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NEW PRODUCT ANNOUNCEMENT

OBJECTIVE DESIGN NOW STOCKS THE FRONT AND REAR PANELS REQUIRED FOR THE CONSTRUCTION OF AN S-100 CARDFILE. THE PANELS, OF 1/8 INCH 6061T6 ANODIZED ALUMINUM, ARE PREPUNCHED AND DRILLED TO THE SPECIFICATIONS OF OUR CRATE DESIGN INFORMATION PACKET. COST IS \$11.95 APIECE OR \$20.00 PER PAIR FOB TALLAHASSEE, FL. ALL ORDERS SHIPPED UPS UNLESS OTHERWISE REQUESTED. CO-OP AND UNIVERSITY PURCHASE ORDERS ACCEPTED. EXPECTED SHIP DATE: JULY 20, 1977. FLORIDA RESIDENTS ADD APPROPRIATE STATE SALES TAX.

OBJECTIVE DESIGN, INC.

**THE
CRATE**

**S-100 CARDFRAME
CONSTRUCTION
PLANS**

**REALLY BUILD YOUR OWN
COMPUTER!**

S-100 CARDFRAME CONSTRUCTION BOOK

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The Objective Design S-100 Cardframe Construction Book is a complete set of plans and instructions for building an S-100 compatible card file and power supply, referred to as a 'Crate'. The Crate is of high quality, making use of standard, commercially available extrusions, card guides, and power supply components. The design is variable and can be adapted to any of the available S-100 motherboards.

The advantages of constructing a Crate as opposed to buying a standard computer include: cost savings, a sturdier cardframe, easier to work with design, and opportunities to meet special requirements by customizing. Equally important, in this highly personal hobby, the custom built Crate affords an opportunity for self-expression in the creation of a fascinating and now unique device--the home computer.

The basic Crate is a simple cardframe whose layout is similar to the IMSAI 8080 commercial computer. Primary components include: the front and rear panels; the structural-, card guide-, and motherboard-supports. 'Critical' dimensions occur only in the placement of those holes in the front and rear panels which align the card guide- and motherboard-support bars: these must match the S-100 card and edge connector dimensions. All of the parts, tools, and diagrams necessary to produce the basic Crate are fully described.

One variation, the short 10" (12 slot) Crate is also presented. For this variation, changes are made in the support bar lengths, the power supply, and the power supply chassis. The Crate builder should not feel constrained to these designs. Availability and/or cost of certain materials and components as well as Crate requirements of size and number of slots may dictate a changed design.

The parts and tools sources given are standard supply houses. There will be many possible substitutes for these items and many other sources. The one item for which there is no substitute is simple mechanical experience. Where appropriate, construction methods are detailed, but this may not be sufficient for the metal working novice. In this case, we suggest teaming with an experienced do-it-yourselfer -- who should appreciate the opportunity to build a computer!

If necessary, the front and rear panels and the power supply chassis can be made by a professional machinist using the drawings included. Despite the cost of this service, the Crate builder will still realize a savings over a commercial cardframe.

Two power supplies are described: a 24 amp version which will power a full sized Crate, and a 12 amp supply for the shortened Crates. The schematics, parts list, and chassis cutouts are all matched. Builders are warned to be careful when substituting for these to make sure they provide adequate power for their Crate. Wire routing and size, ventilation, and noise protection must be taken into account. Poor power supply design and incorrect specifications have plagued the commercial cardframes and continue to do so. You can produce a far more professional product if care is taken here.

Before starting construction the prospective computer builder should spend some time considering the ultimate configuration of his system. Appendix B deals with this subject and makes several suggestions. Remember -- this is an S-100 computer and is not limited to any one processor. Comparison with the price and contents of any of the commercial systems will demonstrate the savings involved with a home constructed unit.

The microcomputer cardframe, or Crate, provides support for a power supply, the computer motherboard, and the computer circuit cards. The front of the Crate allows for special console panels, either functional or decorative. I/O connectors, special power connections and switches and the cooling fan will go in the rear. A Crate should be structurally secure, insuring transportability and long life. Electronic components must be easily accessible for updating and testing.

The objective design cardfile consists of 1/8" aluminum front and rear panels connected by several support bars. These supports may be standard 1/4" x 1/2" extrusions or ordinary bar stock of similar dimensions. These bars serve as supports for the power supply chassis, the motherboard, and the card guides. Two additional bars, placed at the corners of the frame, serve as primary structural supports.

Switches may be mounted directly on the front panel, though it will usually be better to use additional 'dress' panels offset by spacers. An optional cutout will enable the motherboard to extend beyond the front panel for plug-in consoles.

The rear panel has connector mounting holes such as those for the standard 25 pin 'D' connectors. A large cutout is provided for the ventilation fan.

A bottom plate is typically made of sheet aluminum, screwed to the frame. The top and sides can be fabricated from any convenient material: wood, aluminum, or plastic.

At this point you should examine all of the frame drawings to get a feeling for how the different components go together. The majority of the construction work consists of drilling matching sets of holes in the front and rear panels, then connecting the two by the support bars.

The construction details will be separated into discussions of front and rear panels, extrusions, power supply, top and bottom covers and overall assembly. Construction practices are geared to the capabilities of a small home shop. It should be obvious that the availability of equipment outside this range, such as a milling machine, will dictate other construction methods. If you can afford it, the local machine shop should have no trouble turning out the more difficult parts from the drawings. In fact, it should be possible to produce up to four panels simultaneously on a professional milling machine. And don't forget to inquire at your local computer store. They may already have, or be willing to stock, whatever special parts you need.

Read all of the text material thoroughly before beginning any work. Plan out the entire Crate. Gather your materials. The order of subjects in the text is not necessarily the exact construction order. Use safety glasses when operating machinery.

Note: 6-32 hardware is used throughout the Crate assembly with the exception of some 8-32 hardware used to fasten down the transformers in the power supply and 4-40 parts used to mount the motherboard.

Main panels

The front and rear panels are made with 1/8" aluminum. This can come as sheet stock or 19" rack panels (Bud type PA-1104), which are cut to size. It is essential that all dimensions be measured accurately, with the corners cut square. Errors here will cause misalignment of the support bars, since they are positioned by measurements based on the panel edges. See main figure.

The rack panels, as received, must have their ends cut off. The top and bottom edges are fine as they are. If you have two rack panels, you can use one corner of each as a 'T' for scribing out the end cuts on the other. Take note: an inexpensive machinist's 'T' is seldom truly square. A drafting triangle is more accurate.

For sheet aluminum, mark out the entire panel outline with a scribe. Cut along the scribed lines with a hacksaw or sabre saw. One way to get a good, straight cut with a sabre saw is to clamp a straight-edge onto the panel as a guide for the saw. It is vital that the straight-edge be sufficiently thick to prevent the saw from mounting up and over it. Use oil on the blade. Dress the end cuts with a file to produce an even, flat edge.

The two panels must be the same size. Place them together to check the match. Any unevenness must be cut or filed away.

Front panel

If a display, keyboard, or Morrow Micro-Stuff Processor (computer console) which plugs into the S-100 bus will be used, then the slot for the motherboard in the front panel needs to be cut out. Measure the cutout position carefully using the bottom and left edges as references. With the scribe, lay out the cut on the front panel.

Drill a short row of overlapping holes, within the slot and along each scribe line, to provide a starting place for the saw. Using the sabre saw with a straight edge or the Mini-Hack, cut out the slot. File the edges to be even and square.

At this point, measure and mark the position of all holes on the front panel. (see figures 0,1,2,3 and text below)

Card guide support bar holes -- measure these from the bottom and left sides of the panel.

Motherboard support bar holes -- these are also measured from the bottom and left sides.

Power supply support bar holes -- these are set to make the bar edges flush with the panel edges. The dimensions given are for $3/8" \times 1/2"$ and $3/8" \times 3/4"$ bars. (the latter are recommended.) You may have to move the location of the corner bar slightly to keep it flush with the side edge of the panel. Adjust the position of the other power supply support bar along the panel bottom edge the same amount.

Structural support bar holes -- dimensions are given for $3/8" \times 1/2"$ and $3/8" \times 3/4"$ (recommended) bars.

There is an S-100 board now being sold by Morrow's Micro-Stuff which serves as a computer console and CPU. To mount this, or other console boards, you must have the front panel slot with a motherboard extending past the front panel.

Figure 3 shows the additional front panel holes required to mount the George Morrow Console Board. The side holes match with holes on the console board. The two other holes are used with nylon spacers and screws to brace the board against movement when the keys are depressed. Use the edge of a screw and spacer to grab the edge of the board and hold it in place

Warning! You must use nylon parts to grab the George Morrow card edges since power busses run there.

For other console boards (including, of course, your own) you can use similar holding screw/spacer combinations.

You may wish to mount switches (reset, vector, power, etc.) and lights (hold, wait, run, etc.) directly on the $1/8"$ front panel. If your switches do not have their own bezels and such, you can add a mask panel in front of them.

For the George Morrow card, and other consoles, you may also want a mask panel. (note: we have found that a dark, but not opaque, lucite panel yields a striking effect.)

Fig. 2 shows the cutout and hole pattern for the George Morrow card mask.

The mask panel can be mounted with screws and spacers placed around the edge of the front panel. A better idea will be to replace the support bar screws with screw and spacer combinations. See Fig. 12. These are available at \$27.60 per 100 from H. H. Smith (# 8256). You can construct the equivalent from a normal hex spacer and the threaded section of a screw. Put the threaded piece through the panel and into the bar first. Then screw on the spacer and tighten. The mask panel will now bolt onto the spacer. (A 'spacer' can be made from a bent piece of aluminum, if you can't get hold of any in reasonable quantities. See Fig. 13.)

With the front/console/mask panel arrangement figured out, mark the appropriate holes in the front panel.

Use the center punch to dimple the panel at each hole location. Start each hole with the center drill. (If no center drill is available, then first drill each hole with a 1/32" drill. Redrill each hole with a 1/16" drill.) Now drill all holes with a #26 drill. When all of the holes have been drilled, use a file to remove any burrs. Make sure that the panel is not dimpled out at any holes. This will cause uneven panel to panel distances. If there is any dimpling, use the file to achieve a flat surface.

The best way to insure the exact match-up of front and rear panel holes is to clamp the panels together for drilling the common holes.

Rear panel

The procedure for removing the fan cutout is similar to that used for the front panel slot. The fan is positioned from the top right corner. Scribe out the fan cutout. Drill a short row of overlapping holes along the inside of the scribe mark. Use the sabre saw or Mini-Hack to cut out the slot. File to an even edge. Be sure to check the fan mounting hole positions against the fan itself, if one is available. Our experience with the Crates and typical S-100 boards indicates that a fan is not necessary if no cover is used and the boards are placed in every other slot.

If you will be using the 25 pin connectors then cutouts of the given dimensions are required. They are small enough so that overlapping holes can be drilled along the entire outline to accomplish the cut. Now file to the exact shape.

If you are not sure what connectors will be required, cut out a pair of .5" x 2" slots and cover with 1/16" aluminum filler. You can add the connector holes to the filler at any time.

The power cord, switch, and fuse (or breaker) can go in the rear panel in the area between the fan

and the connector cutouts. Be sure to avoid conflict with the card guide support bars. The switch and fuse may also be brought out to the front panel. Position and drill or cut out these holes.

SAE (Stanford Applied Engineering) Standard Extrusions

The card guide support bars must have holes drilled at $3/4$ " intervals along their entire length. SAE sells such bars (#4025) in standard 17" lengths. They have drilled and tapped ends. We recommend these for the card guide and motherboard supports. They also may be used for all of the other support bars, as opposed to simple bar stock. If the extrusions are used as the structural and power supply supports, then care will have to be taken when drilling and tapping the bars for holding down the cover. Instead of drilling out new holes, take advantage of the existing holes and tap them for 8-32 screws. Generally, bar stock will do better and be less expensive. The holes in the SAE bars will not accept the card guides that normally come with IMS type motherboards. Card guides which will fit (#1450) are available from SAE. The locking tabs (series 3000) which hold these guides in place are also required.

You can use the IMS type card guides if you drill out the holes in the SAE extrusions. Note that the SAE bars have holes on $1/4$ " centers, so only each third hole must be drilled. Be careful in starting on the correct hole. For most motherboards, you will want the first card guide to go $1/2$ " from the front panel. The guides will tend to stay in place by the spring action of the nylon. You can have them lock in position by using a countersink hole.

SAE extrusions are also used as the motherboard support bars. SAE connector mounting feet (#2359) fit into the extrusion holes and are held in place with the (series 3000) locking tabs. The bars in our design are positioned for the IMSAI motherboard. If a different board is to be used, then the support bars must be moved or new holes, corresponding to those on the IMSAI board, must be drilled. See appendix A.

You can use the SAE extrusions for the power supply and structural supports. Regular bar stock will also do here. We have used $1/2$ " x $3/8$ " and $3/4$ " x $3/8$ " stock for these bars. See appendix C on costs for information on Small Parts Inc., a source of these bars.

Bar stock must be cut with square ends. A good mitre will help here. Be sure to clamp the bar securely during cutting. Now mark and center-punch the hole position in each end. Start the hole with a center drill and then drill $3/4$ " deep holes with a #35 drill. (Use a $1/32$ " drill if no center drill is available to start the hole.) Use a 6-32 tap (and oil) to thread the hole.

Smaller frames

The depth of the frame can be altered by using shorter support bars. The main difference in a smaller Crate will be in the power supply. A power supply and chassis for a 10" frame is described. There is very little extra space in the layout of the listed power supply components, so a complete chassis plan is provided.

SAE will fabricate 10" bars (and other sizes) for a \$20 setup charge and \$2 per bar. (They have a \$35 minimum.) See Figure 18 for ordering information.

The big flip

If for some reason you might require a Crate with the power supply on the left, pay attention here. Otherwise, please ignore this section, which might be confusing.

If you were to spin the panels 180 degrees on a vertical axis in their centers before connecting them with the support bars, you would have a Crate with the power supply on the left and the card file on the right. Almost. There is one change. The holes for the motherboard supports must be offset on the given drawings by 5/8" to the right. This is because of the anti-symmetric nature of the S-100 cards. (The connector edge is offset by 5/8".) This is why the front panel cutout has been made oversize. It will work with both right-handed and left-handed Crates.

Power supply chassis

The 25 amp supply chassis (for full size Crates) can be constructed with another Bud 1/8" panel, 3/32" sheet aluminum, or a scrap chassis. (Fig. 4) If you use 1/8", you won't need the bend shown. For thinner stock, the added strength will be important.

Cut the chassis to size. Lay out the components as in Fig. 5. Mark the holes needed to fasten down all components. The capacitors and bridges are mounted with terminals up. Be sure that the support bars will not interfere with the component mounting hardware. Drill 8-32 body holes (# 19 drill) for the transformers and 6-32 body holes (# 26 drill) for the other components. Mount all parts.

Wire the power supply according to the given schematic. (Fig. 6) Note that there is only one chassis ground point. Use one of the capacitor bracket screws to hold down this ground connection. Use 14 guage wire for the 8 volt supply and ground. Use 16 guage wire for the +/- 16 volt supply. Solderless terminals should be used for all connections, except those to the transformers. For these, pre-tin the wire and solder. Be sure that the solder flows on the terminals -- you may need a high power iron for this.

Note: Capacitor C2, which is only given for the 25 amp supply, simply improves filtering. It is not to be considered necessary to the supply.

The 12 amp supply for the 10" frame will require some care in its construction. The positioning and spacing of the components is more critical, due to the reduced space available.

Fig. 8 gives the layout for the recommended supply components. Fig. 9 shows an exact chassis plan. The bends described will apply where sheet metal thinner than $1/8"$ is used. Note that all dimensions are given from what will be the edge of the chassis after it is bent. If you are not going to use a bend, then cut the chassis to match the outer bend dimensions. See Fig. 7.

The large holes shown in the small power supply are used only where the capacitors are mounted with their terminals down. This is totally optional with the builder. Wiring to the capacitors (when inverted) is done below the chassis level. Wires reach this level through the $3/4"$ holes near the terminals. The holes for wires and capacitors are made with chassis punches. Be sure and file away any sharp edges after making the holes, to prevent wire insulation from being cut through.

The wire sizes and wiring instructions for the small supply are the same as those of the large supply. Note that C2 in the power supply schematic only exists as a option in the large supply.

Note: For both supplies, C1, the 8V supply rectifier, is not wired as a bridge. A bridge rectifier package is used for convenience.

Assembly / Part 1

Construct the basic framework from the support bars and the front and rear panels. If all has gone well, the bars will all parallel one another, and the Crate will stand evenly on a flat surface.

Place the power supply chassis in the frame. Mark through the mounting holes on the chassis onto the support bars.

If a bottom plate is to be included, cut it out now. Since this plate bears no structural strain, you can use aluminum as thin as .022". The bend described will add strength, but is not essential. Note that dimensions are given for both the full size and 10" chassis. See Fig. 11

Ventilation for the Crate can come from the bottom or the side near the circuit cards, or both. The vent holes can be punched, drilled, or cut. If large cutouts are made, it would be well to cover the area with screening.

Support feet are attached with the screws used to mount the bottom piece or separately screwed to the bottom plate near the support bars. Feet can be homemade from wood, plastic, or rubber and attached with epoxy.

For a cover, note the dimensions shown in Fig. 10. You can construct the top from almost any material -- aluminum, wood, plastic, etc.

The inside width dimension (17") of the cover is the critical one. This should be considered as an absolute minimum. Experience has taught us that it is best to aim at an inside dimension of $17 \frac{1}{16}$ ", especially when bending aluminum. This is one case where too much is fine and too little is useless. Remember to first check the actual Crate width. If you made a slight error there, you will have to adjust the cover width accordingly.

A half cover, just over the power supply, is also a good idea. It protects against shock hazard while still allowing free access to the circuit cards. You might wish to attach a circuit card cover section to the power supply cover with a hinge.

Place the cover on the frame and check the match up with the support bars. Mark and drill the cover holes. Now mark through to the bars.

Assembly / Part 2

Remove the bars which have holes marked. Drill and tap 6-32 holes in the bars.

Using the motherboard as a guide, pick out the holes which will hold the mounting feet. These are the ones where connectors are to be. Mounting feet go on the outside of the motherboard support bars. (Take care here if the motherboard is to extend through the front panel slot.) Place the mounting feet tabs in the holes and lock in with the locking tabs. A 'parallel jaws' pair of pliers works best for this.

Put all of the bars in place. Install the power supply.

With the installation of the power supply, include the power switch, fuse, fan, etc. Wire these according to the schematic and test the supply for proper operation. Check all voltages. These may be a little high, since there is no load. When you are satisfied with the supply, you can connect it to the motherboard.

For the given power supplies the fuse sizes are:
4 amp slow blow for the full size supply, 2 amp slow blow for the 12 slot, 12 amp version.

Cut 3 lengths of wire for connection from the power sources to the motherboard. These are routed from the capacitor terminals, (out through a hole in the chassis with the small supply), over the motherboard, to the power connection pads on the far side of the board. Use solderless terminals for the capacitor connections. Roughen the board pads and pre-tin. Strip and pre-tin the wires. Solder the wires to the board, using more solder. The 8 volt connection may require a high power iron.

The ground connection is run from the ground side of the 8 volt capacitor(s) to the near side of the board. The above instructions also apply here.

Check out the supply again. Test for the correct voltages at the card connector pins.

Place the card guides at the positions where you have connectors (or plan to have) on the motherboard. Lock them in place with the locking tabs.

Try inserting some cards through the guides. If they do not match up sufficiently well with the connectors, you can loosen the motherboard hold down screws and adjust its position. There is also some 'play' in the bar positions. Make sure that you check both ends of the cardfile for proper adjustment.

Bolt on the rear panel connectors. Now put the bottom in place. Additional front (mask) panels and front components can go on now. Insert the computer electronics and make all necessary additional connections. Screw the cover in place.

You really have built your own computer!!

Appendix A

Mounting other motherboards

If the dimensions of the motherboard are fairly close to those of the IMSAI type, you can use the support bar locations given by drilling new mounting holes in the board.

To locate the new holes, construct the basic framework of the cardfile. (Front and rear panels, motherboard- and card guide-support bars; card guides at both ends of the frame) Install connectors on the board at the positions of the card guides. Place mounting feet in the motherboard support bar holes where you expect connectors to line up. The feet go on the outside of each bar.

Place the motherboard on the mounting feet, aligning it by eye with the desired position. (Be sure and allow it to extend through the front panel slot if you are using one.) Insert cards in the guides at both ends of the Crate. Now, using the cards, carefully align the motherboard-- insert the cards in the connectors.

Use one hand (or someone else's) to maintain pressure on the board while you turn the Crate on its side. Mark through the mounting feet threaded insert holes onto the board.

Drill 3/16" holes at each marked location. Use a nylon or fiber shoulder washer with a 4-40 screw to mount the board. An alternative is to drill 4-40 body holes (1/8") and mount the board with nylon 4-40 screws.

Appendix B

System configuration

With the S-100 bus and a full size power supply as a starting point, almost any type of computer system can be realized. However, two problems, both tied to the fact that no console board is present, remain to be solved.

First, how does the system get started? Some CPU cards do not start at location 0 on power up. All will start at 0 on RESET, but only a few have vector circuitry for jumps to other addresses.

Second, there are a few S-100 bus signals which are not implemented on CPU cards normally--but rather are generated by circuitry on console (front panel) boards. These are notably RESET and MWRITE, as well as the optional display light signals for RUN, HALT, WAIT, etc.

The simplest solution is to furnish a console board for the computer. The build or buy question comes to mind. The console is a fairly simple piece of computer hardware to design, and you may have your own ideas about what belongs on one. As we have mentioned throughout the text, Morrow's Micro Stuff sells an intelligent console board which serves as a front panel and CPU card.

The next possibility is to buy a CPU card or special card which will handle at least some of these problems and then 'kluge' in any other necessary circuitry. For instance, the Cromemco Z-80 board provides for an automatic jump on RESET -- but you will have to provide the RESET signal via a switch.

Having a program in prom, even if only a bootstrap, is essential. Since there is no console, you will not be able to 'thumb in' any programs. The more sophisticated floppy interfaces have prom bootstraps built in. Godbout electronics sells the microtec system program on prom, or just the prom board. The ALS8 from Processor Technology is another possibility. You can 'do your own thing' with the Cromemco bytesaver, if you can borrow someone elses system to work on. There are several independents offering small console type proms at reasonable prices.

Appendix F explains the circuitry needed when no console is present in the system. Automatic power up jump circuits are also described, for systems whose prom is not in location 0.

System examples

For the following system examples, we list a \$150 price for the Crate and motherboard. (see appendix C on costs)

Console oriented systems:

Crate	150	Basic IMSAI Unit	700	Basic Altair Unit	840
Morrow					

Card	240	---	---
Total	390	700	840

These systems are roughly equivalent in functional capability. You would add to the Crate+Morrow board just as you would for the IMSAI and altair units.

Even greater savings are possible in systems which do not require a front panel.

Crate	150	
Byte CPU + Parts + Kluge	100	

Total	350	plus....

- + VDM
- + Keyboard
- + Parallel or parallel/serial board
- + 8/16 K memory
- + Cassette R/W board
- + Prom board with monitor or bootstrap
- or.....
- + VDM
- + Keyboard
- + Parallel port board
- + 16 K memory
- + Floppy W/ boot prom (eg. North Star Mini-Floppy)

You can put a Z/80 in place of the 8080 just as easily. S and D Sales is offering a Z-80 CPU card kit for \$150, not that much more than the cost of buying and populating the BYTE 8080 card.

Some new cards have been designed for putting a system together. For example, the TDL System Monitor Board. It contains serial and parallel I/O, a cassette driver, 2K RAM, and a 2K ROM monitor, with power-up start. A system with this board might look like this:

CPU - Z-80 (no 8080, the monitor is written for the Z-80)
+ VDM
+ Keyboard
+ TDL System Monitor Board (\$295)
+ 8/16 K memory

The Morrow's I/O and Cassette Interface Board is another all-in-one board, it combines cassette drive (up to 3 cassettes!), I/O ports, 1/2 K RAM, and 1/2 K monitor ROM.

Crate	150
Byte board and Kluge	100
VDM	200

Keyboard	50
Morrow I/O and Cassette board	120
Memory - 8/16K	200/400

Total	920 / 1120

This 'under \$1000' system will outdo any of the packaged systems available at the same price. And since it is residing in a full size S-100 Crate, you can expand it in any direction you might wish.

Some last words on computer systems. First, we cannot endorse or recommend any of the above products (except our Crate design, of course), primarily because we haven't seen most of them. You can use this as a guide, but investigate all products thoroughly before spending any cash. Your local computer store is great for this.

Second, be prepared for a system cost of at least \$1000. This is the minimum required for general purpose computing. The price tag will go up to \$2000 when you start generating your own good sized programs.

Finally, do not expect everything to work perfectly at first. It will take time and effort to get all of your hardware bugs out. Work systematically at eliminating the problems and have confidence that they are finite in number. As much as possible, avoid the temptation to 'live' with a problem in your system. Sooner or later this will catch up with you. (And please don't ask us how we know!)

Appendix C

Costs

The cost of assembling a cardframe and power supply will vary considerably. The main factor will be a question of how much is already 'in the shop' and how much must be purchased. The price could range from zero, for the basic frames made from existing supplies, to three hundred dollars for a very elaborate version done with all new, non-surplus parts.

Before making any orders for parts be sure to check the magazine ads and your local computer stores. We hope that some of these people will be offering pre-punched panels and most of the main components. (If they aren't, then you might suggest it to them.)

None of the price estimates for the Crate have included the cost of tools. Once again, these may already be 'in the shop' (or in a friend's). Also, any tool purchased does not end its usefulness with the construction of a single Crate.

For universities, clubs, or other potential builders of many Crates the cost of tools is divided by the number of Crates completed. Take note: the second Crate is much easier to build than the first, and so on.

The major parts and their costs:

Power Supply - 25 Amp

T1	12.8V @ 25 Amps	Signal # 12.8-25	\$29.70
T2	24V @ 6 Amps	Signal # 24-6	18.50
C1/C2	9500UF @ 15V	Sangamo 500-953U015DC2B	10.00
		Mallory CG953U015x4C	8.59
Bracket	(3 1/64 x 4 11/16)	VR12 Mallory	.30
C3/C4	9500UF @ 35V	Sangamo 500-952U035BB2B	5.00
		Mallory CG952V035V3C	4.18
Bracket	(2 1/64 x 3 11/64)	VR8	.30
D1	50V @ 27 Amps	Motorola MDA 990-3	3.20
		Westinghouse MB12A25V05	3.00
D2	100V @ 6 Amps	Westinghouse MB11A06V10	3.20

Power Supply - 12 Amp

T1	12.6VCT @ 12.7 A	Abbott # 6B6-160	\$20.37
T2	24VCT @ 3.75 A	Abbott # 6B12-90	14.66
C1	83000UF @ 15V	Mallory CGS833U015V5L	9.42
Bracket	(2 1/64 x 5 43/64)	VR-8	.30
C3,C4	6200UF @ 40V	Mallory CGS622U040BF1	4.06
Bracket	(1 25/64 x 4 11/64)	VR-3	.30
D1	As for 25 Amp supply above		
D2	As for 25 Amp supply above		

Order the transformers from the factory or any distributor which carries them. All of the other parts can be ordered from Sheridan Sales.

Cardfile Components

Support bar extrusions	SAE # 4025	3.45/each
Card guides	SAE # 1450	.16/each
Locking tabs	SAE series 3000	.05/each
Connector mounting feet	SAE # 2359	.14/each

All of the SAE (Stanford Applied Engineering) parts are available from Sheridan Sales, or direct from the factory (with \$35 minimum.)

The following fan and accessory components are manufactured by Howard and listed as the Cyclohm Fan. They are available from many sources, including Herbach and Raderman, Inc. and Tech-Sales.

Fan	Howard # 3-15-2455	\$13.00
Power cord	Howard # 6-170-672 (just for fan)	.60
Finger guard	Howard # 6-182-033 (save those digits)	1.00
Fastening clips	Howard # 6-585-406 (you'll need 4)	.05

The main panels can be made from BUD 7" panels (type PA-1104), which are available with many finishes. BUD is distributed by Newark and others. Cost per panel is \$6.35. Standard sheet aluminum will also do fine, but be sure and use 1/8" and get hard, not soft, aluminum. Try Small Parts and local sources for this. (It generally comes only in large sheets.) Delta Electronics often gets usable pieces. If you are more interested in function than appearance, use surplus panels removed from old equipment. (if a cover and mask panel are used, the main panels are not visible.)

One as yet untried alternative is to use a pre-built cabinet. We don't know of one that will work without modifications. Also, this will be more expensive. The Optima 17 cabinet (as used by MITS for the Altair) might do, but you will have to cut down the extrusions to a shorter length. Order from Optima, # D-071716.

The motherboard is available from your local computer store, or from the Data Domain if none are near you. The IMSAI version will go in without problems. For the short Crate, cut down the 22 slot board, or use one of the smaller versions.

The nuts, bolts, spacers, etc., are available from Delta and Digi-Key and many others as well as local sources. The solderless terminals are made by Waldom. These can be found locally, or through most distributors.

If you leave the 'ears' on the front panel you will have a rack mountable Crate. If you wish, this can go in any of dozens of cabinets made to hold this type of equipment. Try Zero Manufacturing Co. for these.

Most of the distributors and manufacturers are happy to send a catalog in response to a telephone request. For orders, most have a minimum, sometimes as high as \$50. If they are nearby, you may be able to arrange a pickup order that is below minimum. Your best bet is to consolidate your order to get above the minimum. Ordering with other people is always a good idea.

One very good source of materials is Small Parts Inc. They have no minimum, but only charge \$1 for shipping orders less than \$5. All above that are shipped free in the U.S. Some examples from their catalog:

Aluminum Bar Stock	12"	24"	36"
ZRTA-6/12 3/8 x 3/4	1.65	3.00	4.05
ZRTA-6/8 3/8 x 1/2	1.10	2.00	2.70
Aluminum Sheet Metal	12 x 12	12 x 24	
SMA-125 .125"	7.60	13.80	
SMA-063 .063"	3.80	6.90	

They have a complete selection of machine screws, nuts, and washers. You'll also find nylon screws, nuts, and washers -- threaded bars -- aluminum standoffs -- nylon spacers -- cable clamps and wire ties -- and miniature electronic tools.

Appendix D

Tools

The tools are available from many sources. Catalog numbers for the Jensen and McMasters/Carr catalogs are listed with the prices.

Tool	Jensen	McMasters/Carr
Precision shop ruler	39B204 (2.85)	2285A2 (6.90)
Accurate square		6804A11 (5.94)
Drill and counter sink		2915A11 (1.55)
3/64" drill (center drill)		
Drill press or hand drill		
# 26 6-32 body drill	32B120-26 (.60)	
# 18 8-32 body drill	32B120-18 (.60)	
# 36 6-32 tap drill	32B120-36 (.70)	
Tap for 6-32	32B150-6-32 (1.95)	6-32 tap (1.06)
Tap T-wrench	39B216 (3.70)	2546A23 (3.88)
Center punch	39B252 (.95)	3417A1 (1.45)
Mini-hack	18B027 (2.50)	4060A12 (2.18)
Carbide tip scribe	186B010 (2.95)	2157A11 (2.22)
Metal file	173B103 (2.10)	
	173B462 (3.60)	-- available with handle
	173B425 (.60)	
Mitre box (Brookstone)	Y 2732, 5 (21.00)	
C-clamp or vise-grip		
Kerosene or light machine oil		
Brake (for bending)	151B018 (15.95)	requires 2 C-clamps
	88B019 (2.75)	

Appendix E

Sources

Tools

Jensen Tools and Alloys * Electronic and special tools
 4117 North 44 th Street * Catalog available
 Phoenix, Az 85018
 (602) 959-2210

McMaster Carr Supply Co. * Vast selection, but catalog may
 2828 North Paulina St. * be hard to get.
 P.O. Box 4355
 Chicago, Il 60657
 (312) 281-1010

Contact East Inc. * Electronics - catalog
 7 Cypress Drive
 Burlington, Mass 01803
 (617) 272-5051

Techni-Tool Inc. * Electronic tools - catalog
 Apollo Rd.
 Plymouth meeting, Pa. 19462
 (215) 825-4990

Brookstone Co. * Special tools - catalog
 119 Brookstone building
 Peterborough, N.H. 03458
 (603) 924-7181

National Camera * Special tools - catalog
 2000 West Union Ave
 Englewood, Colorado 80110
 (303) 789-1893

Manhattan Supply Co. * Machine tools, good selection and prices
 Ames Court * catalog
 Engineers Hill
 Plainview, Long Island
 N. Y. 11803
 (800) 645-3462

Components and Electronics

Signal Transformer Co.
 1 Junius Street
 Brooklyn, N.Y. 11212

Abbot Transistor/Transformer Div.
1224 Anderson Ave.
Fort Lee, N.J. 07024
(201) 224-6900
or
5180 W. Jefferson Blvd.
Los Angeles, Ca 90016
(213) 938-0155

Stanford Applied Engineering Inc. (SAE)
340 Martin Ave.
Santa Clara, Ca 95050
(408) 243-9200

Small Parts Inc.
6901 N. E. Third Ave.
Miami, Fla 33138
(305) 751-0856

Optima 2166 Mountain Industrial Blvd.
Tucker, Ga 30084
(404) 939-6340

Zero Manufacturing Co.
1121 Chestnut Street
Burbank, Ca 91503
(213) 849-5521
or
288 Main Street
Monson, Mass. 01057
(413) 267-5561
or
St. Petersburg-Clearwater Inter'l Airport
St. Petersburg, Fl 33732
(813) 531-8991

Waldom Electronics, Inc.
4625 West 53 Rd Street
Chicago, Il 60632
(312) 585-1212

Lafayette Radio Electronics
111 Jericho Turnpike
Syosset, L.I. N.Y. 11791

Cramer/Atlanta
3923 Oakcliff Industrial Center
Atlanta, Georgia 30340
(404) 448-9050
and others

Herbach and Rademan, Inc. * Good surplus catalog, get on mailing list
401 East Erie Ave.
Philadelphia, Pa 19134
(215) 426-1700

Delta Electronics Co.
P.O. Box 2
7 Oakland St.
Amesbury, Mass 01913

Digi-Key Corp.
P.O. Box 677
Thief River Falls, Mn 56701
(218) 681-6674

James Electronics
1021-A Howard Ave.
San Carlos, Ca 94070
(415) 592-8097

Newark * Good catalog, available
500 N. Pulaski Rd.
Chicago, Il 60624
(312) 638-4411

Morrow's Micro Stuff
Box 6194
Albany, Ca 94706

Tech-Sales (for Howard fans)
12998 Walsingham Rd.
Largo, Fla 33540
(813) 595-2834

Sheridan/Cincinnati
P.O. Box 37826
Cincinnati, Oh 45222
(800) 543-4695
Other phone numbers....
(800) 582-7027 - in Ohio
(800) 543-8628 - bordering Ohio
(513) 761-5432
another address....
10 Knollcrest Dr.
Cincinnati, Oh 45237

Appendix F

Circuitry for computers without consoles

The designers of the first S-100 compatible CPU cards assumed that a front panel (console) board would always be used with their computers. They allowed a few S-100 signals to be generated on the console board. To retain total compatibility, the later designers of S-100 CPU cards (both 8080 and Z-80) have maintained this convention. If a console is not to be used with an altair/IMSAI compatible processor card, then a minimum of added circuitry is necessary.

Figure 15 gives the circuits required to generate the 'MWRITE' and 'PRESET' signals. Also, a pullup is placed on bus line 20, 'UNPROT' and the 'PROT', line 70, is grounded to prevent false triggering of the memory protect flip-flop. Bus line 21, SS may require a pullup on some CPU cards.

On some CPU cards such as the IMSAI one, 'PRESET' causes a 'POC', power-up-clear, to be generated. 'PRESET' itself is given automatically on power up. This means that the power up and RESET conditions are equivalent.

On other cards, such as the MITS (8800a) one, 'POC' is a separate signal, and does not do a RESET of the CPU. Without a console, such CPUs will power up to an unknown condition. The RESET switch then starts the processor. If you believe the undefined start-up will be a problem, you can add the circuitry to do a RESET automatically on power up. See Figure 15.

The RESET signal will get your processor started at location 0. Unfortunately, much of the software now available for S-100 computers is located at the bottom of memory, and so requires that random access memory be available there. (Considering the hardware significance of this memory area for interrupts, this was a very questionable action.) We get around this problem by having our prom in upper memory and using a vector (jump) circuit to force the CPU there on RESET.

Figure 16 gives a vector circuit. The RESET signal causes the CPU to RESET to 0 and frees the counter formed by the two JK flip flops from a locked state. The CPU outputs 0 on the address lines and attempts to read in the first op code. This is the processor M1 cycle and SM1 is output on the bus. SM1 clocks the counter to enable the '138 decoder. As A0, A1 go through 00, 01, 10 the decoder, combined with the nand gates, will force a 303/8, 000/8, and a switch set number to be forced onto the data input lines.

D0 through D7 are connected to the CPU card via the dip socket normally used by the front panel. The 'SSW DSB' signal (53) allows these lines access to the CPU without interference from the normal bus input signals. The switch bank setting determines the high byte of the vector address. (jump increments are 256 bytes.)

With the jump accomplished, the processor looks for the next op code and again outputs the SM1 signal. The counter then re-enters its initial locked state, with no 'SSW-DSB' and the '138 decoder disabled.

For most systems you will want to set the jump address and leave it. However, it may be convenient to have the hardware ability to jump to various routines (such as boot, mem test, peripheral test, etc.) Figure 17 gives such a circuit, built around an 8223 prom. The prom contains jump codes followed by jump addresses. The 8223 takes the place of the '138, '00, and '05 chips. An octal encoder is tied to the prom address lines 2,3, and 4 so that the different jumps stored in the prom may be used. A rotary switch with 8 positions then determines where the system will jump on reset.

A fixed jump circuit, with the minimum number of packages, is made using the 8223 with its high address lines (2,3,4,) tied to ground. The one jump is programmed in at 0 in the prom.

Appendix G

The number of options presented in the text might tend to obscure the simplicity of the basic Crate. This 'no options' model consists of front and rear panels, 10 support bars, a power supply (with switch, cord, and fuse), motherboard, and card guides. By making use of surplus parts, the cost of the frame and power supply can come to less than the motherboard!

A bill of materials for such a Crate follows. Note that there are two cost estimates: new and surplus. For the latter, we only make a guess based on our finds.

By the way, you'll find that wood panels, lucite covers, flashing lights, etc. notwithstanding, the basic Crate when filled with S-100 cards is extremely impressive.

Note: Sources for a single transformer with the voltages required by the computer are beginning to appear. This can save quite a bit of the power supply cost.

A few last words...

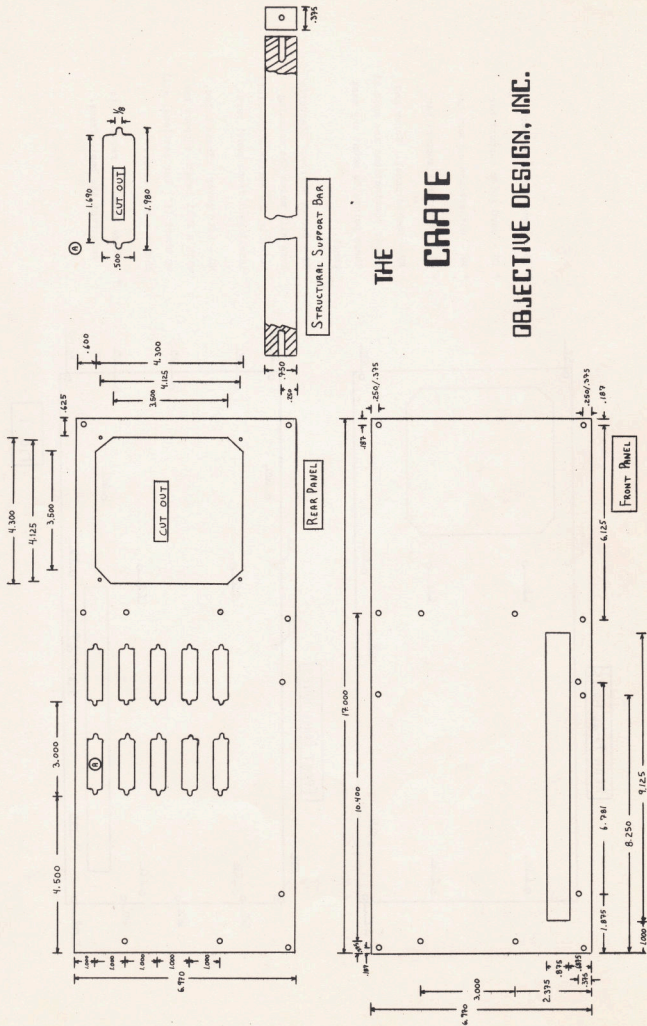
The construction of a computer cardfile and power supply can be as challenging and creative as any other aspect of Personal Computing. As with the writing of a program or designing of an interface, it is an educational experience. If the job is well done, this will show in the long term reliability and performance of the Crate.

The people at Objective Design thank you for buying the Crate Design Book. Your comments and criticisms are invited.

CRATE MATERIALS WORKSHEET

				TOTAL			
COMPONENT	SOURCE	COST/ EACH	QUANTITY	NEW		MIN	
MAIN PANELS	BUD PA-1104/ NEWARK	6.35	2	12	70	5	00
STRUCTURE BARS	3/8 x 3/4 x 12 SMALL PARTS	214.05	4	8	10	6	00
SUPPORT BARS	SAE # 4025	3.45	6	20	70	20	70
CARD GUIDES	SAE # 1450	.16	20	3	20	3	20
MOUNTING FEET	SAE # 2359	.14	20	2	80	2	80
LOCKING TABS	SAE SERIES 3000	.05	50	2	50	2	50
PWR SPLY CHASSIS	BUD PANEL	6.35	1	6	35	2	50
6/32 SCREWS	SMALL PARTS	3.25	100	3	25	—	—
8/32 SCREWS	SMALL PARTS	.50	10	50	—	—	—
4/40 SCREWS	SMALL PARTS	.65	25	65	—	—	—
8V TRANSFORMER	SIGNAL	29.70	1	29	70	28	00
±16V TRANS	SIGNAL	18.50	1	18	50	—	—
8V CAPACITOR	92000 UF/15V MALLORY	8.59	1	8	59	5	00
±16 CAPS	9500 UF/40V MALLORY	4.18	2	8	36	5	00
CAP BRACKETS	SHERIDAN SALES	.30	3	90	—	—	—
DIODE 50V/27AMP	WESTINGHOUSE	3.20	1	3	20	1	50
DIODE 100V/6AMP	WESTINGHOUSE	3.20	1	3	20	1	50
22 SLOT MOTHERBOARD	COMPUTER STORE	50.00	1	50	00	50	00
CARD CONNECTORS	COMPUTER STORE	5.00	10	50	00	50	00
WIRE/ETC	MANY			15	00	5	00
TOTAL				248	20	190	36

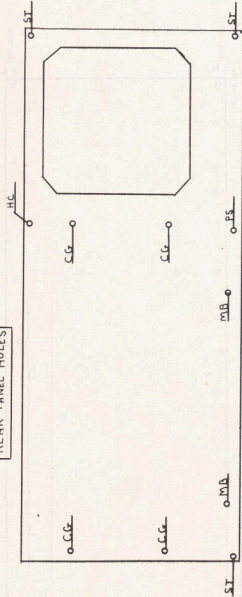
NOTE 1



THE CRATE

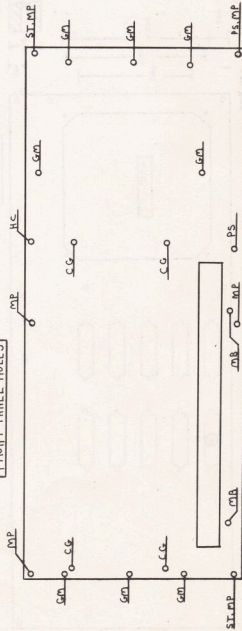
OBJECTIVE DESIGN, INC.

REAR PANEL HOLES



- * PS - power supply support bar
 - * CG - card guide support bar
 - * MB - motherboard support bar
 - * ST - structural support bar
- MP - masked panel. Screw and spacer combinations are used at these points to mount any mask panel.

FRONT PANEL HOLES



- GM - George Morrow. Standoffs here will match the mounting holes in the Morrow Micro-Stuff intelligent front panel card.
- HC - half cover. These holes, with a full length support bar or short (1") bar sections, will anchor a half cover.
- * - These holes are required to construct the basic frame.

FIG 1

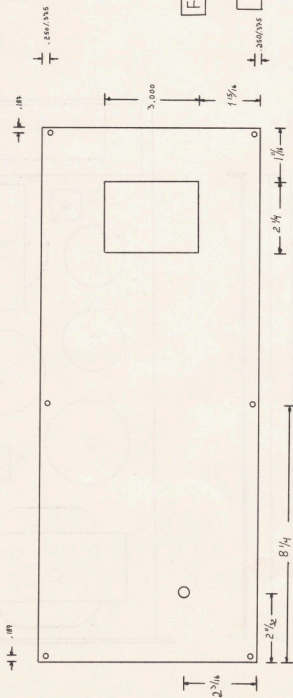


FIG 2

MASK FOR MORROW CONSOLE BOARD

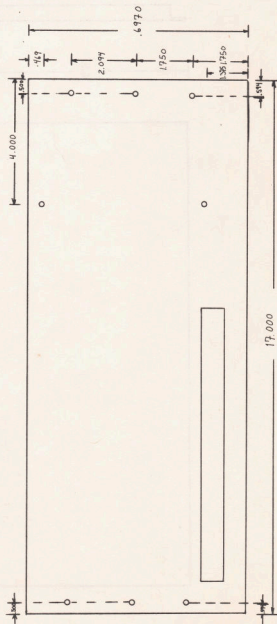
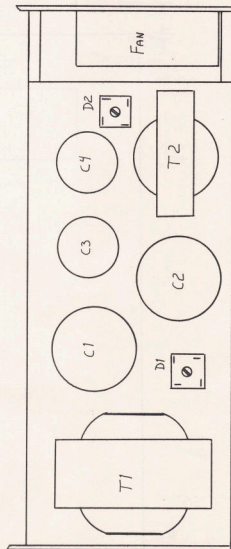
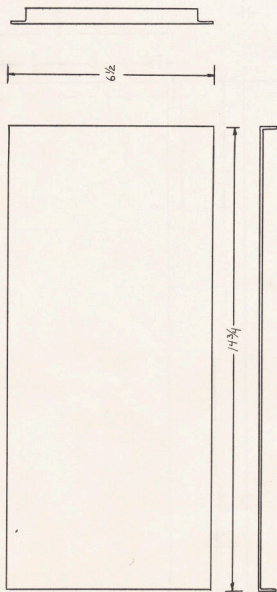


FIG 3

ADDITIONAL FRONT PANEL HOLES
USED FOR MOUNTING MORROW
CONSOLE BOARD

ALL HOLES #36 DRILL
TAP FOR 6-32



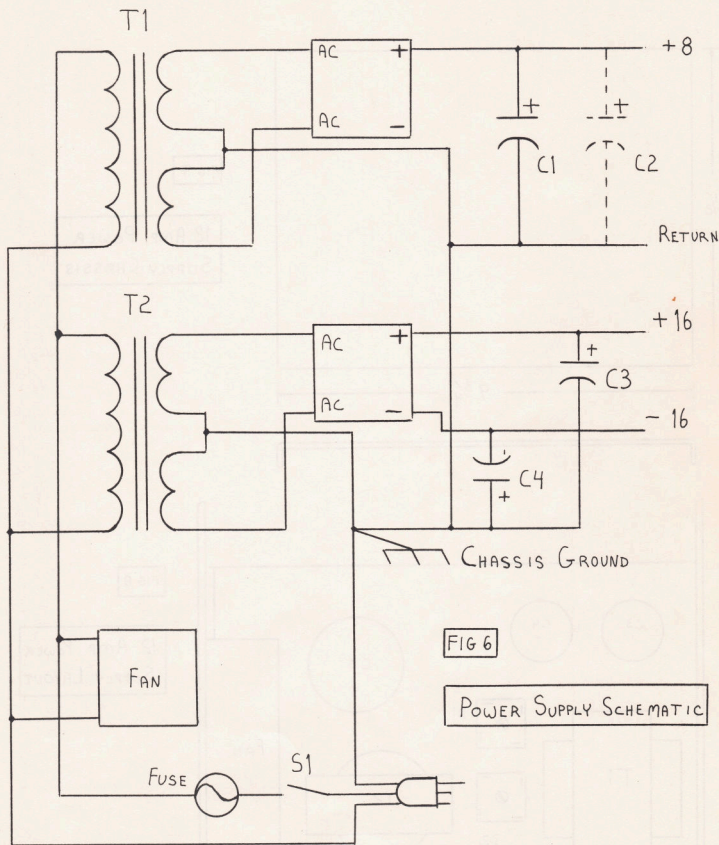
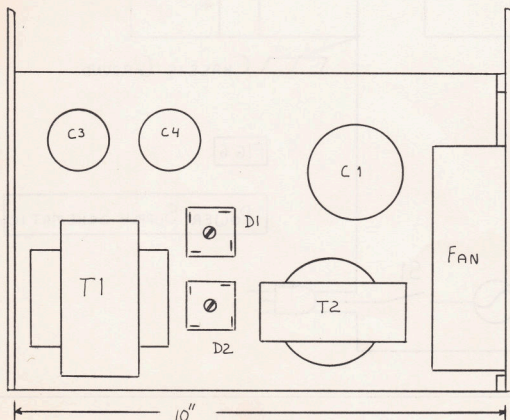
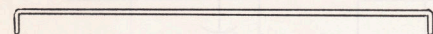
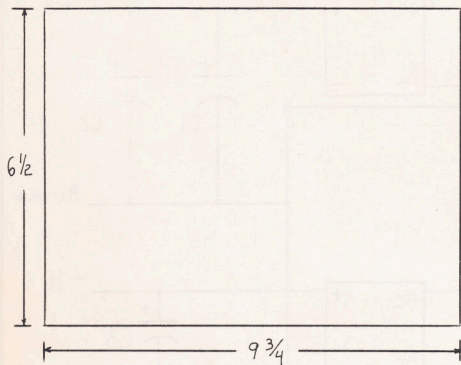


FIG 6

POWER SUPPLY SCHEMATIC



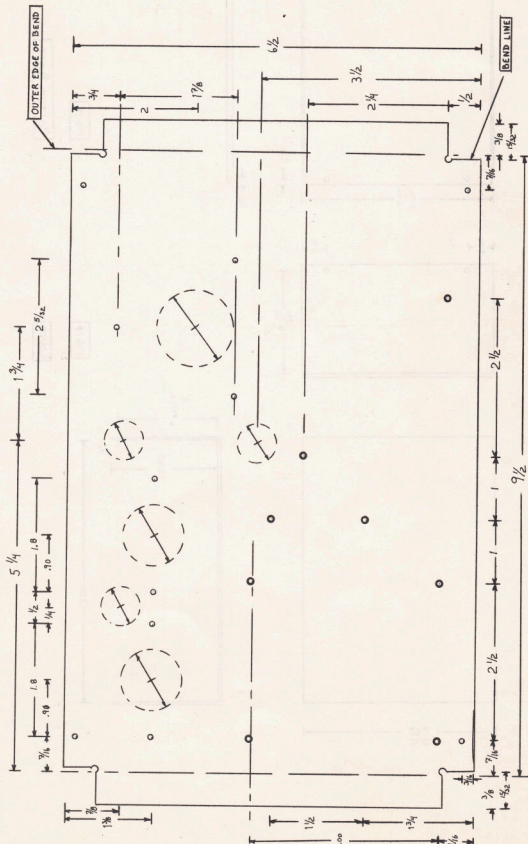


FIG 9

12 AMP POWER
SUPPLY CHASSIS PLAN

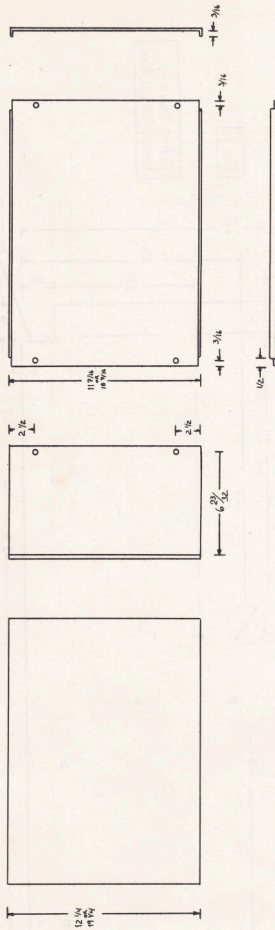


FIG-11

BOTTOM PLATE

FIG-10

COVER

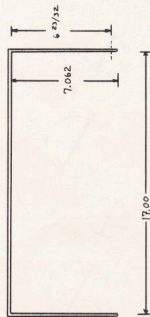


FIG 12

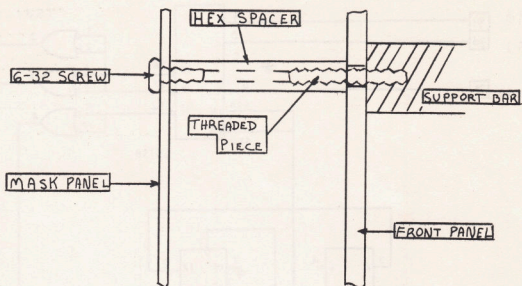


FIG 13

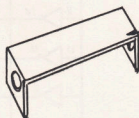
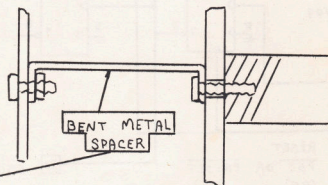
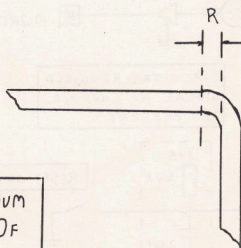


FIG 14



WHEN BENDING ALUMINUM
ALLOW FOR RADIUS OF
BEND

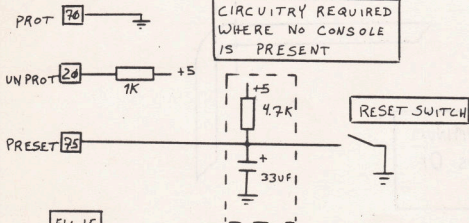
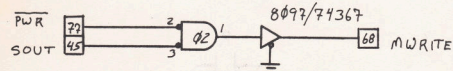
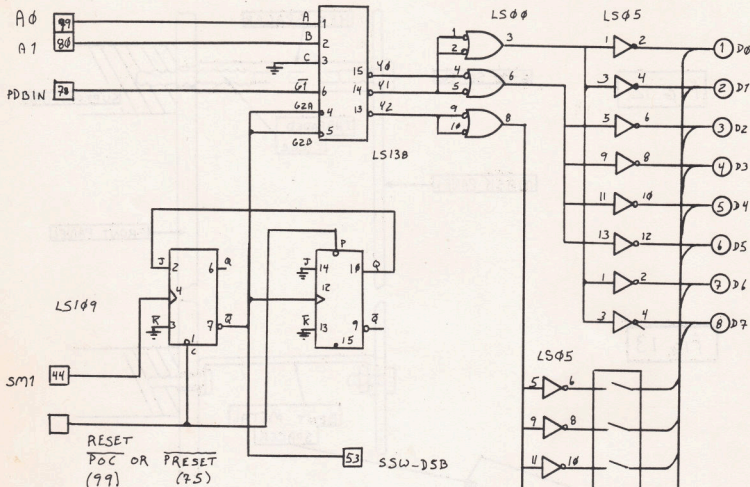


FIG 15

USE POWER UP
RESET OPTION
ON MITS TYPE
CPU CARDS ONLY

DIP SWITCH / 8

POWER UP VECTOR CIRCUIT

FIG 16

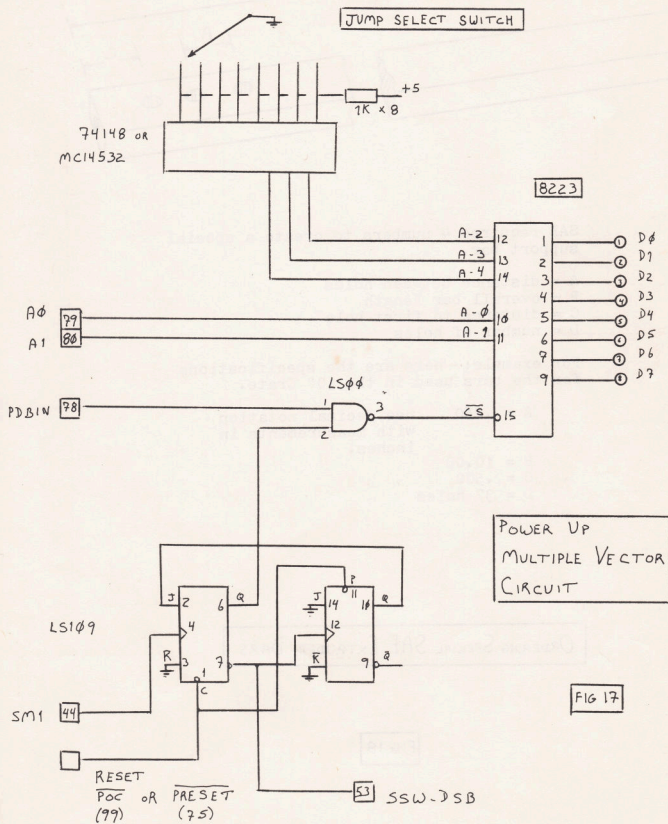
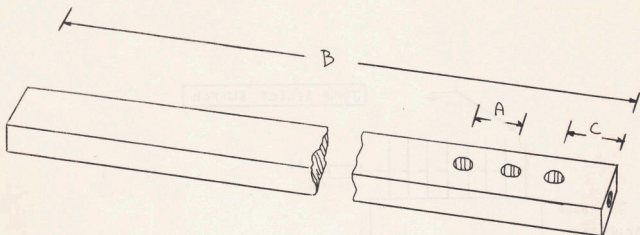


FIG 17



SAE requires 4 numbers to create a special support bar.

- A = distance between holes
- B = overall bar length
- C = distance to first hole
- D = number of holes

For example: here are the specifications for the bars used in the 10" Crate.

- A = .250 use decimal notation with measurements in inches.
- B = 10.00
- C = .500
- D = 37 holes

ORDERING SPECIAL SAE EXTRUDED BARS

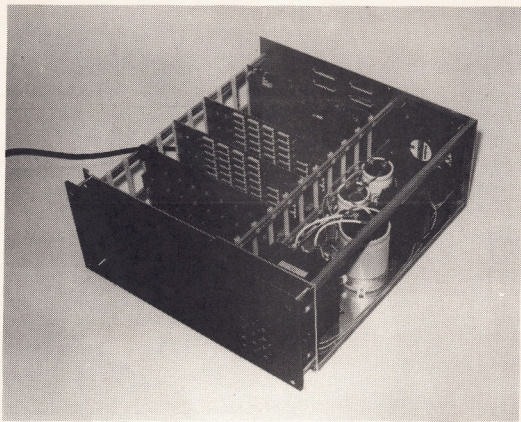
FIG 18

Photographs

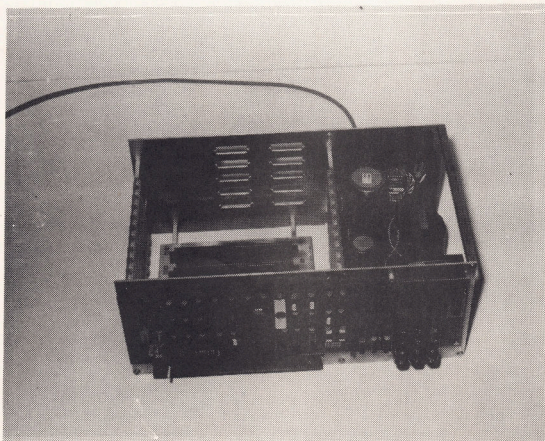
On the following pages are six pictures of the Crate. Combining the text material and drawings with these should result in a good Crate concept.

Points to note in the photographs:

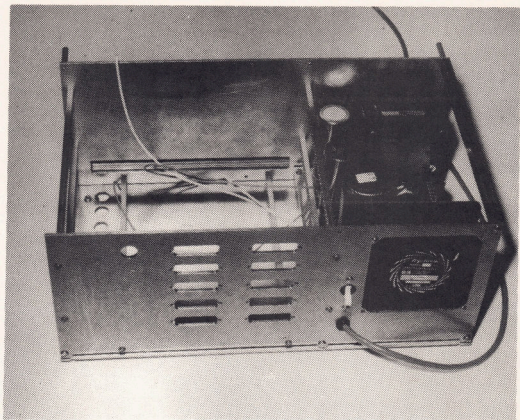
- a) This is the full size Crate. It will accept a 22 slot motherboard and a full set of cards. A George Morrow Intelligent Front Panel is used with a dark lucite mask panel.
- b) The short frame. It holds plenty of cards and still fits on a desk top with room to spare.
- c) A rear view, motherboard not yet in place. Here a circuit breaker serves as fuse and power switch. The bottom plate is already in place. Also note: this Crate has the 'big flip', with the power supply on the left.
- d) This should give you a good idea of the placement of the motherboard and card guide support boards.
- e) Note the power supply connections to the motherboard. Card guides are in place for every socket position. With the Crate, you don't have to remove the motherboard to add new sockets.
- f) A short frame Crate -- upside down. Notice the placement of the motherboard on the mounting feet and the locking tabs which hold the feet to the bars.



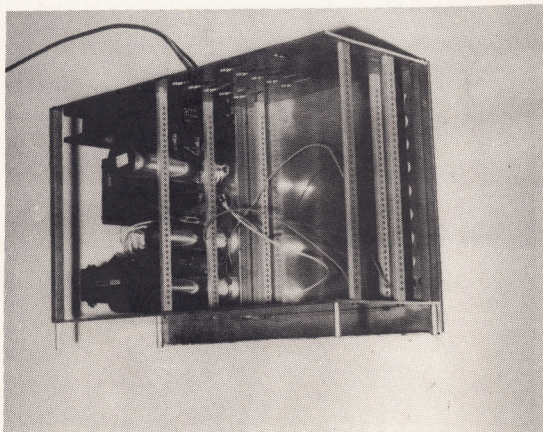
(a)



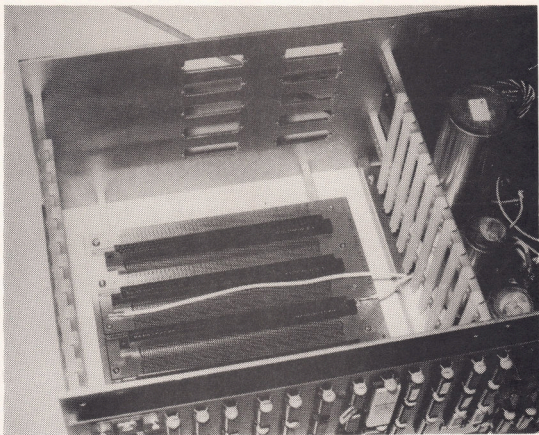
(b)



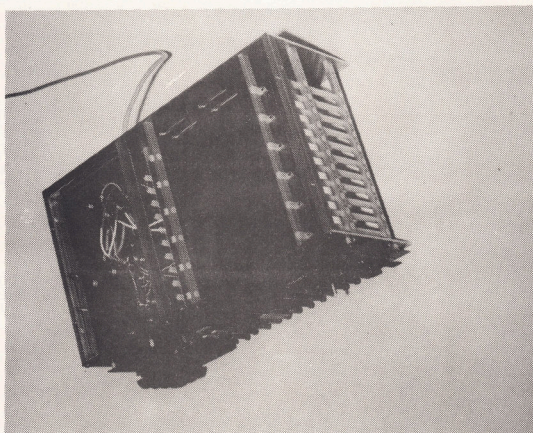
(c)



(d)

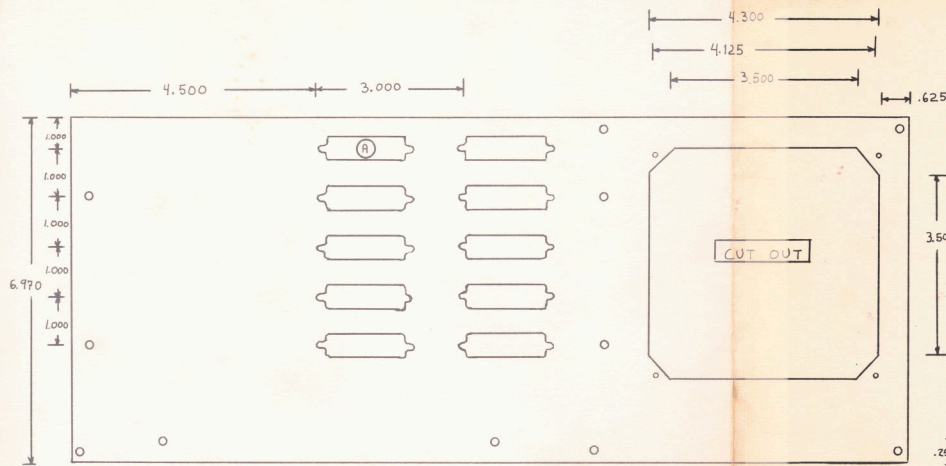


(e)

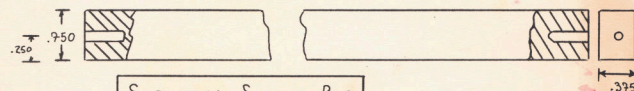
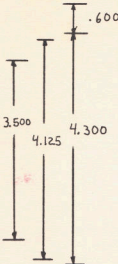
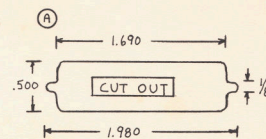


(f)

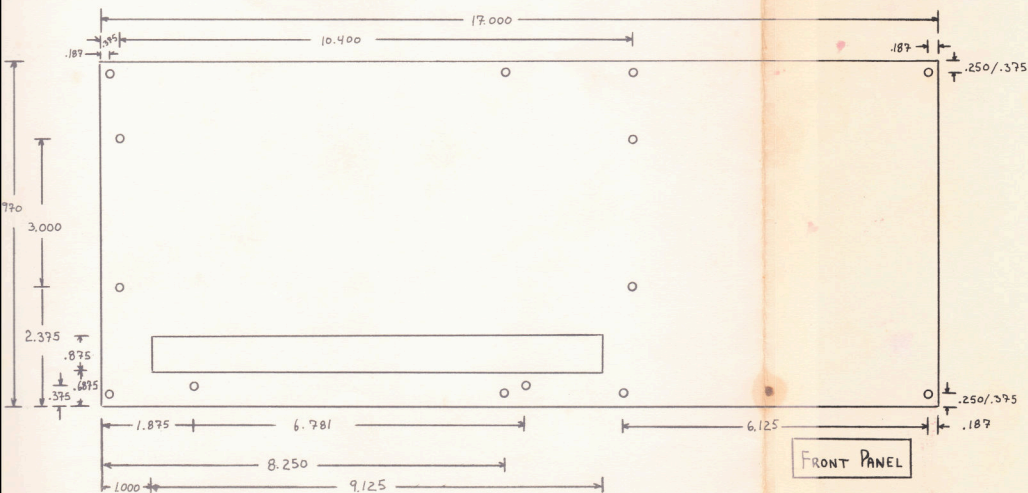
OBJECTIVE DESIGN, INC.
P.O. BOX 20325
TALLAHASSEE, FLA. 32304



REAR PANEL



STRUCTURAL SUPPORT BAR



FRONT PANEL

THE
CRATE

OBJECTIVE DESIGN, INC.