ECL	EMITTER-COUPLED LOGIC
ERR	ERROR
EXT	EXTERNAL
FFS	FRACTIONAL FREQUENCY SYNTHESIZER
FCTN	FUNCTION
FM	FREQUENCY MODULATION
FREQ	FREQUENCY
GEN	GENERATOR
GRAT	GRATICULE
HORIZ	HORIZONTAL
HP-IB	HEWLETT-PACKARD INTERFACE BUS
HP-MSIB	HEWLETT-PACKARD MODULAR SYSTEM INTERFACE BUS
HSWP	HIGH SWEEP
I-P	INSTRUMENT PRESET
I/O	INPUT/OUTPUT
IDENT	IDENTIFY/IDENTIFICATION
IDL	IDLER (IDLER OSCILLATOR)
IF	INTERMEDIATE FREQUENCY
ILLUM	ILLUMINATE/ILLUMINATION
IN	INPUT
INCR	INCREASE
INSTR	INSTRUMENT
INT	INTERNAL
INTEN	INTENSITY
ISOL	ISOLATE
LCL	LOCAL
LIN	LINEAR
LO	LOCAL OSCILLATOR
LSN	LISTEN
LVL	LEVEL
LWR	LOWER
MAX	MAXIMUM
MEM	MEMORY
MIN	MINIMUM
MKR	MARKER
MNL	MANUAL
MNU	MENU
MXR	MIXER
NORM	NORMAL
OC	OPEN COLLECTOR
OPT	OPTION
OUT	OUTPUT

Table B.3 Continued

Abbreviation	Definition
PK	PEAK
PLL	PHASE LOCK LOOP
POS	POSITIVE
POSN	POSITION
PREAMP	PREAMPLIFIER
PRESEL	PRESELECTOR
PWR	POWER
RBW	RESOLUTION BANDWIDTH
RCL	RECALL
REF	REFERENCE
REG	REGISTER
REP	REPETITION
RES	RESOLUTION
RF	RADIO FREQUENCY
RMS	ROOT MEAN SQUARE
RMT	REMOTE
RNG	RANGE
SA	SPECTRUM ANALYZER
SEQ	SEQUENCE
SIG	SIGNAL
SQ	SQUARE
SRQ	SERVICE REQUEST
SSB	SINGLE SIDE BAND
STD	STANDARD
STP	STEP
SWP	SWEEP
TEMP	TEMPERATURE
TERMM	TERMINATION
TLK	TALK
TRIG	TRIGGER
TTL	TRANSISTOR TRANSISTOR LOGIC
UNCAL	UNCALIBRATED
UNLVLD	UNLEVELED
UPR	UPPER
USR	USER
V	VOLT(S)
VBW	VIDEO BANDWIDTH
VDC	VOLTS DIRECT CURRENT
VERT	VERTICAL
VOL	VOLUME
XFR	TRANSFER
XTAL	CRYSTAL
YTO	YIG TUNED OSCILLATOR

Display Annotation Abbreviations

This section provides recommended abbreviations for words and phrases that commonly appear in display annotations on HP 70000 Systems.

Table B.4: Display Annotation Abbreviations

Abbreviation	Definition	Comment
AMPTD, AMP, A	AMPLITUDE	Use AMP first; use A if space is limited.
ANALYZR	ANALYZER	
ANOTATN	ANNOTATION	
ATTEN	ATTENUATION, ATTENUATOR	
AUTO	AUTOMATIC	
AVG	AVERAGE	
CAL	CALIBRATE	
CF	CENTER FREQUENCY	
CHAR, CHR	CHARACTER	Use CHR only if space is limited.
CLR	CLEAR	
COMM	COMMUNICATION	
CONFID	CONFIDENCE	
CONFIG	CONFIGURATION	
CONT	CONTINUOUS	
CONV	CONVERSION	
DEF	DEFINITION	
DETECTR	DETECTOR	
DIV	DIVISION	
DL	DISPLAY LINE	
DSPL, DSP	DISPLAY	Use DSP only if space is limited.
EXCURSN	EXCURSION	
EXTD RL	EXTENDED REFERENCE LEVEL	
FUNCTN, FUNC	FUNCTION	Use FUNC only if space is limited.
GND	GROUND	
GRT	GRATICULE	
HARDCPY	HARDCOPY	
HARMNC#	HARMONIC NUMBER	
HLD	HOLD	
HYS	HYSTERESIS	
ID	IDENTIFICATION	
IMPED	IMPEDANCE	
IDENT	IDENTIFY	
INT	INTERNAL	
IP	INSTRUMENT	
KY	KEY	
LCL	LOCAL	
LIN	LINE	

Table B.4 Continued

Abbreviation	Definition	Comment
LOG	LOGARITHM	
LSN, L	LISTEN	
LVL	LEVEL	
MAN	MANUAL	
MIN	MINIMUM	
MKR, MK	MARKER	Use MK only if space is limited.
MXR	MIXER	
NEG	NEGATIVE	
NO.	NUMBER	
N START	START HARMONIC NUMBER	
N STOP	STOP HARMONIC NUMBER	
OSC	OSCILLATOR	
P STATE	PROTECT STATE	Use P only if no space for PROTECT.
PARAMS	PARAMETERS	
PATHLOK	PATHLOCK	
PK	PEAK	
POS	POSITIVE	
POSN	POSITION	
PT	POINT	
REL	RELATIVE	
RES BW, RBW, RB	RESOLUTION BANDWIDTH	Use RBW first, RB if no space
ROM	READ ONLY MEMORY	
SIG	SIGNAL	
SRC	SOURCE	
STMTS	STATEMENTS	
SWP	SWEEP	
THRESHD	THRESHOLD	
TRACKG	TRACKING	
TRIG, TRG	TRIGGER	Use TRG only if space is limited.
TRK	TRACK	
UDK	USER DEFINED KEY	
UNCAL	UNCALIBRATED	
UNCOR	UNCORRECTED	
VID	VIDEO	
VID BW, VBW	VIDEO BANDWIDTH	Use VBW only if space is limited.
WRT	WRITE	
XCH	EXCHANGE	

NOTES:

(a) The first rule of abbreviation is "Don't unless you must."

(b) Due to predominant industry usage or preference, certain abbreviations do not conform to ANSI Y1.1-1972 standards or are not covered by the standards.

(c) For SI units (International System of Units) and symbols, refer to section 610, HP Mechanical Design and Manufacture Manual.

Electronegativity Potentials

Table B.5: Electronegativity Potentials

No.	Metal	Symbol	Volts
1	Magnesium	Mg	+2.34
2	Beryllium	Be	+1.70
3	Aluminum	Al	+1.67
4	Zinc	Zn	+0.76
5	Chromium	Cr	+0.71
6	Iron	Fe	+0.44
7	Cadmium	Cd	+0.40
8	Indium	In	+0.38
9	Cobalt	Co	+0.28
10	Nickel	Ni	+0.25
11	Tin	Sn	+0.14
12	Lead	Pb	+0.13
13	Hydrogen	H	0.00
14	Stainless steel	316	-0.09
15	Antimony	Sb	-0.10
16	Bismuth	Bi	-0.20
17	Silicon	Si	-0.26
18	Copper	Cu	-0.34
19	Steel	S. M.	-0.58
20	Silver	Ag	-0.80
21	Palladium	Pd	-.82
22	Platinum	Pt	-.86
23	Gold	Au	-1.68

Emissivity of Materials

Table B.6: Emissivity of Electronic Assembly Material.

Material	Emissivity
Commercial aluminum (polished)	0.05
Anodized aluminum	0.80
Aluminum paint	0.27 to 0.67
Commercial copper (polished)	0.07
Oxidized copper	0.70
Stainless steel (polished)	0.17
Stainless Steel (with heavy oxide)	0.85
Rolled sheet steel	0.66
Air drying enamel (any color)	0.85
Oil paints (any color)	0.92
Lamp black in shellac	0.95
Varnish	0.90
Zirconium coating on molybdenum	0.65

Pin Assignments for 50 Pin Module Connector

Table B.7: Pin Assignments for 50 Pin Module Connector

Pin	Assignment	Pin	Assignment	Pin	Assignment
1	AC-A	12	AC-B	22	40 kHz RTN [3]
2	HP-IB RTN [1]	13	HP-IB RTN [1]	23	HP-MSIB RTN [1]
3	DIO1	14	DIO2	24	RTS
4	DIO4	15	DIO3	25	HP-MSIB RTN
5	DIO6	16	DIO5	26	HP-MSIB RTN
6	DIO7	17	DIO8	27	HP-MSIB RTN [1]
7	EOI	18	NRFD	28	IFC-RTN
8	SRQ	19	NDAC	29	DAV-RTN
9	ATN	20	IFC		
10	REN-RTN [1]	21	DAV		
11	REN				

Pin	Assignment	Pin	Assignment
30	AC-A	40	AC-B
31	HP-MSIB RTN [1]	41	SPARE [1]
32	CTS	42	MD6
33	MD7	43	MD5
34	MD4	44	MD8
35	MD3	45	HP-MSIB RESET
36	MD1	46	MD2
37	ACK	47	MD0
38	CLK RTN [1]	48	BSY
39	LINE SYNC RTN [2]	49	CLK
		50	LINE SYNC [4]

[1] These pins are connected to chassis ground in the mainframe. Connection to all returns must be made in the module for the respective bus (HP-IB and/or HP-MSIB) as part of keeping electromagnetic emissions within specifications.

[2] *Do not connect directly to module ground.* Any $\frac{1}{8}$ module using the LINE SYNC function needs to maintain a minimum of 20 ohms between LINE SYNC RETURN and module ground. A $\frac{1}{4}$ module is 10 ohms minimum and a $\frac{3}{8}$ module is 6.7 ohms minimum.

[3] Pin 22 is to be used for grounding of cable shield drain wire when a separate 40 kHZ power cable is used. Module 40 kHz RFI filter returns may also connect to this pin provided *they are kept separate from all other module returns and grounds.*

[4] Any $\frac{1}{8}$ module using the LINE SYNC function needs to present an impedance of 100 k ohms or greater to the mainframe. A $\frac{1}{4}$ module is 50 k ohms minimum and a $\frac{3}{8}$ module is 33 k ohms minimum.

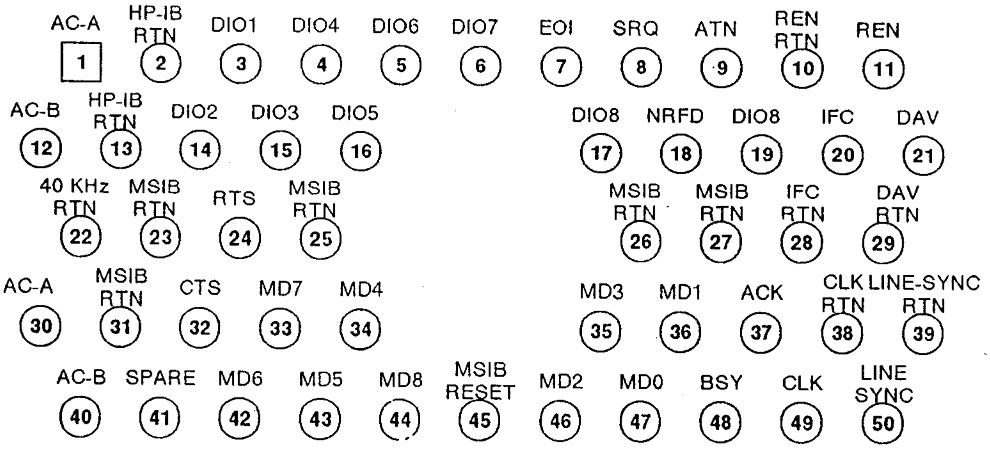

Figure B.1: 50-pin Module Connector (View of Mating Face on Mainframe)

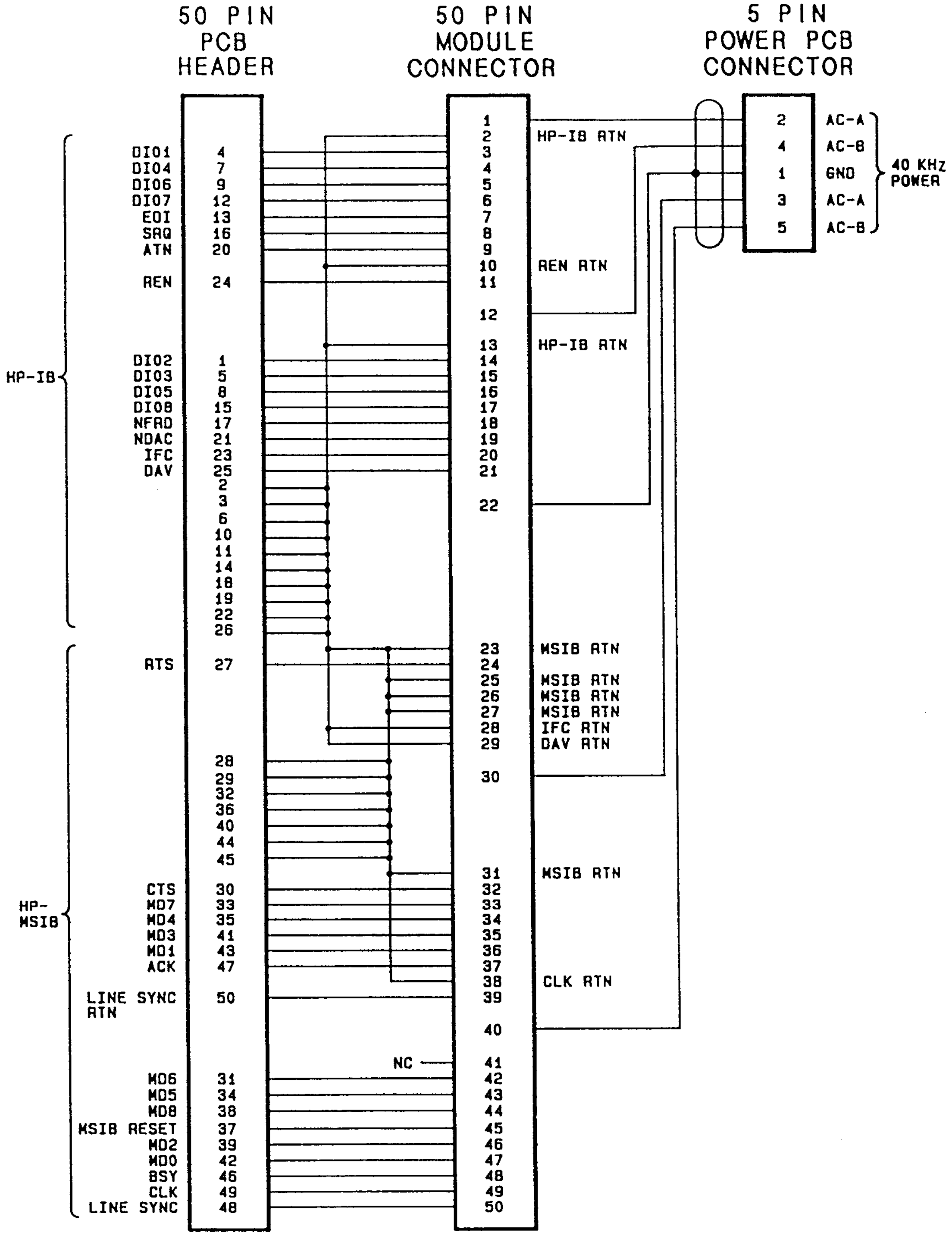

Figure B.2: 50-pin Module Connector Assembly Pin Designations - HP Part No. 70700-60001

C

Examples of Safety Warnings

SAFETY SYMBOLS

The following safety symbols are used throughout this manual and in the instrument. Familiarize yourself with each of the symbols and its meaning before operating this instrument.

⚠	Instruction manual symbol. The instrument will be marked with this symbol when it is necessary for the user to refer to the instruction manual in order to protect the instrument against damage. Location of pertinent information within the manual is indicated by use of this symbol in the table of contents.
⚡	Indicates dangerous voltages are present. Be extremely careful.
CAUTION	The CAUTION sign denotes a hazard. It calls attention to a procedure which, if not correctly performed or adhered to, could result in damage to or destruction of the instrument. Do not proceed beyond a CAUTION sign until the indicated conditions are fully understood and met.
WARNING	The WARNING sign denotes a hazard. It calls attention to a procedure which, if not correctly performed or adhered to, could result in injury or loss of life. Do not proceed beyond a WARNING sign until the indicated conditions are fully understood and met.

GENERAL SAFETY CONSIDERATIONS

WARNING

BEFORE THIS INSTRUMENT IS SWITCHED ON, make sure it has been properly grounded through the protective conductor of the ac power cable to a socket outlet provided with protective earth contact. Any interruption of the protective (grounding) conductor, inside or outside the instrument, or disconnection of the protective earth terminal can result in personal injury.

WARNING

There are voltages at many points in the instrument which can, if contacted, cause personal injury. Be extremely careful. Any adjustments or service procedures that require operation of the instrument with protective covers removed should be performed only by trained service personnel.

CAUTION

BEFORE THIS INSTRUMENT IS SWITCHED ON, make sure its primary power circuitry has been adapted to the voltage of the ac power source. Failure to set the ac power input to the correct voltage could cause damage to the instrument when the ac power cable is plugged in.

D

Useful Tools Reference

The following tools are useful in prototyping and building 50-pin module cables. HP part numbers are for Hewlett-Packard internal use only. Other users should order these tools directly from Hughes Aircraft Company, Connecting Devices Division, 17150 Von Korman Ave., Irvine, CA, 92714-4966.

Table D.1: HP 70000 Related Tools

HP Part No.	Description	Mfg	Mfg Part No.
	Fifty-Pin-Connector Tools:		
8710-1613	Insertion tool	Hughes	TW022IT0000
8710-1621	Removal tool	Hughes	TW022RT006
8710-1627	Removal tool, replacement tip	Hughes	TW022NG006
8710-1620	Crimping tool	Hughes	M22520/2-01
8710-1626	Crimping tool, locator stop*	Hughes	TLSW22

* Locator stop required with crimping tool.

E
Parts Available from Hewlett-Packard

This appendix lists part numbers and descriptions for available Hewlett-Packard parts appearing in this document. To order a listed part from your nearest Hewlett-Packard office, quote the Hewlett-Packard part number and the quantity.

Direct Mail Order System

Within the USA, Hewlett-Packard can supply parts through a direct mail order system. Advantages of using the system are as follows:

(a) Direct ordering and shipment from the Hewlett-Packard Parts Center in Mountain View, California.

(b) No maximum or minimum on any mail order (there is a minimum order amount for parts ordered through a local Hewlett-Packard office when the orders require billing and invoicing.

(c) Prepaid transportation (there is a small handling charge for each order.)

(d) No invoices - to provide these advantages, a check or money order must accompany each order.

Mail order forms and specific ordering information are available through your local Hewlett-Packard office.

HP 70000 Related Parts

Table E.1: HP 70000 Related Parts

HP Part No.	Description	Mfg	Mfg Part No.
	Fifty-Pin Connector, Module Receptacle:		
70900-80001	Connector receptacle for hybrid assembly. Soldertail contacts @ 2–11, 13–21, 23–29, 31–39, 42–50. Crimp contacts @ 1, 12, 22,30,40, 41.	HP	
1252-1003	Connector receptacle, no pins.	Hughes	
5021-3274	Connector receptacle, soldertail contacts.	Hughes	
70001-80004	Connector receptacle, crimp contacts.	Hughes	
1252-0179	Soldertail contact.	Hughes	
1252-0180	Crimp contact.	Hughes	
5041-3934	Protective connector cover.	HP	
	Fifty-Pin Connector, Mainframe Plug: Use with above parts only.		
70001-20005	Plug receptacle, soldertail contacts.	Hughes	
5180-2353	Plug receptacle, crimp contacts.	Hughes	
1252-0181	Soldertail contact.	Hughes	
1252-0182	Crimp contact.	Hughes	
70001-40020	Protective connector cover.	HP	

Miscellaneous Parts

Table E.2: Miscellaneous Parts

HP Part No.	Description	Mfg	Mfg Part No.
70001-600013	Extender (Service) module	HP	
8710-1651	Hex-ball driver, 8 mm	Bondhus	
9170-1369	Toroid core (to reduce ground currents in coaxial cable)	TDK	H5C2 T3 6-1.5
70595A	Module Development Design Guides	HP	
	Electromagnetic Compatibility Design Guide	HP	
	Mechanical Design Guide	HP	
	Electrical Design Guide	HP	
	LO coaxial interconnect cable, right to left	HP	
5021-5448	1/8 module	HP	
5021-5449	2/8 module	HP	
5021-5450	3/8 module	HP	
5021-5451	4/8 module	HP	
5021-5452	5/8 module	HP	
5021-5453	6/8 module	HP	
5021-5454	7/8 module	HP	
	LO coaxial interconnect cable, left to right	HP	
5021-5491	1/8 module	HP	
5021-5492	2/8 module	HP	
5021-5493	3/8 module	HP	
5021-5494	4/8 module	HP	
5021-5495	5/8 module	HP	
5021-5496	6/8 module	HP	
5021-5497	7/8 module	HP	

HP 70001 Mainframe Rack Mount Hardware

Table E.3: HP 70001 Mainframe Rack Mount Hardware

HP Part No.	Description	Mfg	Mfg Part No.
5061-9678	Rack mount kit HP 70001 w/o handles	HP	
5061-9684	Rack mount kit HP 70001 w/ handles	HP	
5061-9690	Front handle kit	HP	
5061-9772	Rack mount kit w/ previously attached handles	HP	
1494-0059	Slide kit for HP 70001 HP system enclosures (product wts to 38.6 kg/85 lbs)	HP	
1494-0060	Slide kit for HP 70001 non-HP system enclosures (product wts to 38.6 kg/85 lbs)	HP	
1494-0063	Tilt slide kit for HP 70001 HP system enclosures (product wts to 38.6 kg/85 lbs)	HP	
1494-0061	Slide adapter kit, standard slides non-HP system enclosures	HP	
1494-0064	Slide adapter kit, heavy duty slides (1494-0058) non-HP system enclosures	HP	
1494-0058	Heavy duty slide kit, for HP 70001 HP system enclosures (product wts to 38.6 kg/85 lbs)	HP	

Module Parts Kits

Table E.4: Module Parts Kits

HP Part No.	Description	Mfg
70591A	1/8 Module Assembly *	HP
70591-00001	Top cover, 1/8 module	HP
70591-00002	Front dress panel, 1/8 module	HP
70591-00003	Rear panel, 1/8 module	HP
70700-20006	Front frame, 1/8 module	HP
70700-20007	Rear frame, 1/8 module	HP
70700-20008	Base, 1/8 module	HP
70592A	2/8 Module Assembly *	HP
70592-00001	Top cover, 2/8 module	HP
70592-00002	Front dress panel, 2/8 module	HP
70592-00003	Rear panel, 2/8 module	HP
70900-20097	Front frame, 2/8 module	HP
70700-20030	Rear frame, 2/8 module	HP
70900-20096	Base, 2/8 module	HP
70593A	3/8 Module Assembly *	HP
70593-00001	Top cover, 3/8 module	HP
70593-00002	Front dress panel, 3/8 module	HP
70593-00003	Rear panel, 3/8 module	HP
70593-20001	Front frame, 3/8 module	HP
70593-20002	Rear frame, 3/8 module	HP
70593-20003	Base, 3/8 module	HP
	4/8 Module Assembly	HP
	4/8 module components are not available	
70700-20010	Insulator, left (for 1/8, 3/8, 4/8 modules)	HP
70700-20011	Insulator, right (for 1/8, 3/8, 4/8 modules)	HP
70592-20001	Insulator, plastic, 2/8 module	HP
5001-5840	Grounding spring, safety	HP

* Includes all module parts, a 50 pin module connector, and all related module assembly hardware, shipped unassembled. Assembly instructions are included.

Shipping Containers

Each module parts kit is packaged in "family" cartons. Only two different cartons are used for module kits, the 1/8 and 2/8 kits to be contained in the 9211-5822 and 3/8 and 4/8 contained in the 9211-5823. A corregated double wall separator provides additional protection for the module kit parts. The cartons will have the module kits in unassembled form and provide good protection at a minimal package size. See drawings for shipping containers in appendix F, figure F.3, for additional details of both size cartons.

F

Drawings

The information contained herein is accurate to the best of our knowledge at the time of publication. Drawings and specifications are subject to change for correction and/or improvement of the product.

Table F.1: ERS Drawings

HP Drawing Number	Drawing Title
70001-90003	E.R.S.-Parts, Assembly, Notes
70001-90003	E.R.S.-1/8 Module
70001-90003	E.R.S.-1/4 Module
70001-90003	E.R.S.-3/8 Module
70001-90003	E.R.S.-4/8 Module
70001-90003	E.R.S.-Miscellaneous

Engineering drawings contained in this section will allow fabrication or analysis of specific module parts supplied in the HP 7059X Module Parts Kits (see table E.4

Table F.2: Module Parts Drawings

HP Drawing Number	Description
No drawing number.	Module Parts Kits, exploded view
70591-00001	Top cover, 1/8 module
70591-00002	Front dress panel, 1/8 module
70591-00003	Rear panel, 1/8 module
70700-20006	Front frame, casting, 1/8 module
70700-20006	Front frame, machined, 1/8 module
70700-20007	Rear frame, casting, 1/8 module
70700-20007	Rear frame, machined, 1/8 module
70700-20008	Base, casting, 1/8 module
70700-20008	Base, machined, 1/8 module
70592-00001	Top cover, 2/8 module
70592-00002	Front dress panel, 2/8 module
70592-00003	Rear panel, 2/8 module
5021-5460	Front frame, casting, 2/8 module, sheet 1
5021-5460	Front frame, casting, 2/8 module, sheet 2
70900-20097	Front frame, machined, 2/8 module
70900-20030	Rear frame, casting, 2/8 module, sheet 1
70900-20030	Rear frame, casting, 2/8 module, sheet 2
70900-20030	Rear frame, machined, 2/8 module
70900-20096	Base, casting, 2/8 module, sheet 1
70900-20096	Base, casting, 2/8 module, sheet 2
70900-20096	Base, machined, 2/8 module, sheet 1
70900-20096	Base, assembly, 2/8 module, sheet 2
70593-00001	Top cover, 3/8 module
70593-00002	Front dress panel, 3/8 module
70593-00003	Rear panel, 3/8 module
70593-20001	Front frame, casting, 3/8 module
70593-20001	Front frame, machined, 3/8 module
70593-20002	Rear frame, casting, 3/8 module
70593-20002	Rear frame, machined, 3/8 module
70593-20003	Base, casting, 3/8 module
70593-20003	Base, machined, 3/8 module
70594-00001	Top cover, 4/8 module
70594-00002	Front dress panel, 4/8 module
70594-00003	Rear panel, 4/8 module
70594-20001	Front frame, casting, 4/8 module
70594-20001	Front frame, machined, 4/8 module
70594-20002	Rear frame, casting, 4/8 module
70594-20002	Rear frame, machined, 4/8 module
70594-20003	Base, casting, 4/8 module
70594-20003	Base, machined, 4/8 module

Table F.3: Miscellaneous Parts Drawings

HP Drawing Number	Description
70001-00033	Ground spring, module
70001-00034	Ground spring, module
70001-00035	Ground spring, mainframe
No drawing number.	Suggested printed circuit board outlines for Module Parts Kits.
9220-4552	Separator, packaging 3/8, 4/8
9220-4553	Separator, packaging 1/8, 2/8
9211-5822	Carton, Corrugated 1/8, 2/8
9211-5823	Carton, Corrugated 3/8, 4/8