

X-BENCH

Rev A

The X-Bench is a workshop bench designed specifically to accommodate the 1000mm X-Carve CNC router sold by Inventables.¹ In this document I'll provide all the details necessary for you to reproduce an X-Bench for your own workshop.



X-Bench's features include:

- ribbed construction
- drawer storage (though these plans include only the drawer fronts and drawer slides)
- a keyboard tray (top drawer)²
- an electronics enclosure with shelving for computer, controller, etc. that is “positive pressure” ventilated with air filtered through a standard (10" x 20") A/C filter³
- a "cordless" design – all cords and wires are routed through the bench top's structure
- three built in electrical outlets – one for use by the electronics equipment inside the cabinet
- a mobile design – simply unplug the one electrical cord and wheel the X-Bench away...
- the ability to be fairly easily disassembled into three major "units" (not counting the legs) – *box*, *shelf* and *cabinet*
- an opening in the bench top for edge-routing of boards⁴
- the ability to mount a monitor pole at any corner of the workbench⁵
- the ability to manufacture the box top, box bottom and shelf top parts in two separate halves thereby allowing all cut-outs in these pieces to be made using the X-Carve (though no drawings of these “half-parts” are currently provided)⁶
- a cabinet unit that's reversible, allowing you to decide on which side the shelves/drawers are located

This document, including all related images, etc. is provided “as-is”. At the time of publication, I have yet to build an X-Bench for myself and therefore I cannot personally confirm the accuracy of these plans, ease of construction or even the utility of the finished product. As such, consider this initial revision of the X-Bench to be like a “beta” release of software – likely to have a “bug” or two. That said, I've done everything within reason to ensure the correctness of the information contained in these pages. If you should encounter any problems or errors, please contact me per the information at the end of this document.

1 See <http://www.inventables.com/>.

2 This tray should also be able to accommodate a fairly modern laptop. Just be aware that it won't be protected from dust.

3 The X-Carve's control wiring will likely have to be extended in order to reach the controller located in the cabinet.

4 To take full advantage of the X-Bench's edge-routing capability, the X-Carve's base frame requires modification so that the support member running fore-aft down the center of the frame is made to run laterally instead. With this modification, you'll be able to edge-route boards over 20" wide. Without it you'll be limited to edge-routing boards that are no wider than about 10".

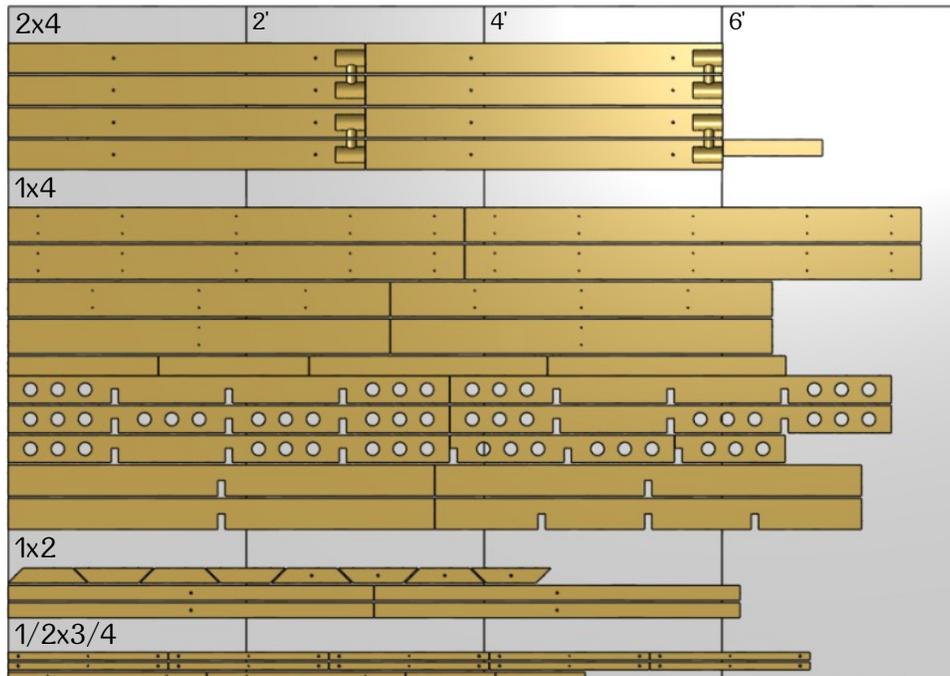
5 This feature can be implemented partially or is completely optional if you already have a means of mounting a monitor.

6 Various other X-Bench parts can be manufactured using the X-Carve as well.

Materials Needed

This section lists the various materials/items that need to be obtained in order to build an X-Bench.

Solid Wood



4 x 8' of 2 x 4

These are used to manufacture the X-Bench's legs as well as the filter frame's "filler block".

10 x 8' of 1 x 4

These are used to produce ribs, edge boards, etc.

3 x 8' of 1 x 2

These are used to manufacture the cabinet left-right members as well as the cabinet corner braces.

3 x 8' of 1/2 x 3/4 trim moulding

This is used to produce the drawer slides as well as the air filter frame.

Plywood

4 x 4' x 4' half sheets 3/8" plywood

In addition to some smaller parts, the 3/8" plywood (see *illustrations 1 through 4*) is primarily used for the three largest X-Bench parts: the *box top*, the *box bottom* and the *shelf top*. The half sheets for these three parts can optionally be obtained as two quarter sheets (2' x 4') assuming that you don't mind having a seam running down the center of your bench top and shelf surfaces.⁷ Besides being easier to transport, this has the added advantage that the X-Carve itself can be used to make the cut-outs in these parts – especially, the box bottom which contains various holes and cut-outs.

Note that 3/8" is the nominal thickness of the plywood and the actual thickness *should* be 11/32".

1 x 4' x 4' half sheet 3/4" plywood

The 3/4" plywood (*illustration 5*) is used to produce various cabinet parts.

Note that 3/4" is the nominal thickness of the plywood and the actual thickness *should* be 23/32".

⁷ From a rigidity standpoint, it shouldn't make a lot of difference whether you choose a single sheet or two quarter sheets of plywood for the box top. The X-Carve is relatively light and the box top's rib structure should be more than adequate to support it without flexing.

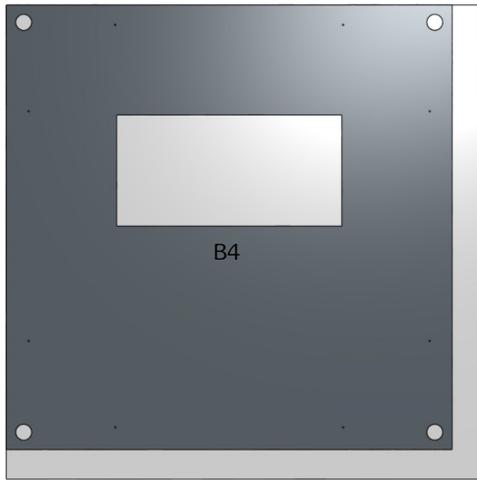


Illustration 1: 3/8" Plywood

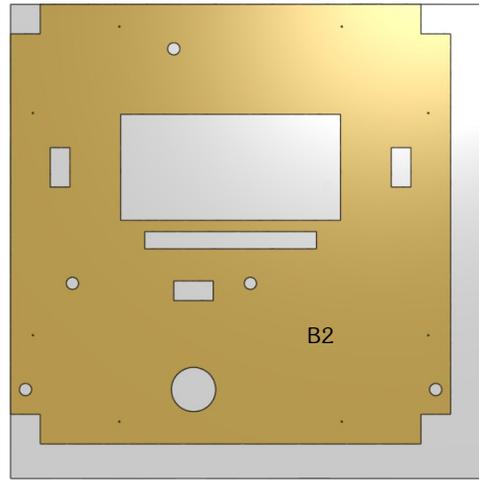


Illustration 2: 3/8" Plywood

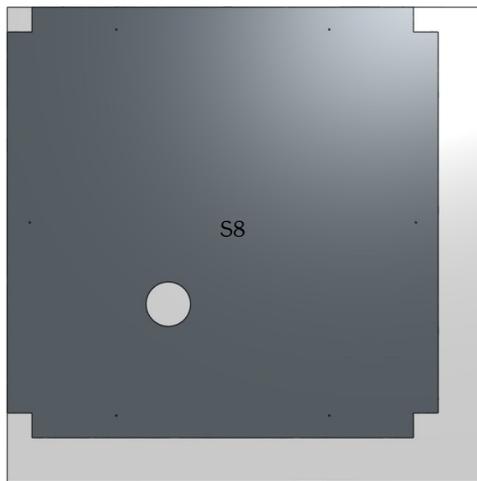


Illustration 3: 3/8" Plywood

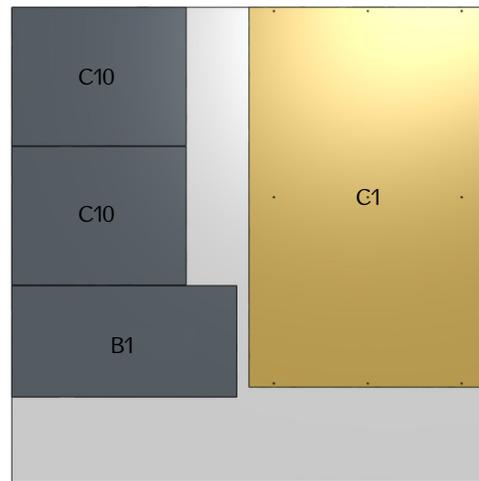


Illustration 4: 3/8" Plywood

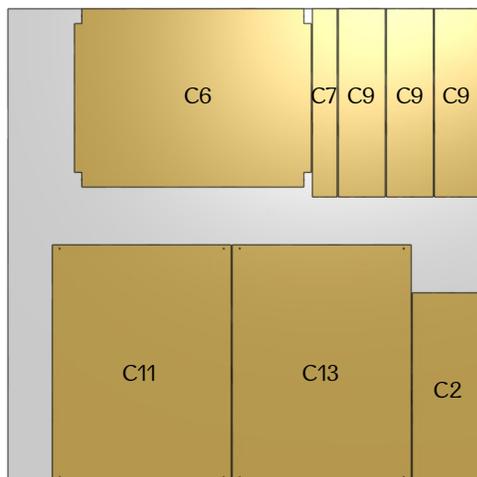


Illustration 5: 3/4" Plywood

Fasteners

8 x 3" x 1/4" hex bolts

Two of these are needed per leg assembly to combine the two leg parts together.

8 x 1/4" T-nuts

Two of these are needed per leg assembly to combine the two leg parts together.

8 x 1/4" washers

Two of these are needed per leg assembly to combine the two leg parts together.

4 x 1/4" x 2" carriage bolts

These are used as “pins” to lock the cabinet unit in place and keep it from sliding on the shelf during use.

6 x 1/4" fender washers

These will be used as shims to vertically position the cabinet unit. They should be 1/16" in thickness.

16 x pocket hole screws

These are used to attach the eight cabinet corner braces. Either a 1" or a 1 1/4" length screw should work just fine. The former requires that you use a 1/2" countersink and the latter, a 1/4" countersink in order to sink the screw about 1/2" into the cabinet's side.

64 x 1 3/4" wood screws

56 of these are needed to attach the box and shelf edge boards. 8 are needed to attach the cabinet sides to the cabinet left-right members.

45 x 1" wood screws

22 of these are needed to attach the box top, box bottom and shelf top. 9 are needed to attach the cabinet back to the cabinet spine and sides. 4 will be used to attach the air filter frame to the shelf unit. 10 are needed to attach the wooden drawer slides.

32 x 5/8" “pan” head screws

These screws are needed to attach the eight shelf corner (Simpson Strong-Tie) brackets. They are basically wood screws except that they have a “pan” shaped head (not unlike a pocket hole screw). Note that this quantity assumes that you'll use four screws per bracket. Also, it's important that these

screws be short enough that they don't protrude through the outside face of the shelf edge boards. As an alternative, *half* of these can be replaced by bolts/nuts (used just to attach the bracket to the edge boards). If bolts are used, they'll need to be about 1 1/4" long.

48 x 1/4" x 1" wood dowels

These are used in various places to aid in alignment of parts.

Miscellaneous

1 x 120mm axial fan

This will serve as the cabinet's exhaust fan. It should ideally be a unit intended for industrial use that runs straight off mains (AC) voltage. Here's the one that I'll be using:

<https://www.amazon.com/AC-Infinity-HS1238A-Cooling-120mm/dp/B004YTSB7C>

1 x 120mm fan grill

This is used to cover the air vent opening at the bottom of the cabinet. Note that a grill is only needed if you attach the exhaust fan *below* the cabinet floor (which is recommended) and not *above* it. These are commonly used to cover the exhaust fan in a desktop/tower computer case and a Google image search will provide many potential sources. Aside from being purchased, it can also be 3D printed.

1 x "1U" perforated vent panel

This is a common "rack unit" vent panel. It will be used to cover the air exhaust vent located in the box bottom (seen in *illustration 8*) in order to help keep bugs out of the box unit. It will require four small wood screws to fasten it (not listed). I purchased this one:

<https://www.amazon.com/Middle-Atlantic-Products-Vented-VTF1/dp/B0002D0ERY>

The perforations are a bit on the smallish side for this particular panel but it should still work given that the overall surface area is roughly 30 square inches.

8 x Simpson Strong-Tie corner brackets

These can be found at Home Depot (<http://www.homedepot.com/p/Simpson-Strong-Tie-18-Gauge-Galvanized-Steel-Angle-A23/100374944>). For the purpose at-hand, these are not exactly ideal as they're actually designed to be used with nails; however, considering that they're quite strong, perfectly sized for the job and reasonably priced, they're hard to beat. Note that if you decide to use a different bracket, *be sure that it attaches to the leg assembly only via the "inner" leg part* as the Strong-Tie bracket does. This can be seen in *illustration 23*.

2 x cabinet door hinges

I believe that these should be *half-overlay* "euro" style hinges that mount to the inside face of each cabinet side.

6 x drawer/door handles

Almost anything should work for these.

5 sets of drawer slides

Anything that can mount directly to the cabinet side and spine ought to work just fine. *Note that this hardware is optional* as it's assumed that the drawer slides will be created in the more traditional fashion – that is, by routing a channel down the center line of each drawer side which then mates with a wood rail or “slide” that is attached to the cabinet frame (see <http://designsbystudioc.com/how-to-make-drawer-slides/>).

4 x shelf support rails

These are optional but they can make both mounting and adjusting your shelves easier. They can be obtained from various sources including: <http://www.wwhardware.com/shelf-hardware-organizers/shelf-closet-hardware/shelf-hardware/rpc-economy-shelf-standards-c58> and <http://woodworker.com/24-zinc-standard-mssu-853-056.asp>. These are useful in allowing you to drill a minimum number of mounting holes for supporting multiple shelves (which should help you to avoid interference with the drawer slide mounting holes). Note that it might be possible to make your own support rails from 1/2 x 3/4 trim moulding and then attach them using the 1/4” holes that will already exist in the cabinet sides and spine (intended for use with the default, wooden drawer slides option).

3 x single electrical outlet boxes with covers

One of these will be used to power the computer, controller, etc. inside the cabinet and the other two will be mounted on the underside of the box unit, accessible from the left and right sides of the workbench. For simplicity sake, these can be the kind of outlet boxes that have the little “tabs” that allow you to affix them directly to drywall. The outlet box I plan to use is the Carlon 14 cu in 1-gang plastic, model no. B114RB sold at either Home Depot or Lowes.

1 x “4 square” junction box

This 4" x 4" electrical box is used both as an entry point for bringing mains power into the X-Bench as well as a means of easily distributing power lines to the three electrical outlet boxes. Ideally, this should be a metal box that allows use of cord retainers (Romex connectors). Note that the depth of the junction box + cover must be less than 2.75".

4 x Romex connectors

These will be used to secure the electrical wiring that emerges from the junction box. Note, use of these assumes that you'll be using a *metal* junction box (see above).

10 ft of electrical wiring

This is the wiring needed *internally* to connect the electrical outlets and the junction box. Use standard house electrical (Romex) wiring if you have it available. Another option is to re-purpose a good, heavy gauge extension cord.

10 ft of electrical cord

This will be used *externally* as the workbench's power cord. Such can be bought at a home improvement center or it can be made from a heavy gauge extension cord.

1 x 10 x 20 A/C filter

These should be available at most home improvement centers.

6 ft of 1 5/8" OD fence post pipe

This will be used as a monitor pole, enabling you to mount your computer monitor at a given corner of the workbench. As only about 3 feet of pipe is needed for this purpose, the additional 3 feet can be used to mount either a work light (or perhaps an additional monitor). This pipe can be obtained at a home improvement center like Home Depot or Lowes. Note that if you already have a means of mounting a monitor then this item isn't required.

1 x 20 1/2" x 15 5/8" x 1/8" glass or acrylic pane

This will be set inside of the cabinet door frame.

2 x 1 1/4" plugs/caps

These are needed to plug any holes that are unused in the box bottom. They can be made from wood using your X-Carve, 3D printed out of plastic or possibly found on-line or at a home improvement center.

4 x 1 5/8" plugs/caps

These are needed to plug any monitor mount holes that are unused in the box top. They can be made from wood using your X-Carve, 3D printed out of plastic or possibly found on-line or at a home improvement center.

1 x set of 4 casters

These will allow you to easily move your X-Bench to different locations in your shop. Note that the bottom of an X-Bench leg is 3" square so you'll need a caster having a top plate that is smaller than that. Though I haven't yet purchased them, this particular set of casters looks promising:

<https://www.amazon.com/gp/product/B01H5PX6KI>.

Tools Needed

Listed below are the tools that you might use to build the X-Bench (not including minor ones). Note that some functions provided by the tools listed may also be provided by your X-Carve.

table saw

A table saw is mostly needed for ripping the leg parts and various ribs to their proper widths. That said, it can be very handy for cutting various other parts to size as well.

drill press

A drill press (or hand drill) will be needed for drilling holes that can't easily be cut using your X-Carve.

circular saw

A circular saw is needed to cut the larger plywood parts to size.

miter saw

A miter saw is needed to miter the edges of the box edge boards. It is also a good choice for cutting the solid lumber parts to length although in some cases this latter functionality can be obtained using a table saw or circular saw.

router

A router is needed to cut the groove in the edge boards as well as the cabinet door frame members. As an alternative, you can cut these using a table saw. Of course, the X-Carve could be applied to cut these as well.

1 5/8" Forstner drill bit

This bit is a good choice for drilling the large hole into the top of each leg. Note that it must be long enough to drill a hole that is about 3" deep. As an alternative, the X-Carve should effectively be able to cut this hole (by cutting a semi-circle shaped cross-section into each leg part).

Building the X-Bench

In this section is the list of X-Bench parts to build. It's organized according to the three major X-Bench components: the *box* unit, the *cabinet* unit and the *shelf* unit. The only parts that lie outside of these are the bench's four leg parts, which are categorized as *miscellaneous*. As you'll see from browsing the list, the first word of a part's name determines the component category that part belongs to. Included with each listed part is the quantity needed, the raw material the part is built from and in some cases, notes regarding the part's manufacture.

The parts listed in this section can be manufactured in any order. That said, if your X-Carve isn't already set up and functional, you may want to produce the cabinet parts *last* as you could then use your X-Carve mounted on the nearly completed X-Bench to aid you in manufacturing those remaining cabinet parts.

Included in this section are images rendered of the X-Bench intended to aid you in identifying the parts that need to be manufactured. The identifying labels seen on the later images refer to the parts listed later in this section.

General Woodworking Tips

Following are some woodworking tips to keep in mind as you build your X-Bench:

1. Think safety first!
2. Take your time, think it through... and do it right.
3. Be sure to read *all* instructions – including footnotes – pertaining to the manufacture of a part before you begin manufacturing it. *This can save you a lot of pain and suffering!*
4. If making cuts using *traditional tools*, make all of your measurements as carefully and precise as you can, but more important, try to *minimize the number of measurements that you must make to begin with*. In other words, if two or more cuts should be made identical, don't measure each one individually. Doing so virtually guarantees that errors will result that can cause problems in the end. If two measurements/cuts *should* be the same, *then ensure that they are the same!* For example, when cutting multiple of the same part to length using a miter saw, rather than measuring the length of each part individually (and needlessly introducing errors), use a means of “blocking” to help ensure that each part is actually cut to length *identical* to the others.
5. Mark lines to be cut and hole centers to be drilled using a marking instrument that has a very fine but strong point (preferably one that doesn't require constant sharpening).
6. Always make cuts of questionable accuracy on a scrap piece of wood first so that you can measure and make adjustments prior to making the cut for real. Likewise, if you're not experienced with a wood working technique, be sure to practice it first using scrap materials before attempting it on your actual work piece.
7. Check your quality as you go. For example, when cutting to-size a piece of plywood that is supposed to be square, afterwards check to be sure that it actually is square before proceeding to the next step.

Build Notes

Although the X-Bench drawings indicate that the box unit's top and bottom panels (plus the shelf unit's top panel) are all constructed from half-sheets (4' x 4') of plywood, in fact, these can be manufactured in two pieces with each one being cut from a *quarter* sheet (2' x 4') of plywood. If done this way, the seam between the two pieces should run along the workbench's fore-aft center line, which lies over a rib. In addition to making it easier to transport the plywood materials to your workshop, this makes it possible for the X-Carve to be utilized in the manufacture of these parts (although granted, this mostly makes sense for manufacturing the box bottom as it has various holes and cut-outs which might otherwise be tedious to measure and cut by hand).

Although the X-Bench plans show a monitor mounting hole drilled into the top of each workbench leg (and a corresponding hole drilled into the box top), if you're absolutely certain that you'll only mount your monitor at one corner of the X-Bench, then you don't need to cut the mounting holes into the other three legs. Personally, I'd rather have the option to easily switch the location of the monitor but there's no reason why you couldn't start with just one mounting position and add the others later as needed. Also, not only are you not obligated to make *all* four corners of the X-Bench capable of mounting a monitor (by drilling a hole into the top of each leg), *if you have another means of mounting a monitor, you don't have to cut a mounting hole in any of the workbench's corners to accept a monitor!* Just be aware that these monitor mounting holes provide the additional benefit that wires can easily be routed through them – and that's regardless of whether a monitor is actually mounted in the hole or not. Therefore, given that X-Carve's control wires emerge from the front/left of the machine, you'll almost certainly want to drill out the leg at the front left corner of the X-Bench, if only to route the X-Carve's control wires down into the cabinet. It's also worth mentioning that even if you reverse the cabinet, the X-Carve's control wires must still enter the box at its front left corner. It's just a matter of do you route the wires through the leg itself or do you route them over the box's left edge and into the hole that's drilled into the box's bottom...

Dimensions are shown on the engineering drawings as *decimal* values. Some of these will present no problem as they represent common Imperial fractions such as $\frac{1}{4}$ " or $\frac{1}{2}$ ". Others aren't quite so common. To help with these, I've included the following table:

0.062 = 1/16	0.125 = 1/8	0.187 = 3/16
0.312 = 5/16	0.375 = 3/8	0.437 = 7/16
0.563 = 9/16	0.625 = 5/8	0.687 = 11/16
0.812 = 13/16	0.875 = 7/8	0.937 = 15/16

The cabinet unit is designed so that it can be “finished” using standard cabinetry techniques. It is considered a “frame-less” design that doesn't incorporate a face frame in order to conceal the raw edges of the cabinet box. As such, you should be able to find lots of information on the web (including YouTube videos) that explain the process of building cabinet drawers, mounting shelves and mounting a cabinet door. For example, here is a YouTube video showing how to construct cabinet drawers using a pocket hole jig: <https://www.youtube.com/watch?v=sKVo-rLv-W8>.

Design-wise, the edge-routing functionality of the X-Bench is somewhat incomplete as some sort of structure must be incorporated for attaching a board to be edge-routed at a given angle (typically 90°) with reference to the bench top. Some experimentation will likely be needed here but one possibility is to “hinge” a piece of “one-by” lumber along the bottom edge of the edge-routing frame so that it can be set at a desired angle and the board being edge-routed can then be clamped to it. Voilà!

If you decide to build the X-Bench cabinet so that its shelves and drawers are reversed – that is, the drawers are located on the left and the shelves on the right – in addition, you'll need to reverse (or “flip”) both the box bottom and the shelf top as well. Furthermore, the air filter frame will need to be attached in the space to the *right* of the shelf's fore-aft centerline – and *not* to its left.

The X-Bench's Parts

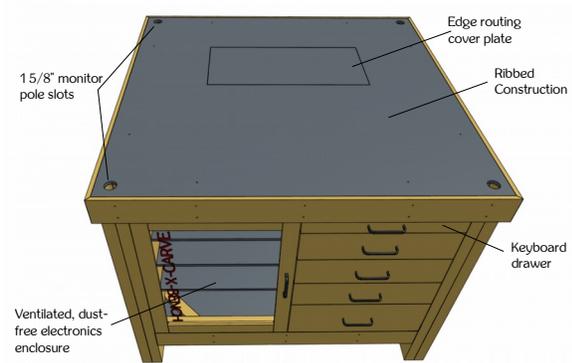


Illustration 6

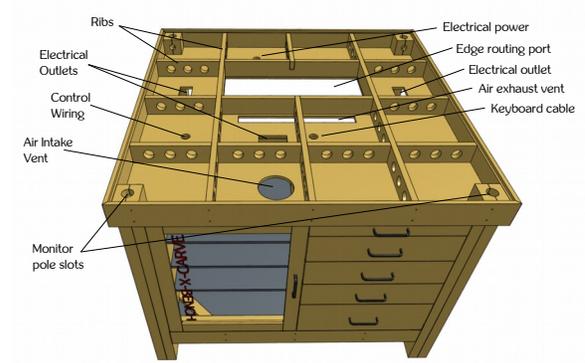


Illustration 7

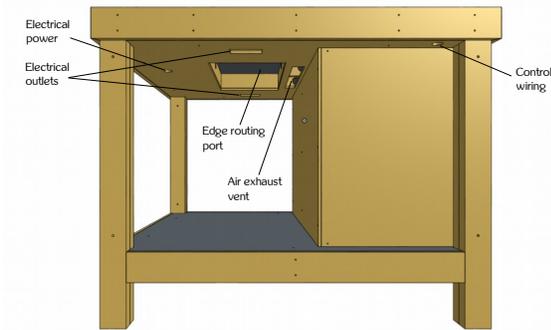


Illustration 8

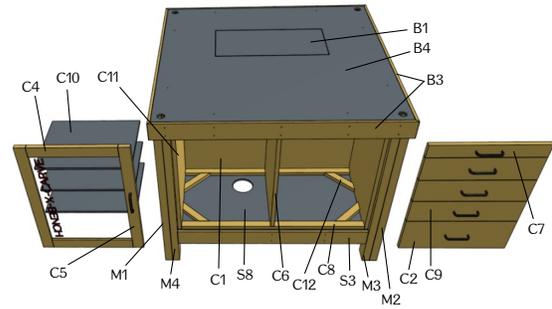


Illustration 9

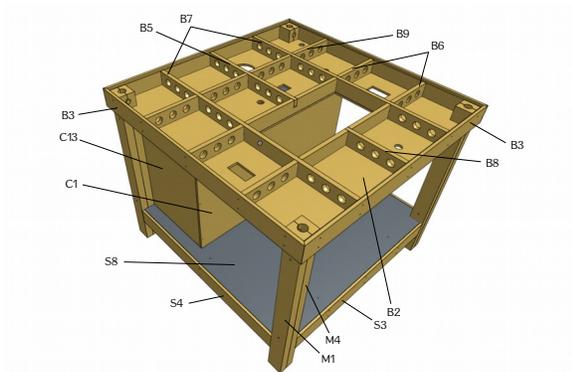


Illustration 10

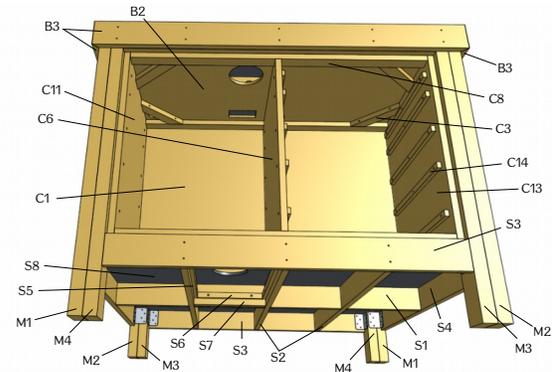


Illustration 11

Building the Legs

Each of the X-Bench's legs is comprised of two half-leg parts that are almost mirror images of one another. These are an *inner* leg part and an *outer* leg part. As you might guess, the “outer” part is the one facing *outward* from the side of the workbench. Both inner and outer parts can be either type “A” or type “B”.⁸ As such, there are two possible leg assembly combinations: an inner A part combined with an outer B part and an outer A part in combination with an inner B part. These two combinations account for all four X-Bench legs as the combination for a given corner applies also to its *opposite* corner. Both combinations can be seen in *illustration 12*.

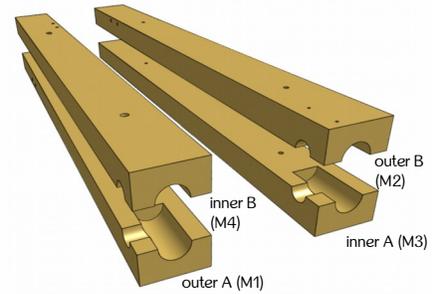


Illustration 12: leg part combinations

Note that it's very important to locate all of a leg part's features with reference to its *top and not its bottom*. Otherwise, you may find later that the cabinet unit doesn't fit between the box and shelf units!

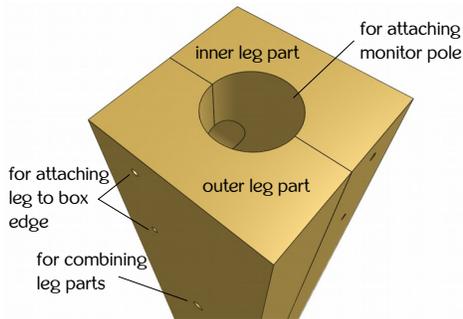


Illustration 13: top of a leg

The first step to producing the X-Bench's legs is to cut each of the eight leg parts to length from a 2x4 and then rip them to 3" wide on a table saw. The next step is to drill the two 1/4" holes that are located on the center line of the wide face of each part. These are for attaching the two leg halves together using 3" long 1/4" bolts. If cut on the X-Carve, these holes may require a special bit to allow for the 1 1/2" depth of cut. As an alternative to drilling them completely through the material, you can set the X-Carve to cut the holes to a shallower depth

and then finish them using a hand drill or a drill press. Note that on the inside face (cabinet side) of the two inner leg parts, these two holes must be slightly enlarged to 5/16" (for about 3/8" depth) to accept the 1/4" T-nuts.

A leg's attachment to the box unit (through the box edge boards) is made via the four small (3/32") holes as seen in *illustration 13*. These holes are located on the *wide* face of the *outer* leg parts and on the *narrow* face of the *inner* leg parts. Note that you won't be able to drill the two holes that are located on the narrow face of the inner leg part using your X-Carve, due to the machine's limited Z-axis travel – these must be drilled either using a drill press or a hand drill. As such, consider employing a jig of some sort that makes locating and drilling these holes easier. All four of the holes are drilled 1" deep.

⁸ The two types are true mirror images of one another and so, for example, an outer type “A” is a mirror image of an outer type “B”.

As seen in *illustration 14*, each of the leg parts also has two *alignment* holes to make it easier to attach the leg assembly to the shelf unit at the correct height. These two holes are located on the outer part's narrow face and on the inner part's wide face. These 1/4" holes are drilled 3/4" deep.

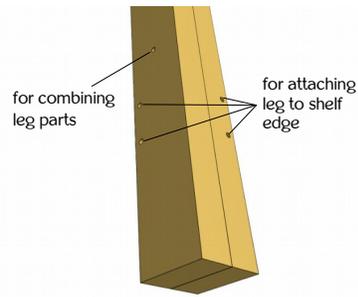


Illustration 14: bottom of a leg

Cutting the large 1 5/8" hole in the top of each leg assembly can be done either using traditional tools or using your X-Carve. If you choose the former, you'll need a drill bit that can not only drill the desired diameter but also the depth of

hole as shown in the drawings (3"). A good choice to consider here is a Forstner bit which will leave a flat-cut bottom. You can either clamp or bolt the two leg halves together (the latter assuming you've already drilled the two holes that are intended for combining the two leg halves) and then the hole can easily be drilled. The important thing is to drill the hole as *perpendicular* to the leg's top surface as you can.

If instead you choose to shape this hole using your X-Carve, you will need access to the appropriate 3D software necessary for making this sort of carving (though once the g-code has been generated, anyone should be able to benefit from using it).

The X-Carve can also be used to cut the 1" diameter hole in the side of each leg. Note that this hole can actually have a *rectangular* cross-section and therefore you could just cut a 1" wide groove or pocket (which doesn't require full 3D capable software).

Last but not least, after manufacturing each leg part, be sure to label it (with "M1", "M2", "M3" or "M4") so that later, during assembly, you can more easily pair up the leg parts.

M01 - Misc Outer Leg A

Qty 2, 2 x 4

M02 - Misc Outer Leg B

Qty 2, 2 x 4

M03 - Misc Inner Leg A

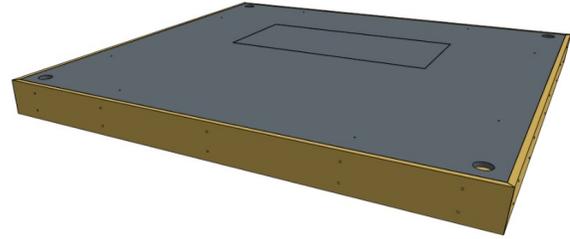
Qty 2, 2 x 4

M04 - Misc Inner Leg B

Qty 2, 2 x 4

Building the Box

The box assembly is comprised of various types of ribs, four edge boards, top and bottom sheets and an edge routing cover plate. All construction is either using 1x4 lumber or 3/8" plywood. Note that box ribs (all variations) have regular hole and notch spacing; therefore, consider using a jig to help produce them. Of course, these can also be cut using the X-Carve.



Again, the box top and bottom can both be created in two halves with the resulting seam running fore and aft along the center rib. This alternative construction makes it possible for you to make the cut-outs for these parts using your X-Carve.⁹

The first step in creating the box ribs is to cut them all to length. After that, each one must be ripped on the table saw to a consistent height of 2 3/4". Finally, the holes and notches must all be cut.

Each of the box ribs has two 3/32" pilot holes drilled into its ends. These are for attaching the box edge boards to the rib structure. These holes are drilled 1" deep. Consider employing a jig of some sort to make locating and drilling these holes easier.

WARNING: Be sure to cut the notches in the box ribs to the depth specified by the respective drawings (1 7/16"), *and no shallower*.¹⁰ If a notch is cut too shallow, it can result in a misalignment of parts and a box top surface that isn't as flat as it should be.

B1 - Box Edge Routing Cover Plate

Qty 1, 3/8" plywood

The edge routing cover plate rests in the large opening cut into the box top. Note that *this part is optional* as it would only be used to close off the edge routing port in the event you needed to use the X-Bench for a purpose other than accommodating the X-Carve.

B2 - Box Bottom

Qty 1, 3/8" plywood

This part can be manufactured in two halves (be they from two quarter sheets of plywood or from a single half-sheet of plywood cut in two pieces). This will allow you to use your X-Carve to produce all

⁹ From a rigidity standpoint, it shouldn't make a lot of difference whether you choose a single sheet or two quarter sheets of plywood for the box top. The X-Carve is relatively light and the box top's rib structure should be more than adequate to support it without flexing.

¹⁰ A notch cut a bit deeper would likely be okay, but not shallower. Notches are sized so that when the rib structure is assembled, there should be a 1/8" gap inside of each joint.

of the cut-outs (though granted, two “passes” per each half will be required as a quarter sheet of plywood is still too large to be fully processed on a 1000mm X-Carve).

WARNING: The dimensions of the cut-outs for the three electrical outlets *are an approximation only*. The exact dimensions depend on the particular kind of electrical outlet box you've chosen to use.

Note that these plans don't currently take into consideration the need to connect your computer to a local area network (LAN) *using an ethernet cable*. If you'll be using ethernet to connect the X-Bench computer to your network, you might want to consider adding an additional rectangular cut-out located in the open space to the right of the one that contains the electrical junction box (see *illustration 24*). You'll want to size the cut-out so that you can attach a wall plate containing an ethernet jack to the box bottom. This will enable you to easily disconnect the network cable if/when you need to roll the X-Bench to a different location in your shop.

B3 - Box Edge

Qty 4, 1 x 4

These comprise the box's four edges. The small holes that are drilled into each one are 5/32" diameter and are used to attach the edge board either to a leg part or to one of the box ribs. The ends of each box edge board is mitered at a 45° angle.

B4 - Box Top

Qty 1, 3/8" plywood

Remember that you need to drill a 1 5/8" hole in a corner of the box top *only* if you intend to mount a monitor or route control wires into the box at that corner.

B5 - Box Half Rib

Qty 1, 1 x 4

It might be easiest to produce this part by creating a *Box Isolating Rib* (B7) and then cutting it in two places thus resulting in a *Box Half Rib* (B5) and a *Box Quarter Rib* (B8).

B6 - Box Isolating Cross Rib

Qty 2, 1 x 4

B7 - Box Isolating Rib

Qty 2, 1 x 4

B8 - Box Quarter Rib

Qty 1, 1 x 4

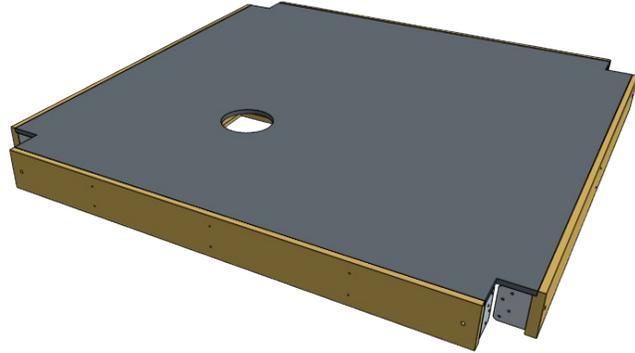
It might be easiest to produce this part by creating a *Box Isolating Rib* (B7) and then cutting it in two places thus resulting in a *Box Half Rib* (B5) and a *Box Quarter Rib* (B8).

B9 - Box Rib

Qty 1, 1 x 4

Building the Shelf

The X-Bench's shelf unit is constructed similar to the box unit. It consists of two types of ribs, two types of edge boards, a top sheet and a few minor air filter frame parts. With the exception of these minor parts, all construction is either using 1x4 lumber or 3/8" plywood. Note that shelf ribs have regular hole and notch spacing; therefore, consider using a jig to help produce them. Again, these can also be cut using the X-Carve.



The first step in creating the shelf ribs is to cut them all to length. After that, each one must be ripped on the table saw to a consistent height of 3 1/8". Finally, the notches must all be cut.

Each of the shelf ribs has two 3/32" pilot holes drilled into its ends. These are for attaching the shelf edge boards to the rib structure. These holes are drilled 1" deep. Consider employing a jig of some sort to make locating and drilling them easier.

Likewise, two 1/4" holes are drilled into the ends of both types of shelf edge boards. These are used to help align the bench legs with the shelf unit during assembly. They are drilled 3/8" deep.

Also regarding the shelf edge boards, one or more holes will need to be drilled near each end of these boards for attachment to a shelf corner bracket; however, these holes need *not* be drilled until later when the legs are being attached to the shelf as locating the holes is most easily accomplished using the corner brackets themselves as templates.

S01 - Shelf Center Rib

Qty 1, 1 x 4

S02 - Shelf Cross Rib

Qty 3, 1 x 4

S03 - Shelf Edge Front-Back

Qty 2, 1 x 4

S04 - Shelf Edge Side

Qty 2, 1 x 4

S05 - Shelf Filter Frame Long Side

Qty 2, 1/2 x 3/4

Each part is cut to length and then a 1/4" hole is drilled near each end of the part to accept wood dowels. These will allow the filter frame to be pre-assembled thus making it easier to attach to the underside of the shelf unit. The two additional 5/32" holes that are drilled into this part are for the screws used to attach the frame to the shelf unit.

S06 - Shelf Filter Frame Short Side

Qty 2, 1/2 x 3/4

Each part is cut to length and then 1/4" holes are drilled into both its top and end faces to accept wood dowels. These will allow the filter frame to be pre-assembled thus making it easier to attach to the underside of the shelf unit.

S07 - Shelf Filter Frame Filler Block

Qty 1, 2 x 4

This part is needed in order to properly size (and position) the filter frame. Two 1/4" holes are drilled into it to allow it to be attached to the rest of the filter frame.

S08 - Shelf Top

Qty 1, 3/8" plywood

As with both the box top and box bottom, the shelf top can be created in two halves with the resulting seam running fore and aft along the shelf center rib. The small holes needed to mount the fan can be marked and drilled at this time (or later during assembly) using the fan unit itself as a template.

Building the Cabinet

The cabinet unit of the X-Bench is constructed from 3/8" and 3/4" plywood as well as 1x2 strips.¹¹ It has no top or bottom as these functions are provided by the X-Bench's box and shelf units.

The door frame is designed so that each of its members can be joined either using pocket holes, wood dowels or by simply driving wood screws (including *pocket hole* screws) through the frame member's edge. Although the drawings for each of the door frame parts show 1/4" alignment holes intended to be used with wood dowels, these are optional if you'd rather connect the frame members using another method of attachment.

As already noted, these plans don't cover construction of the drawers and only the drawings for the drawer fronts and slides are provided. Again, as noted in the section *Build Notes*, there exists many resources on the web – including YouTube videos – for helping you to construct cabinet drawers.



C01 - Cabinet Back

Qty 1, 3/8" plywood

C02 - Cabinet Bottom Drawer Front

Qty 1, 3/4" plywood

C03 - Cabinet Corner Brace Top

Qty 4, 1 x 2

Note that this part is identical to C12 except that it has no 1/4" hole drilled through its center. Therefore, it may be advantageous to produce both parts at the same time using the same process (with C12 simply undergoing the additional drilling step).

This part is cut to length and then the ends are cut to a 45° angle. Then, as seen from the engineering drawing, an attachment hole of 5/32" diameter is drilled into the center of

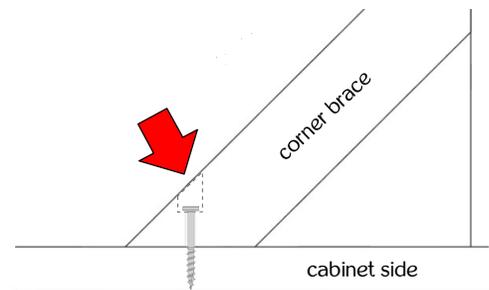


Illustration 15: countersunk hole in corner brace

¹¹ Actually, the door frame members must be cut from 1x4 lumber.

each end face. This hole is drilled perpendicular to the face and is cut clear through the material. As the intent is to employ *pocket hole* screws to attach each corner brace to both the cabinet side and left-right member, these attachment holes need to be countersunk to a width of 3/8" and to a depth that allows the screws to be inserted into the cabinet's side without going clear through it. This is shown in *illustration 15*.

The depth of the countersink depends on the length of the pocket hole screws chosen. If you use 1" screws, the countersink will need to be approximately 1/2" and if you use 1 1/4" screws, it will need to be about 1/4".

C04 - Cabinet Door Rail

Qty 2, 1 x 4

These are the shorter, top and bottom pieces of the door frame. Again, the dowel alignment holes are *optional* depending on which method of assembling the door frame you choose.

C05 - Cabinet Door Stile

Qty 2, 1 x 4

These are the longer, side pieces of the door frame. Again, the dowel alignment holes are *optional* depending on which method of assembling the door frame you choose.

C06 - Cabinet Spine

Qty 1, 3/4" plywood

This board separates the two sides of the cabinet unit. Each of its corners must be notched and drilled so that it is held in place by the *Cabinet Left-Right Member* boards. Note that the 1/4" holes drilled through the face of the board will be used to attach the default drawer slides and these holes won't be required if you'll be using actual drawer slide hardware instead. In that case you'll need to locate and drill the required mounting holes as per the instructions provided with the drawer slide hardware.

C07 - Cabinet Keyboard Drawer Front

Qty 1, 3/4" plywood

C08 - Cabinet Left-Right Member

Qty 4, 1 x 2

C09 - Cabinet Mid Drawer Front

Qty 3, 3/4" plywood

C10 - Cabinet Shelf

Qty 2, 3/8" plywood

C11 - Cabinet Left Side

Qty 1, 3/4" plywood

Note that the 1/4" holes drilled into the face of the board will be used to attach the default drawer slides and these holes won't be required if you'll be using actual drawer slide hardware instead. In that case you'll need to locate and drill the required mounting holes as per the instructions provided with the drawer slide hardware.

C12 – Cabinet Corner Brace Bottom

Qty 4, 1 x 2

This part is the same as C03 with an added 1/4" hole drilled through its center; therefore, the notes for C03 also apply for C12. Furthermore, since both parts are nearly identical, it may be advantageous to produce both at the same time using the same process (with this part simply undergoing the additional drilling step).

C13 - Cabinet Right Side

Qty 1, 3/4" plywood

Note that the 1/4" holes drilled into the face of the board will be used to attach the default drawer slides and these holes won't be required if you'll be using actual drawer slide hardware instead. In that case you'll need to locate and drill the required mounting holes as per the instructions provided with the drawer slide hardware.

C14 - Cabinet Drawer Slide

Qty 10, 1/2 x 3/4

Manufacturing of this part is only required if you've chosen to use the default method of attaching the drawers to the cabinet frame (as opposed to using conventional drawer slide hardware).

The Engineering Drawings

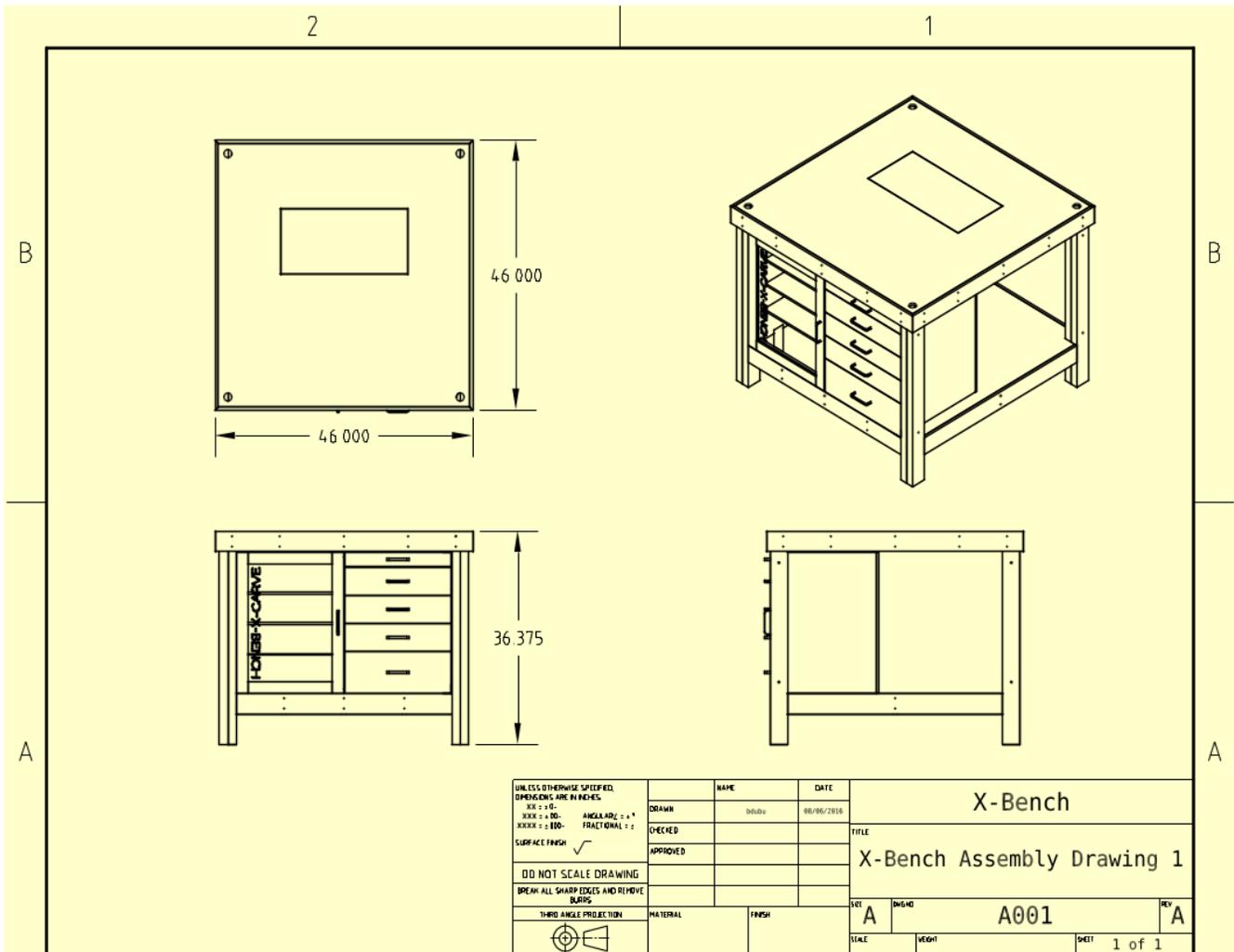
In this section you'll find the engineering drawings used to construct the X-Bench parts. These were produced using Onshape.¹² In general, each drawing should provide the details needed for you to produce its corresponding part. That said, dimensions may be missing from a drawing if they can either be derived from other dimensions or an identical feature elsewhere in the drawing is already dimensioned. If you encounter errors or have difficulty obtaining the dimensions for a part or for one of its features, feel free to contact me per the information at the end of this document.

Be sure to check the prior sub-sections for any notes that might pertain to a given part. Note that the prefix of each part listed is a reference to the drawing no. (“DWGNO”) seen at the bottom of each drawing. Note also that much of the information provided by default at the bottom of each drawing is irrelevant to building the X-Bench's parts and should be ignored (for example, the instruction, “DO NOT SCALE DRAWING” hardly applies).¹³

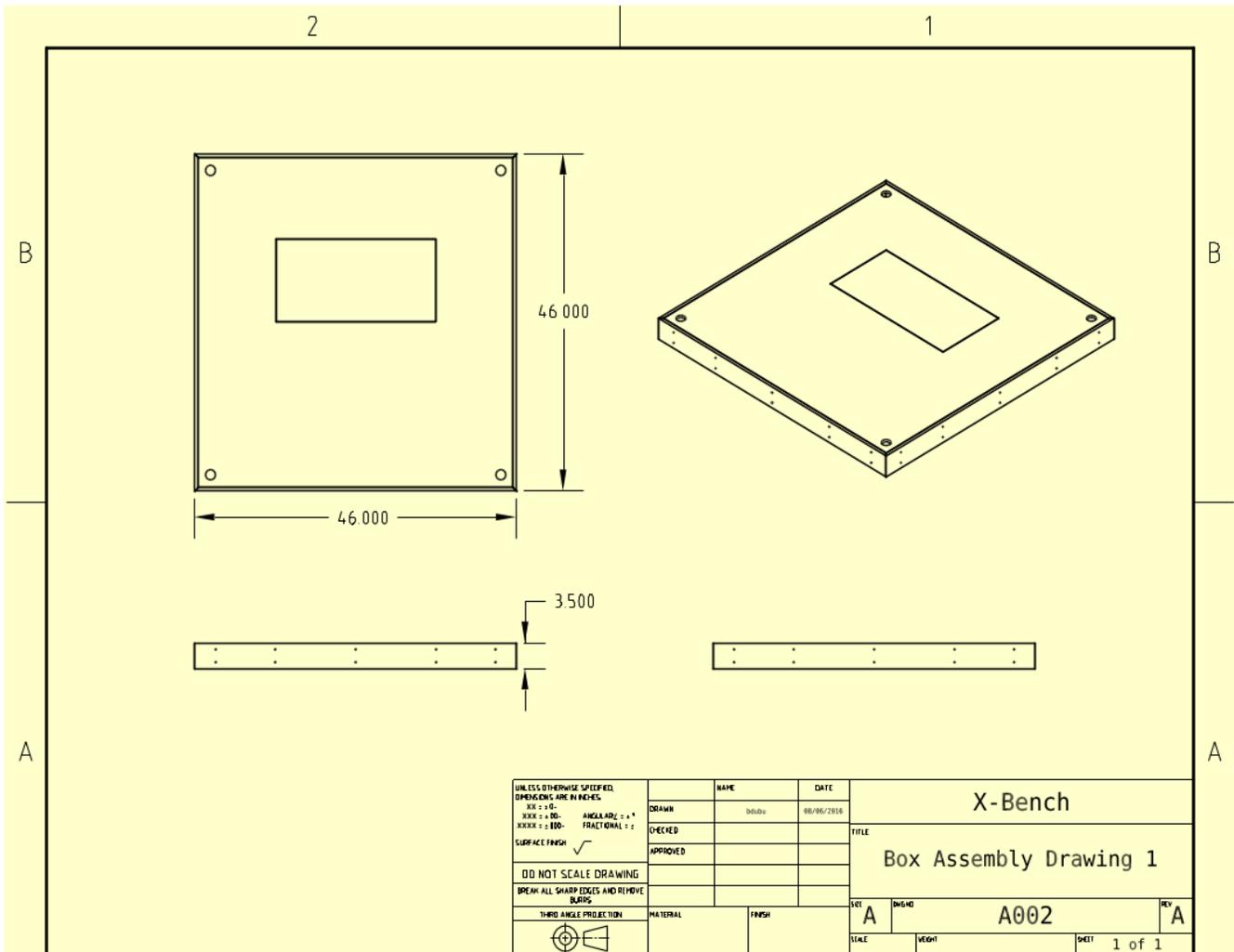
¹² See <http://www.onshape.com/>.

¹³ As a recent user of Onshape, (not to mention CAD in general), it hardly seemed problematic enough for me to figure out how to get rid of all of these overly-formal drawing details, so I just left them. ;-)

A1 – X-Bench Assembly



A2 – Box Assembly



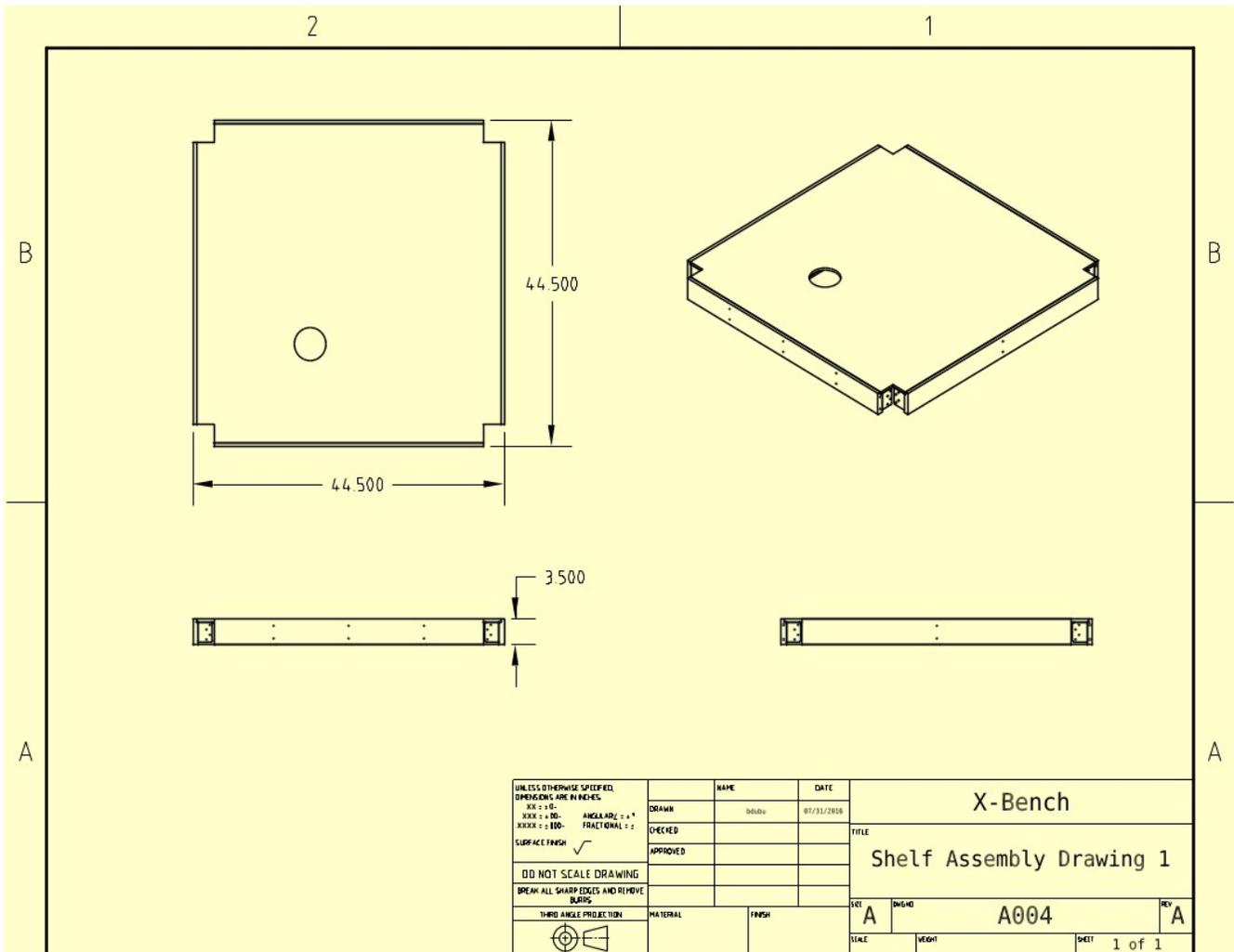
A3 – Cabinet Assembly

The drawing includes the following views and dimensions:

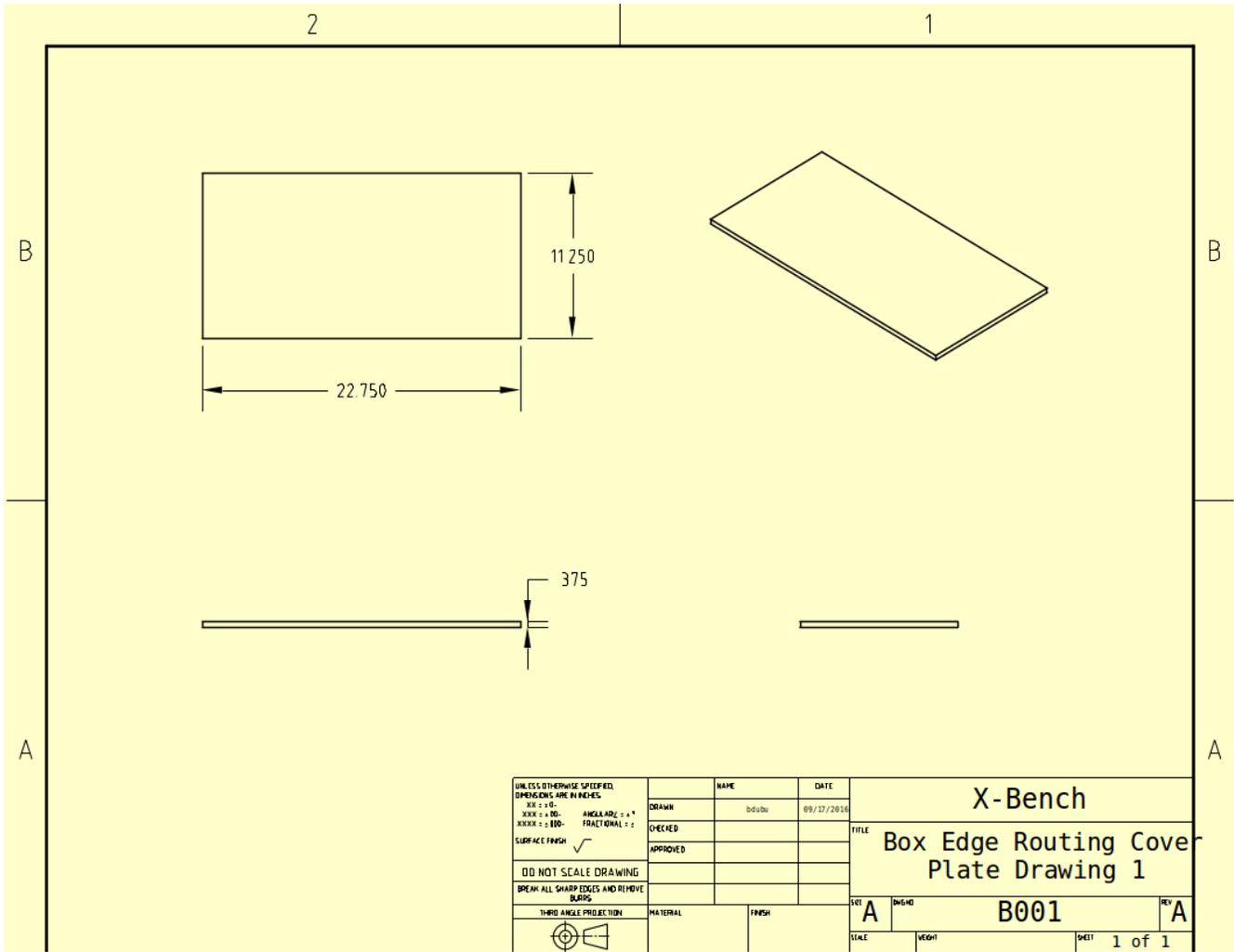
- Top View (Left):** Shows a rectangular frame with a width of 38.375 and a height of 19.250. It features diagonal bracing on the sides.
- Perspective View (Right):** Shows the cabinet with drawers and a door.
- Front View (Bottom Left):** Shows the cabinet with a door on the left labeled "HONEY-X-CARVE" and four drawers on the right. The total height is 24.000.
- Side View (Bottom Right):** Shows the profile of the cabinet door.

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES: XX = ± 0.0625 XXX = ± 0.125 SURFACE FINISH ✓ DO NOT SCALE DRAWING BREAK ALL SHARP EDGES AND REMOVE BURRS THIRD ANGLE PROJECTION		NAME	DATE	X-Bench	
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CHECKED			Cabinet Assembly Drawing 1		
APPROVED			SET	DWGNO	REV
			A	A003	A
	MATERIAL	FINISH	SCALE	VEGHT	DEET
					1 of 1

A4 – Shelf Assembly

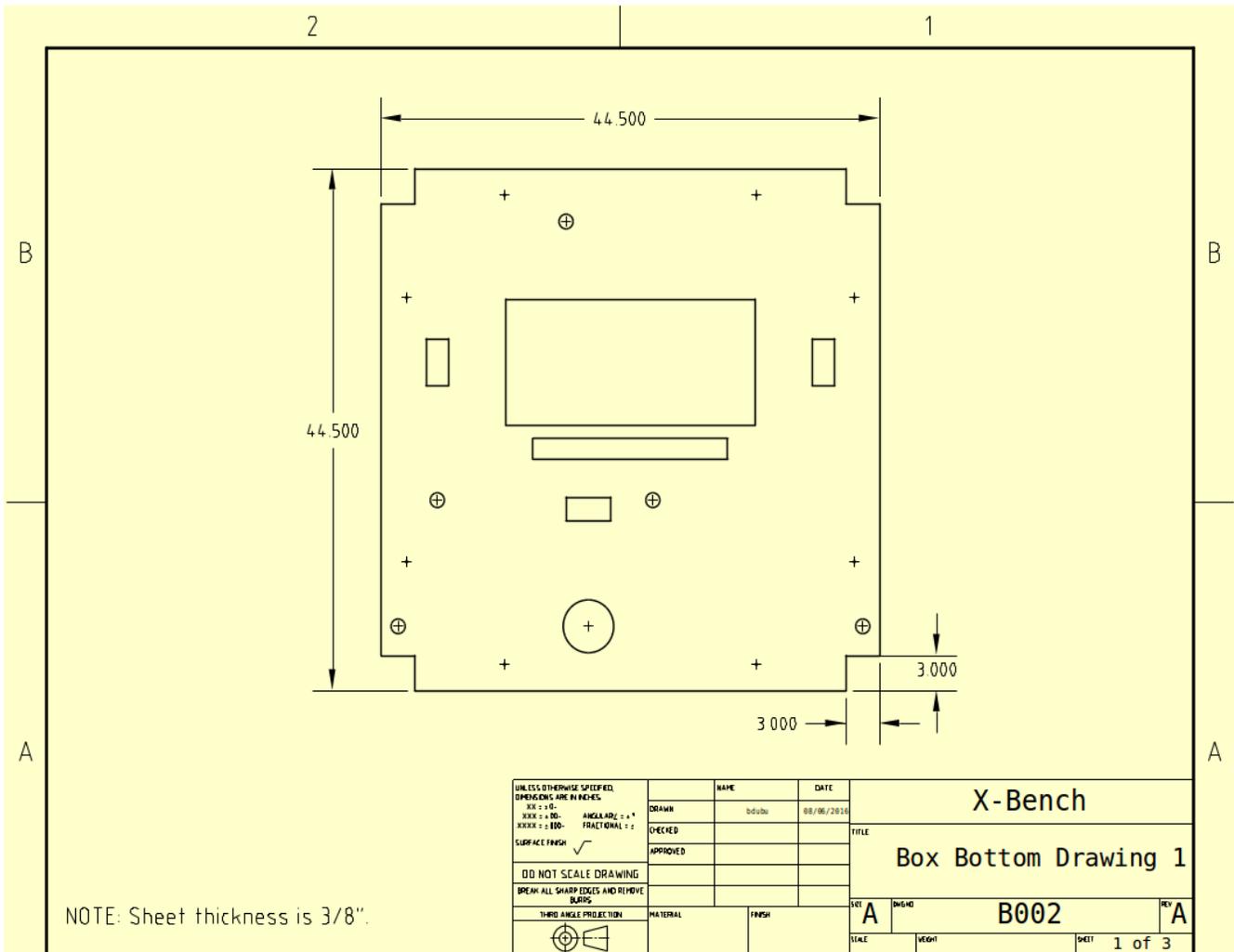


B1 – Box Edge Routing Cover Plate

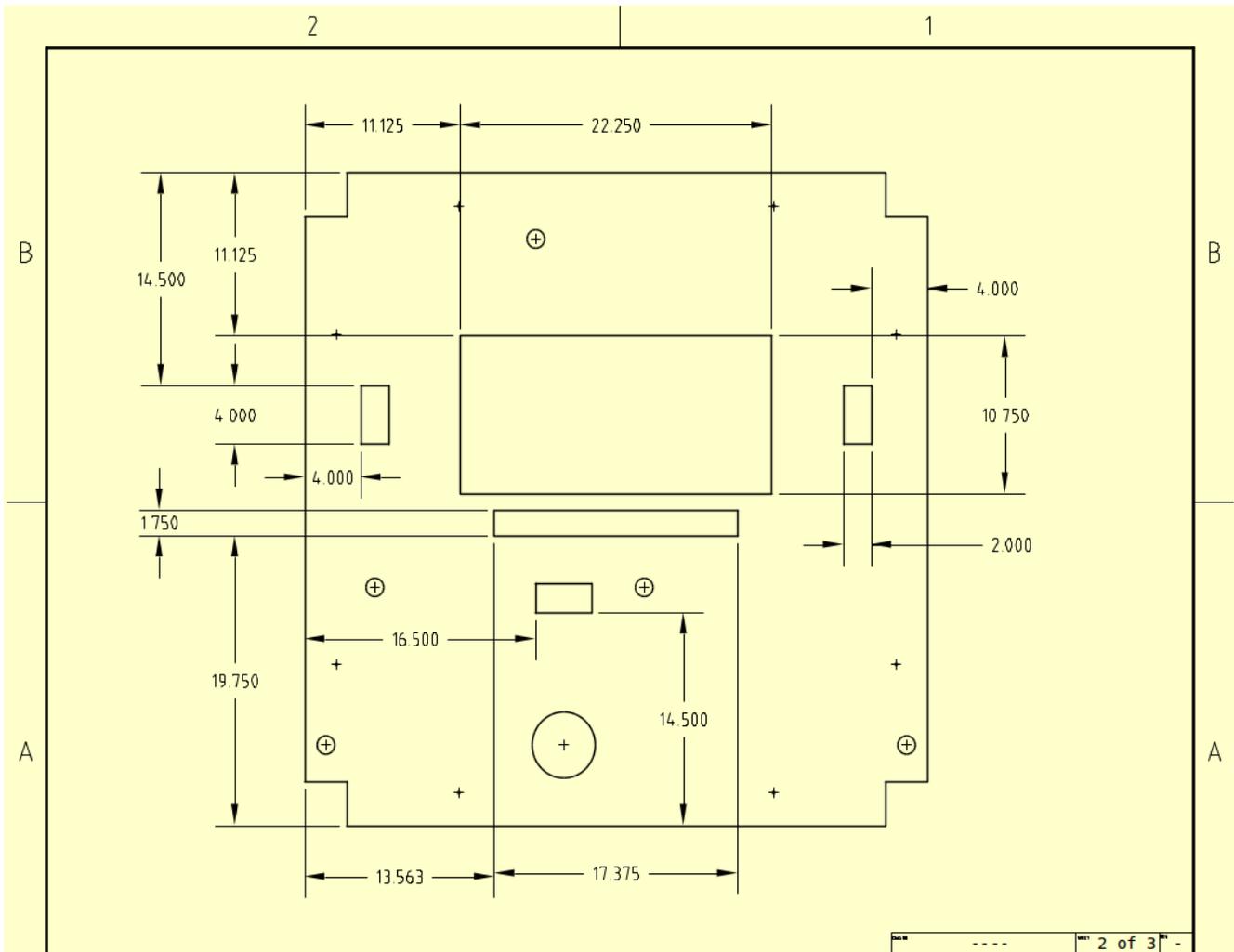


<small>UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES: XX = ±0. XXX = ±0.01. XXXX = ±0.005. SURFACE FINISH: ✓ DO NOT SCALE DRAWING BREAK ALL SHARP EDGES AND REMOVE BURRS THIRD ANGLE PROJECTION</small>	NAME	DATE	X-Bench	
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	CHECKED		TITLE Box Edge Routing Cover Plate Drawing 1	
	APPROVED			
MATERIAL	FINISH	SET	DWGNO	REV
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		SCALE	VEGHT	DEET
				1 of 1

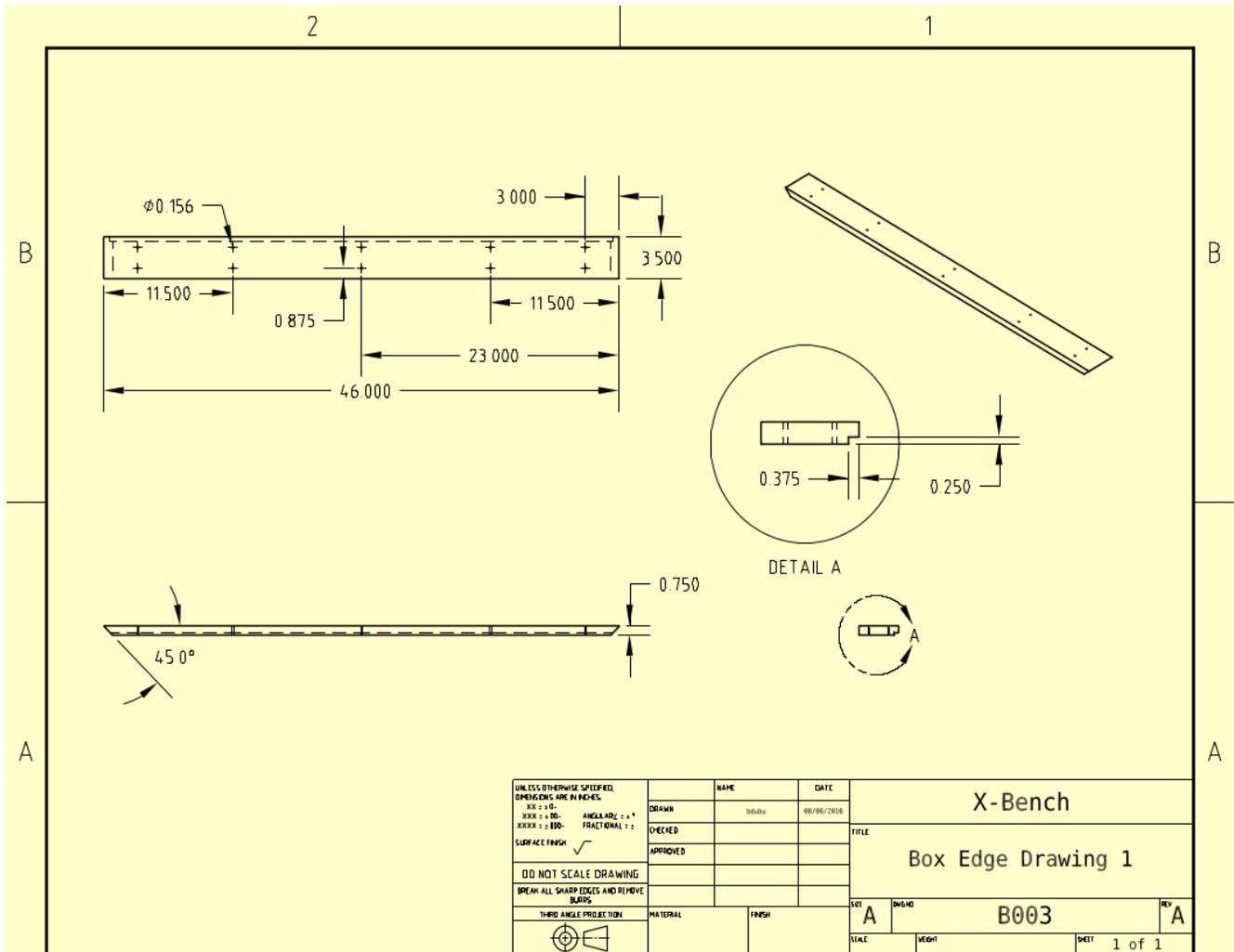
B2 – Box Bottom (1 of 3)



B2 – Box Bottom (2 of 3)

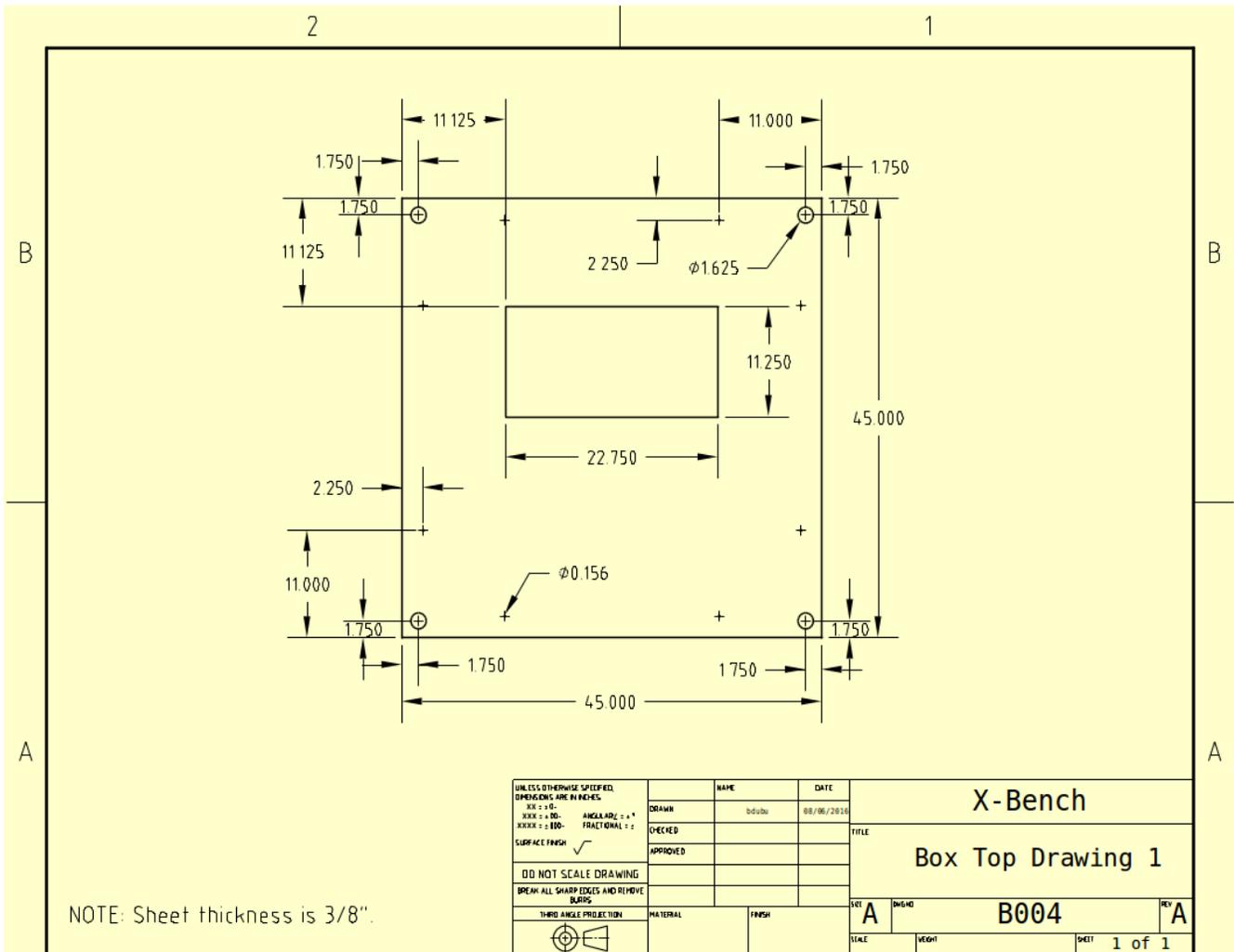


B3 – Box Edge

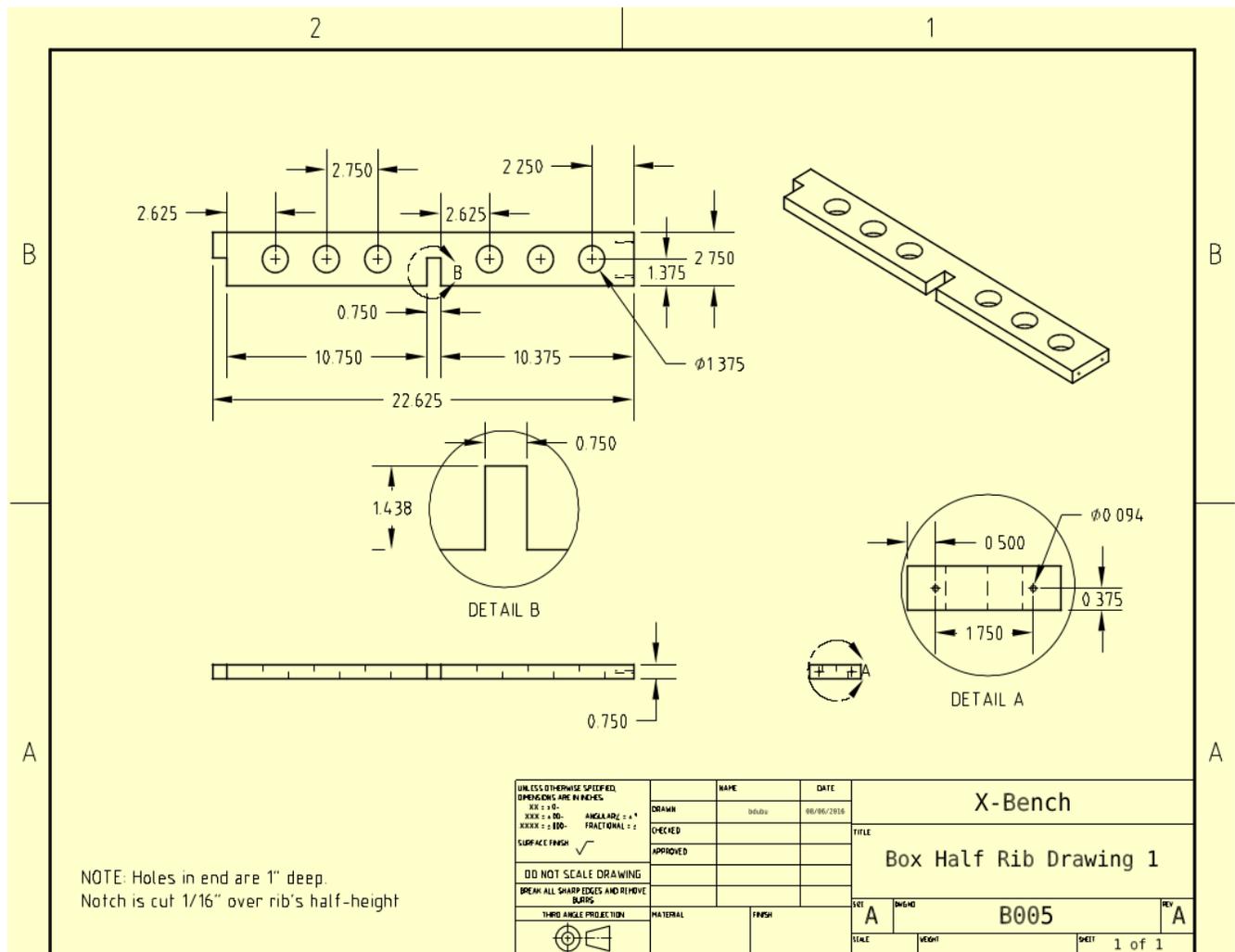


UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES: XX = ±0. XXX = ±0.001 XXXX = ±0.0005 SURFACE FINISH: ✓ DO NOT SCALE DRAWING BREAK ALL SHARP EDGES AND REMOVE BURRS THIRD ANGLE PROJECTION	NAME	DATE	X-Bench	
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	APPROVED			
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			SCALE	VEGHT
				DETT 1 of 1

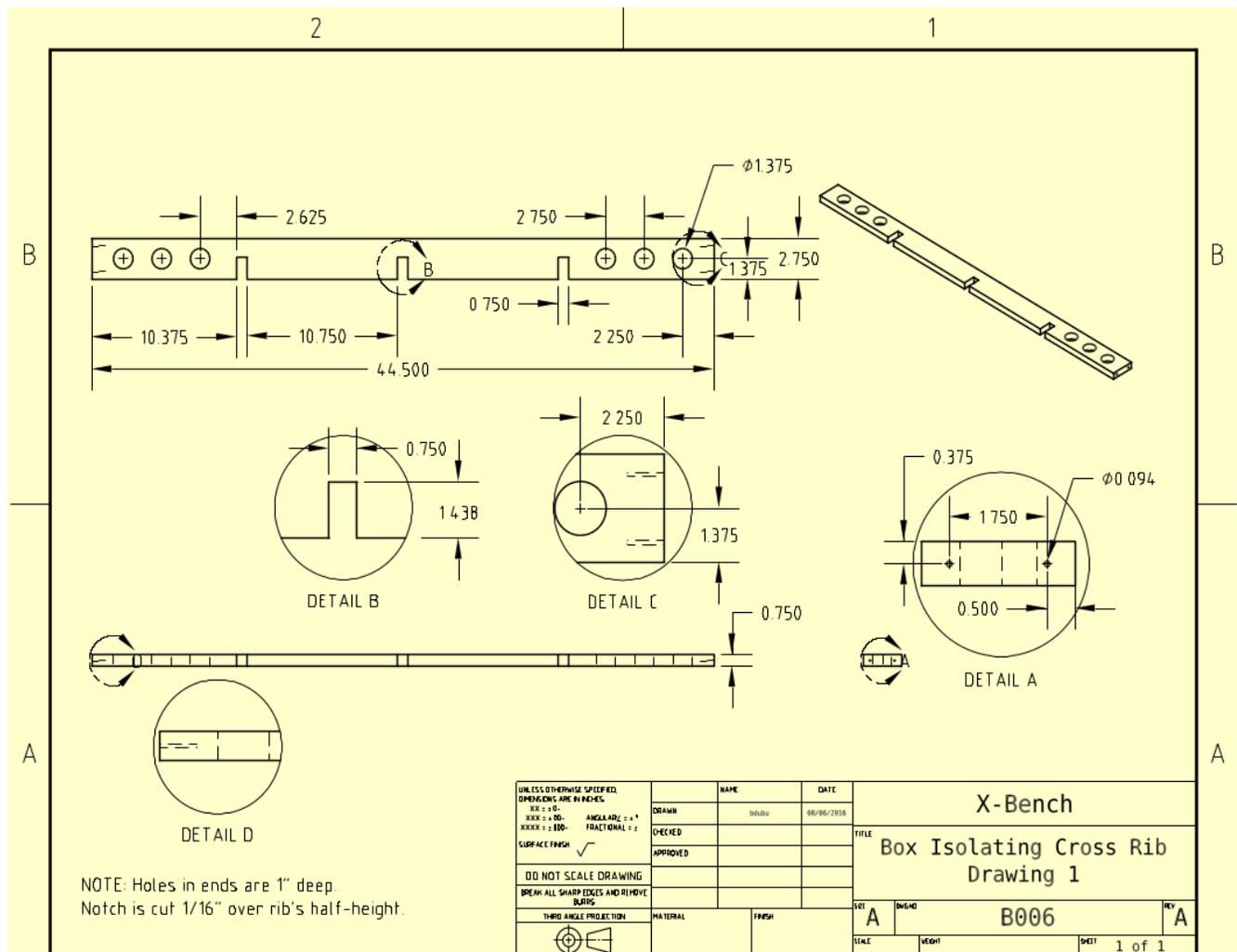
B4 – Box Top



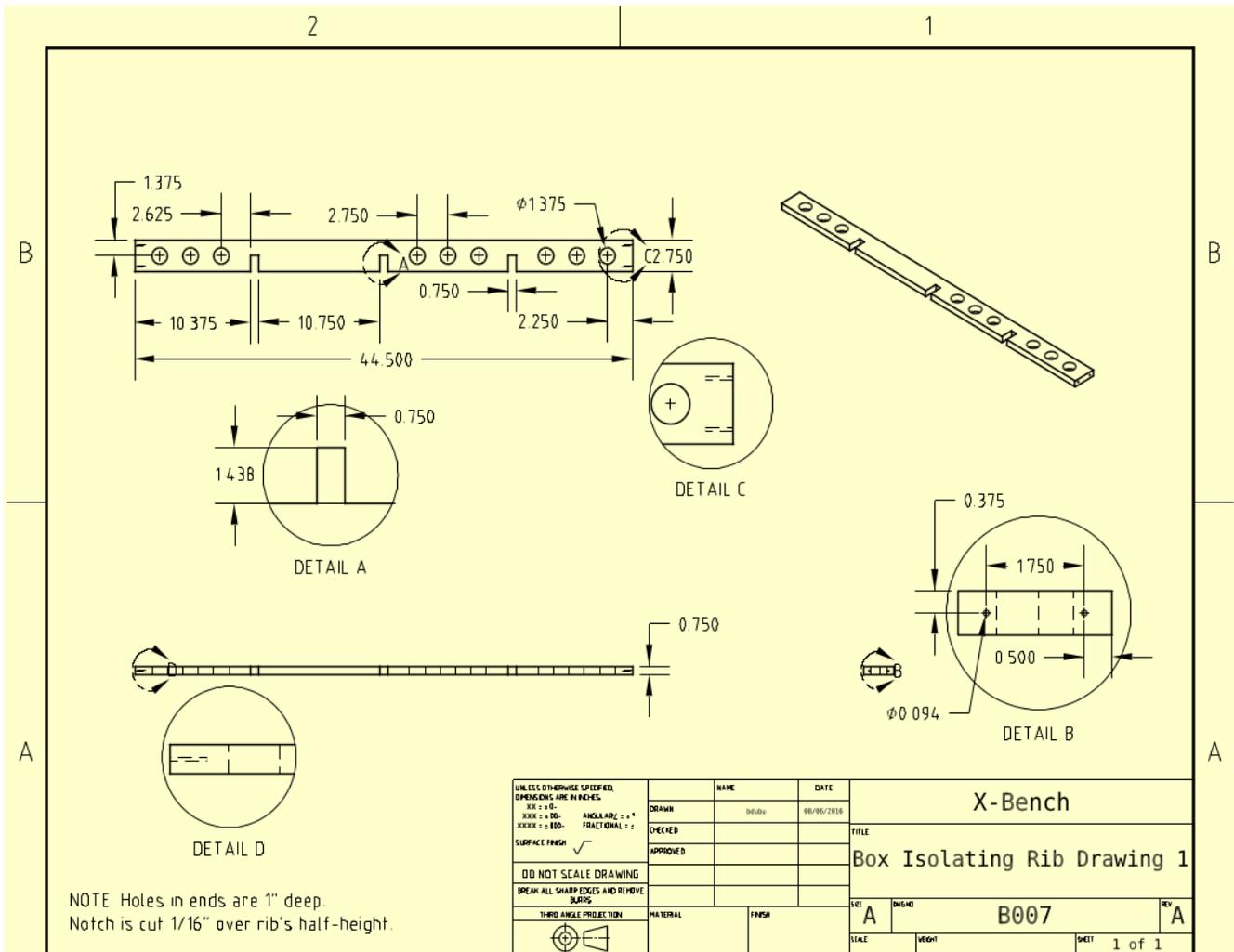
B5 – Box Half Rib



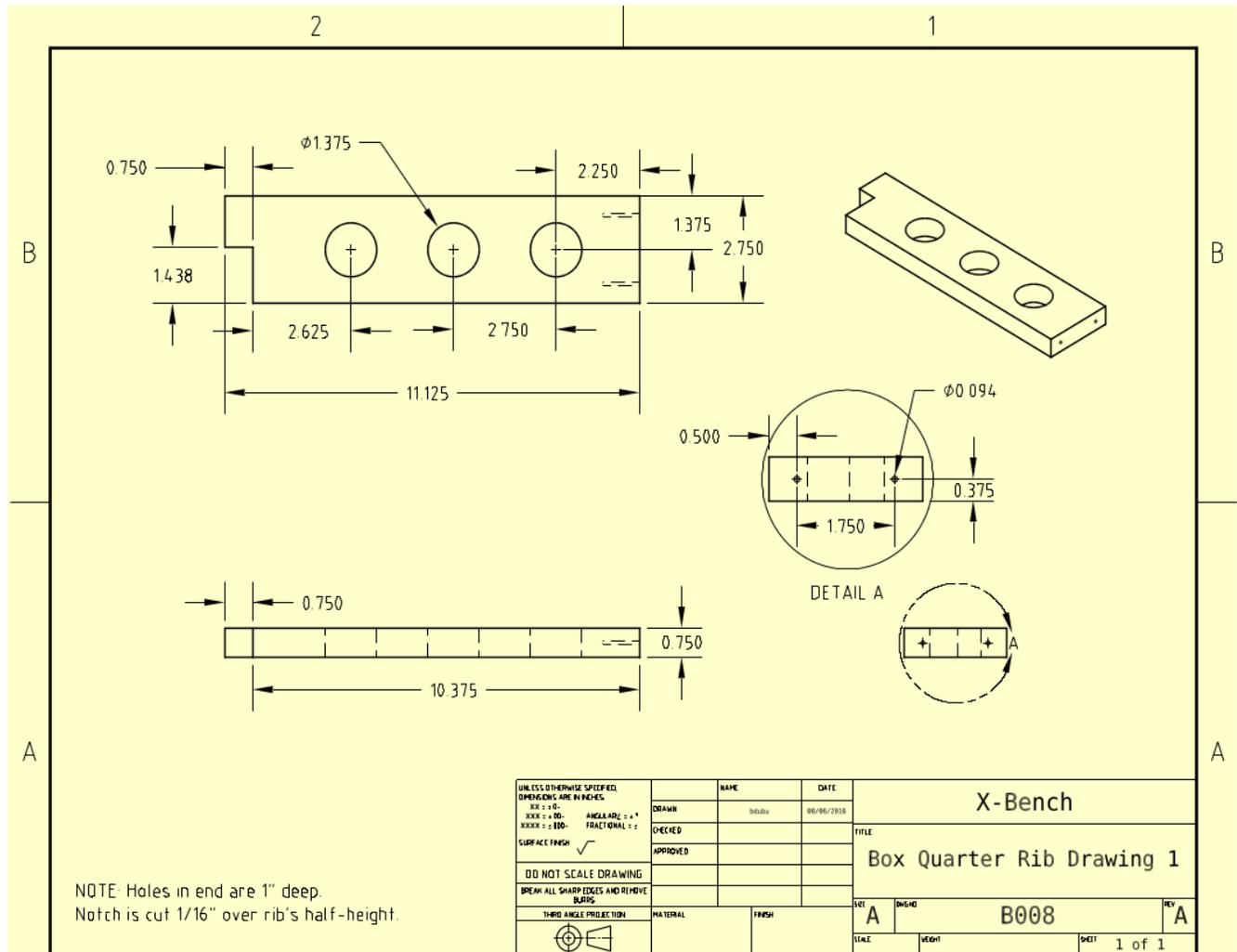
B6 – Box Isolating Cross Rib



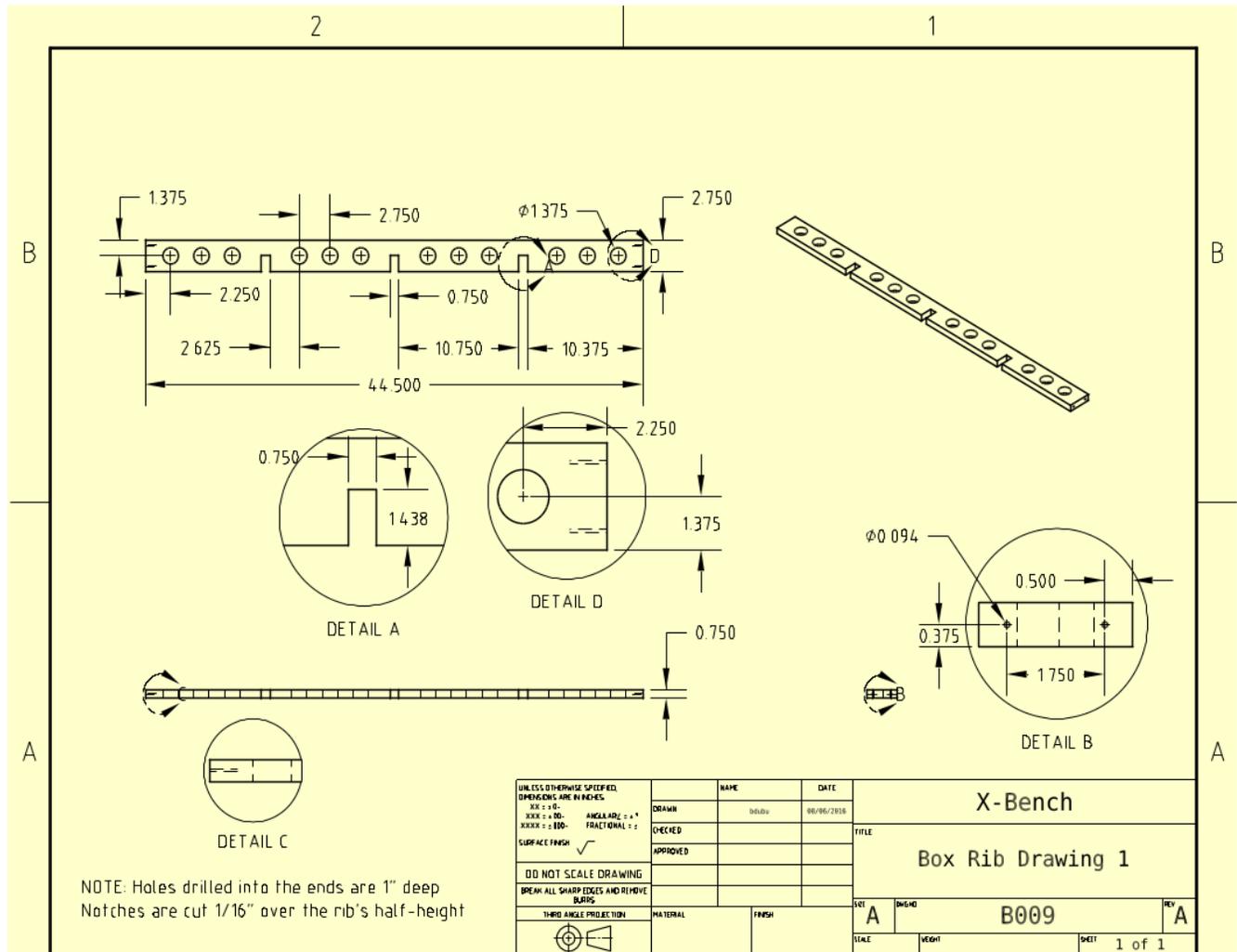
B7 – Box Isolating Rib



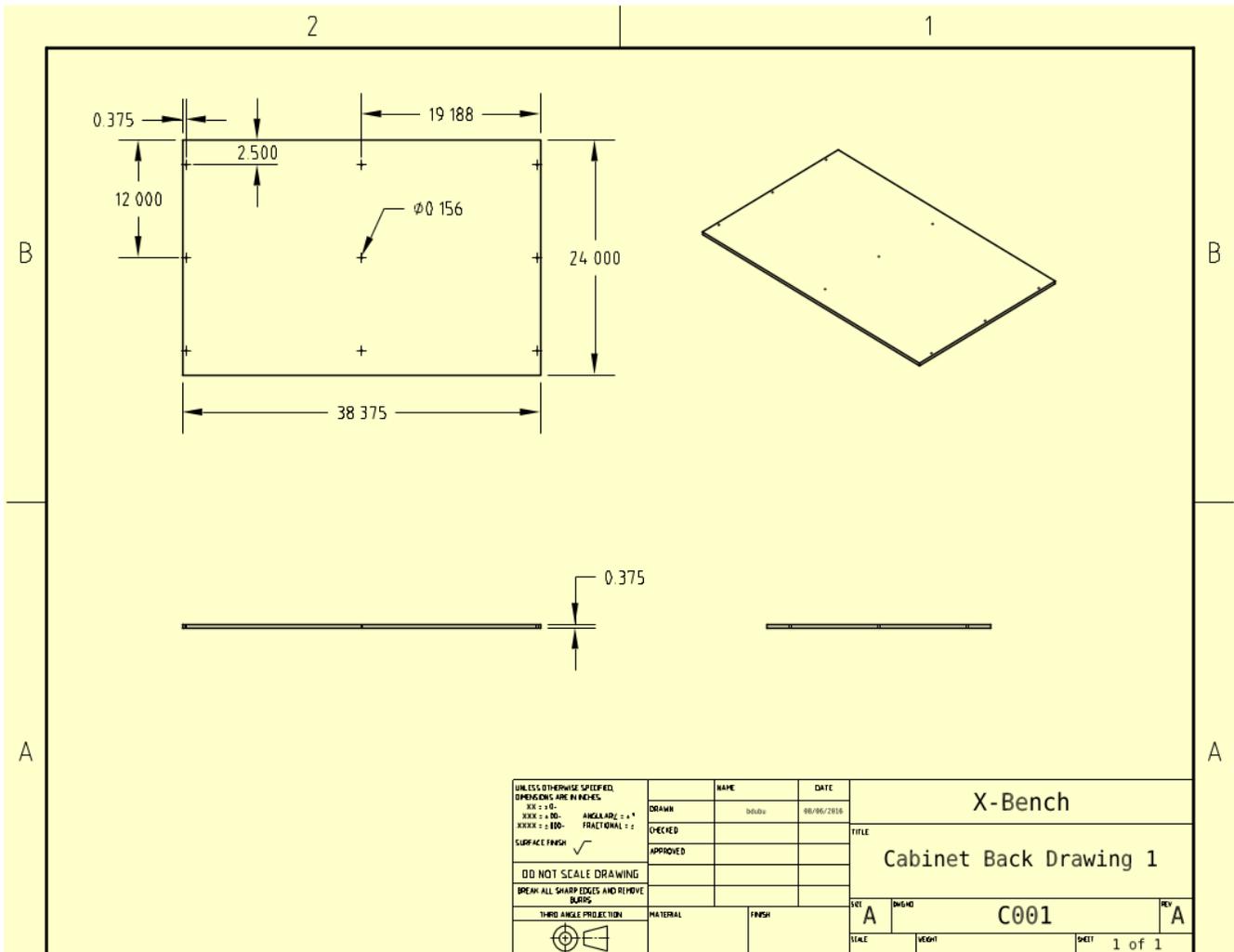
B8 – Box Quarter Rib



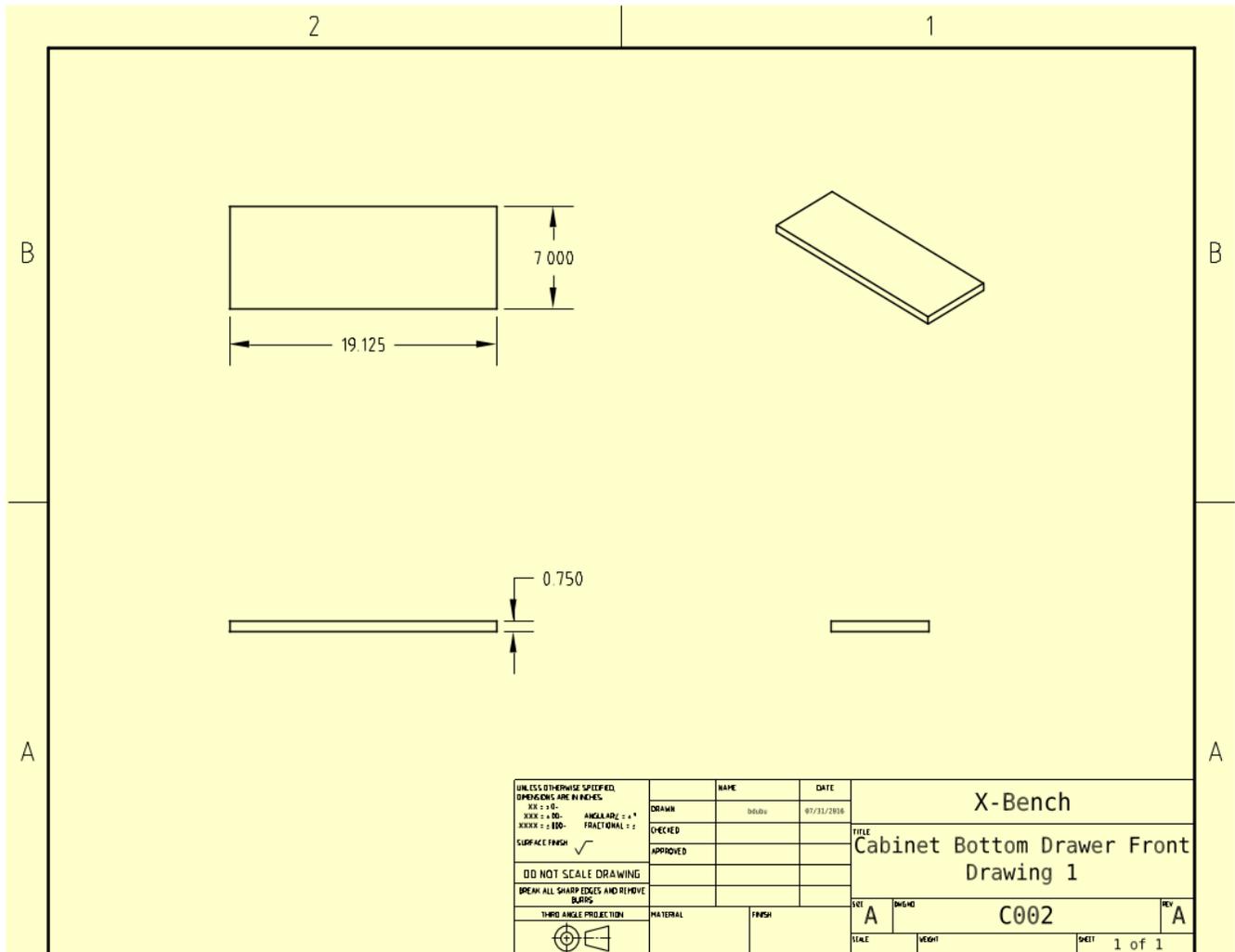
B9 – Box Rib



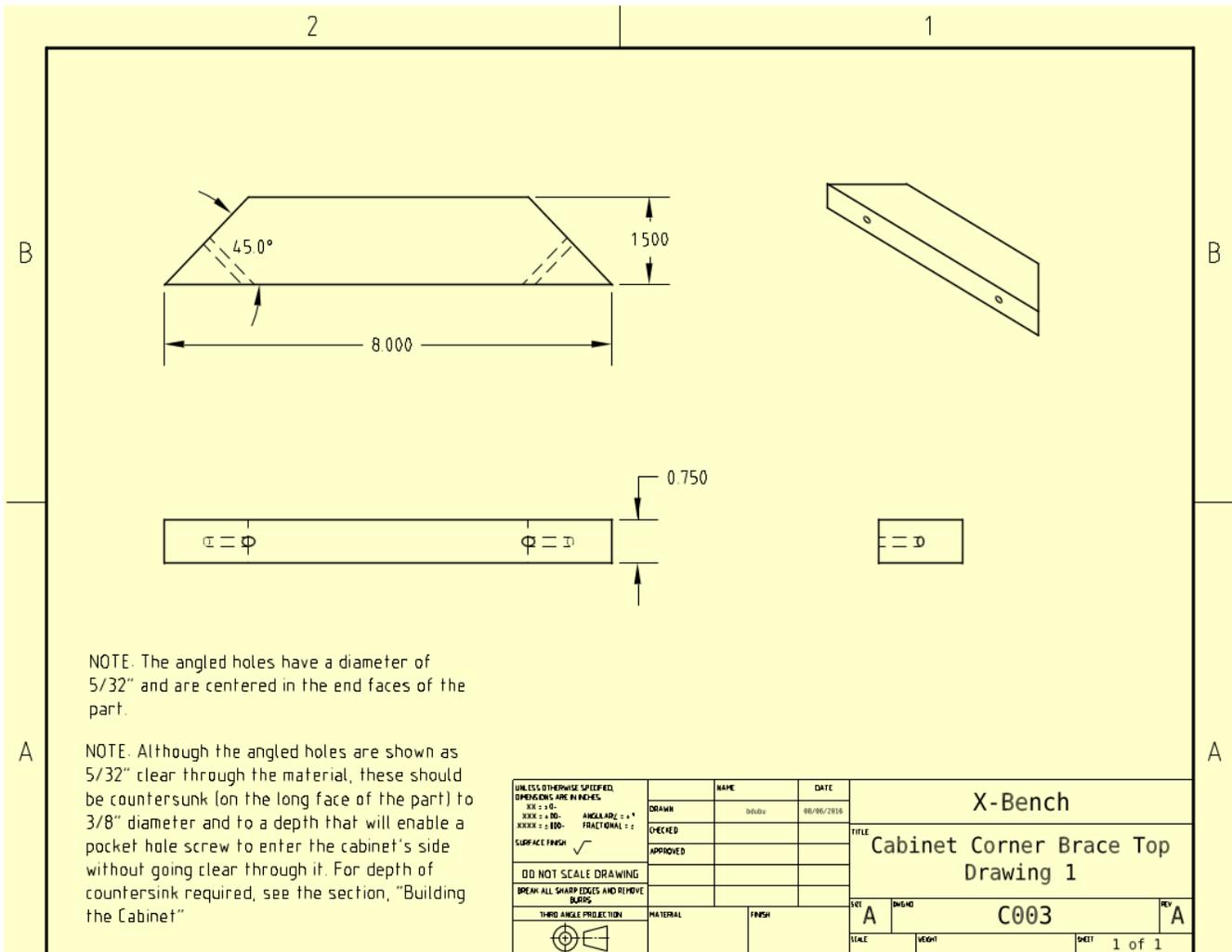
C1 – Cabinet Back



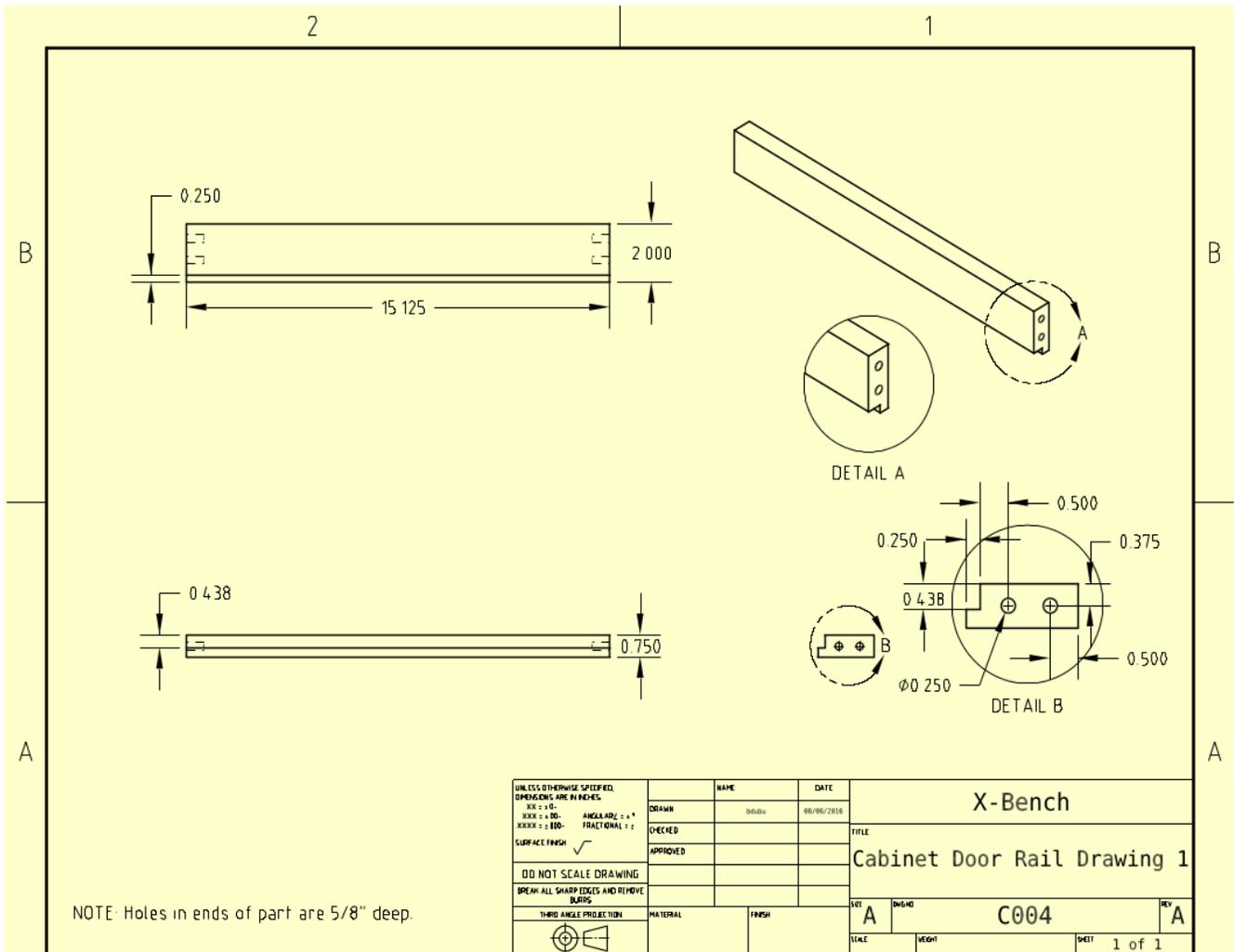
C2 – Cabinet Bottom Drawer Front



C3 – Cabinet Corner Brace Top

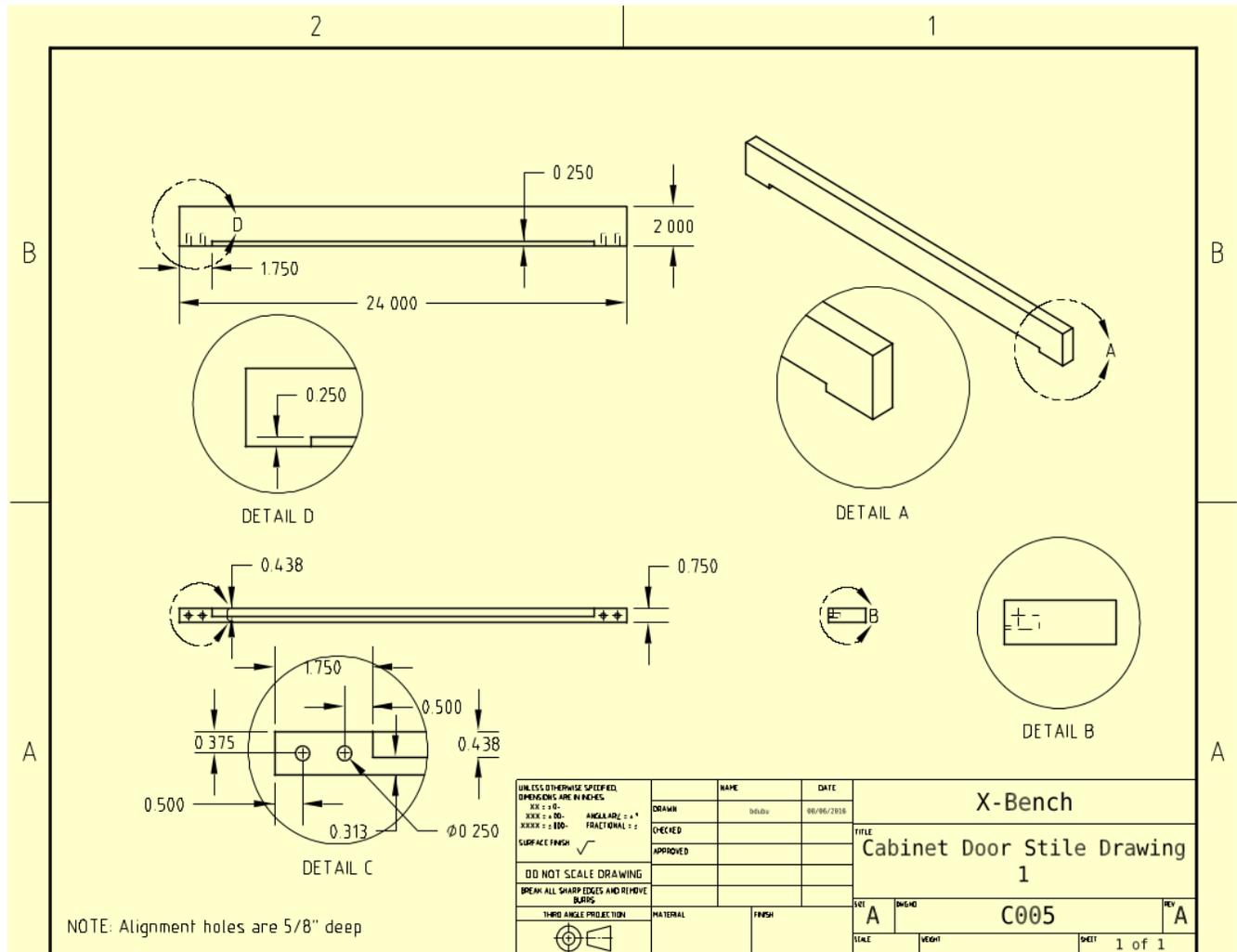


C4 – Cabinet Door Rail

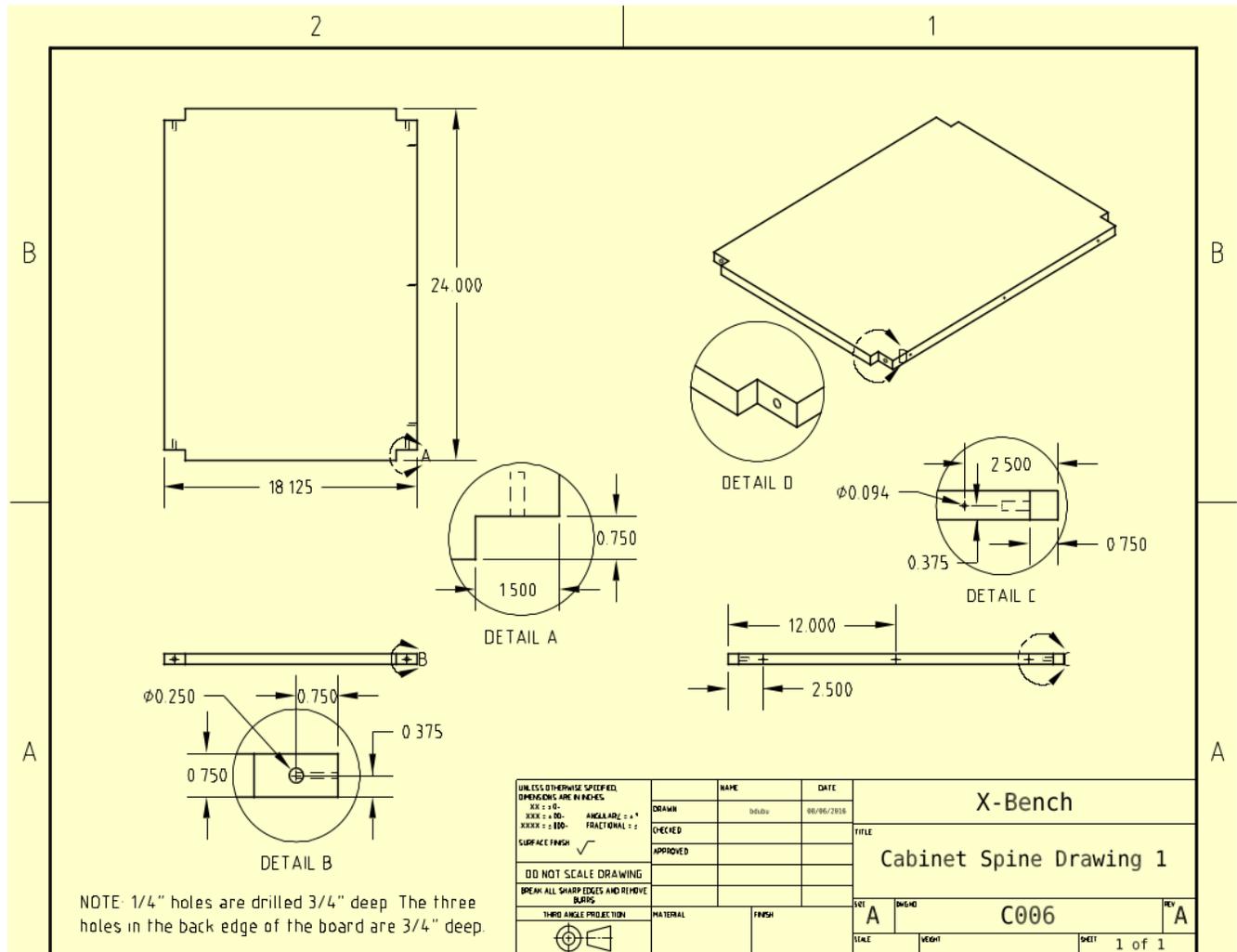


NOTE: Holes in ends of part are 5/8" deep.

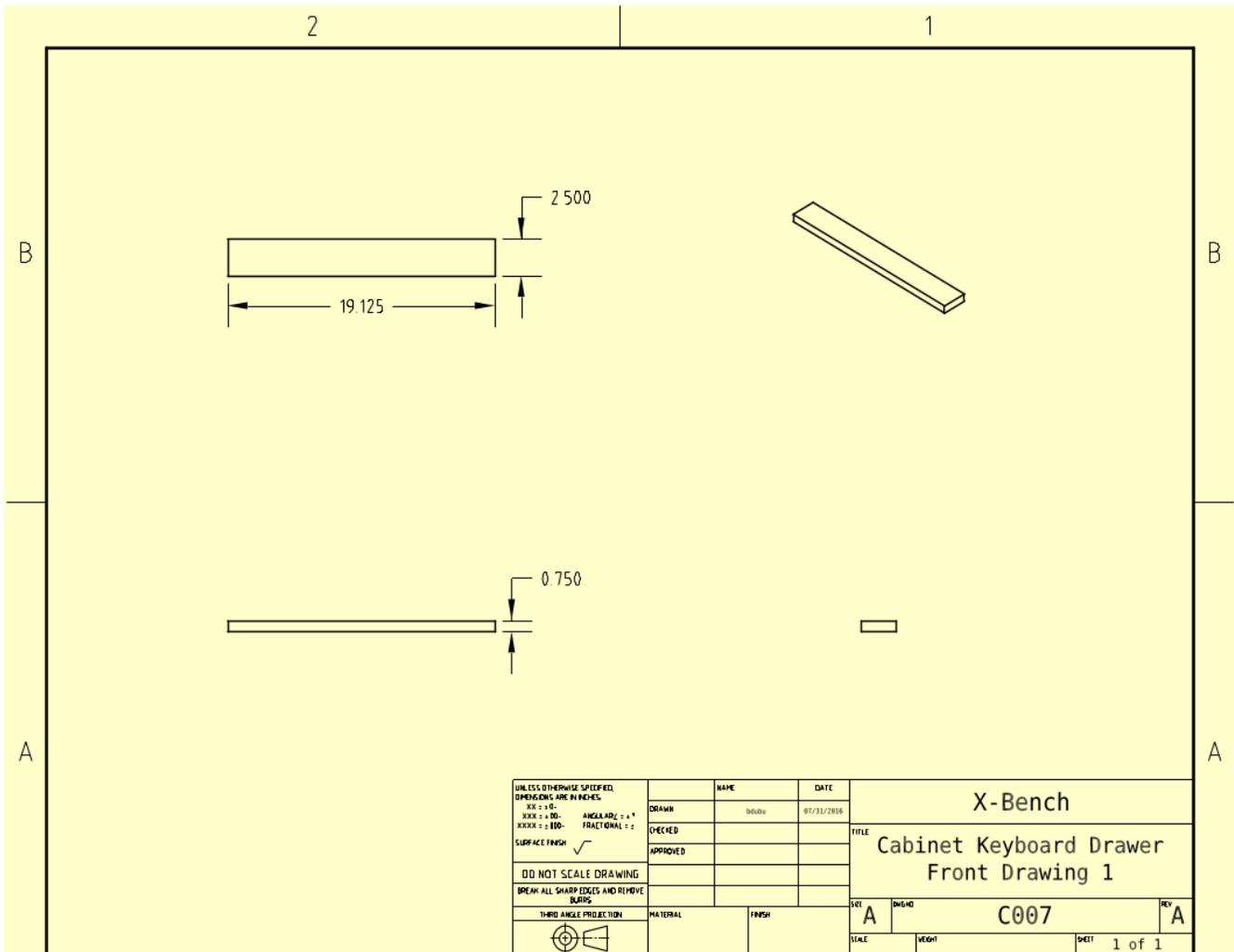
C5 – Cabinet Door Stile



C6 – Cabinet Spine

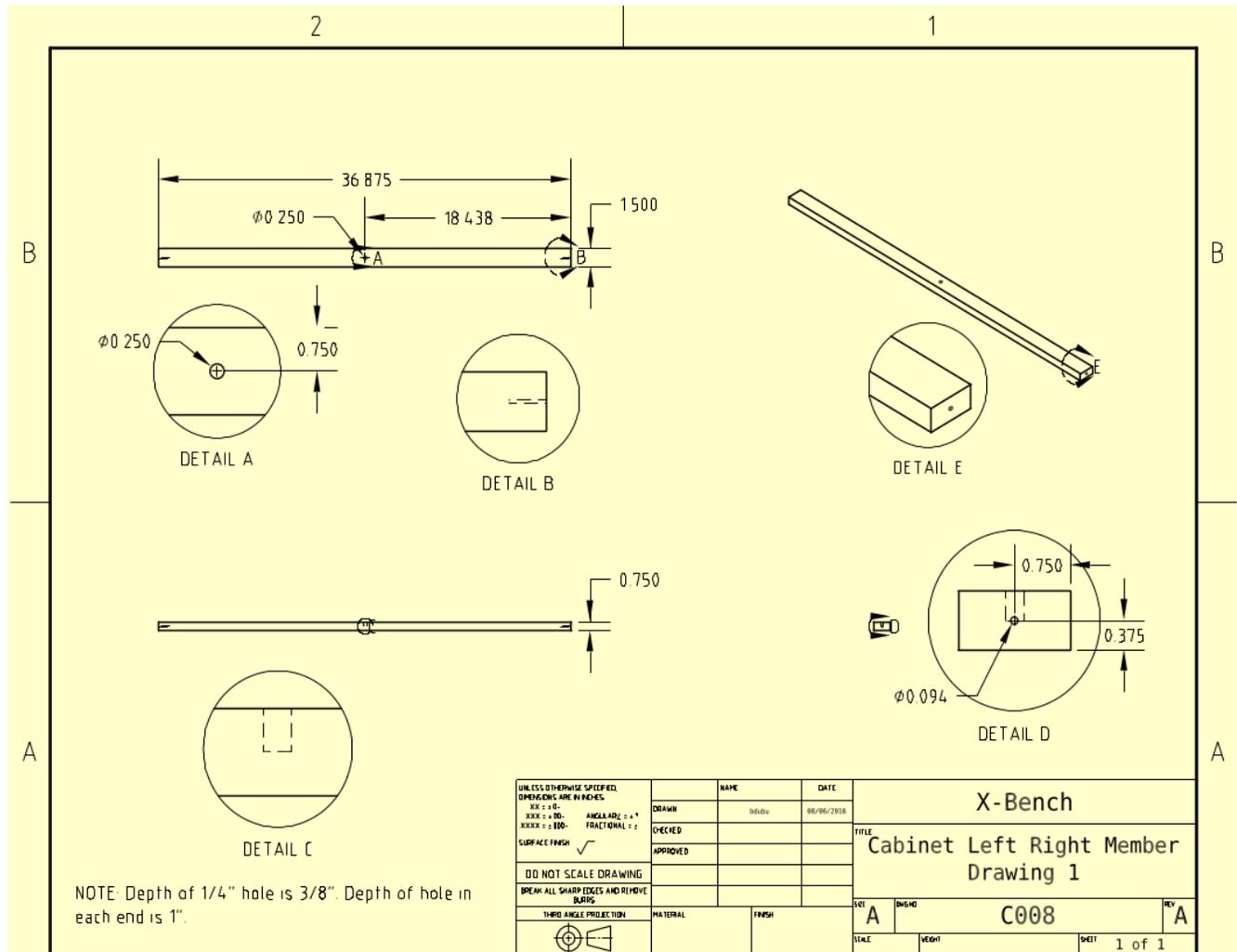


C7 – Cabinet Keyboard Drawer Front

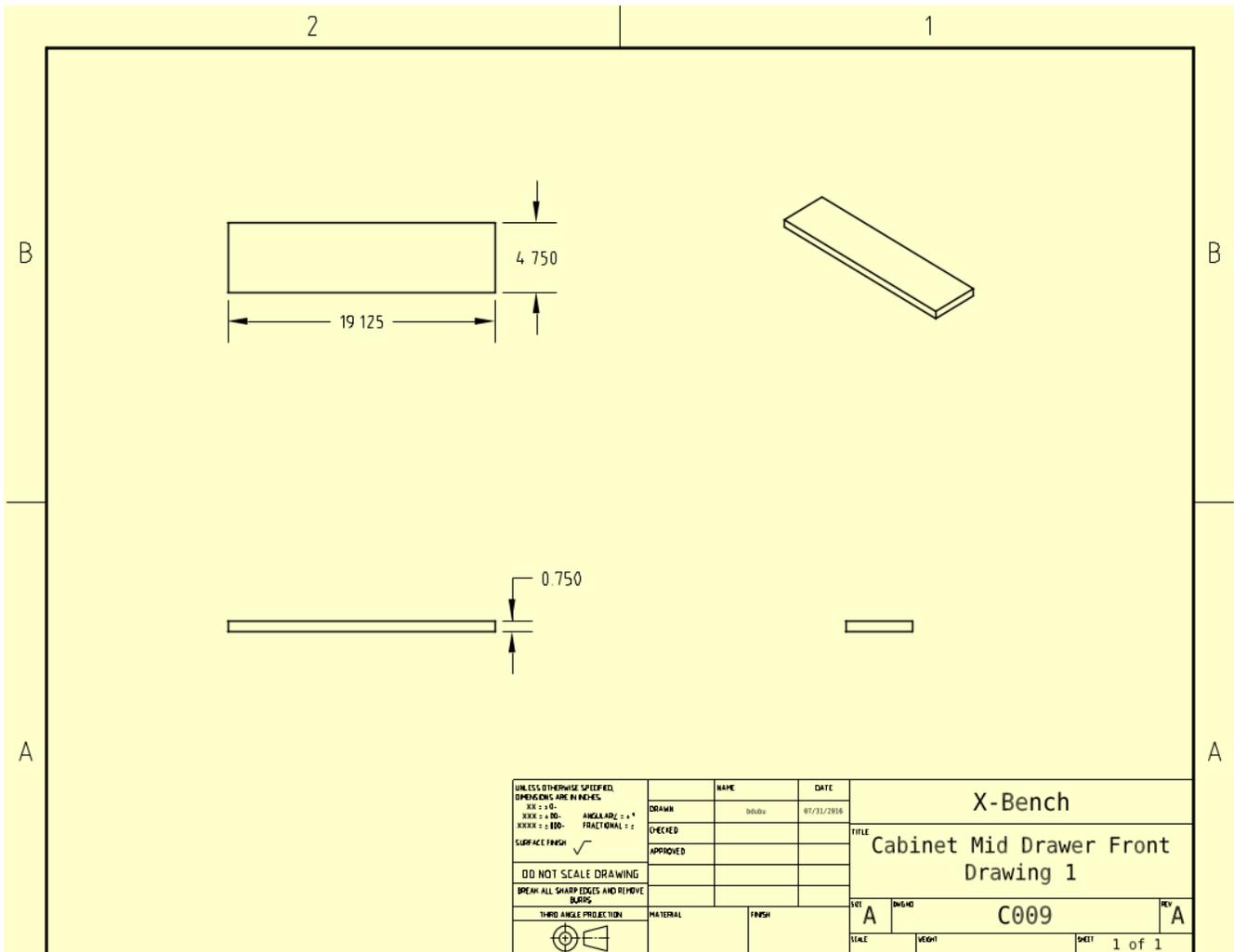


UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES: XX = ±0.000 ANGLES ARE ± 1° XXX = ±0.005 FRACTIONAL = ±		NAME	DATE	X-Bench	
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DO NOT SCALE DRAWING			A	C007	A
BREAK ALL SHARP EDGES AND REMOVE BLINDS	MATERIAL	FINISH	SCALE	VEGHT	DEET
THIRD ANGLE PROJECTION					1 of 1

C8 – Cabinet Left Right Member

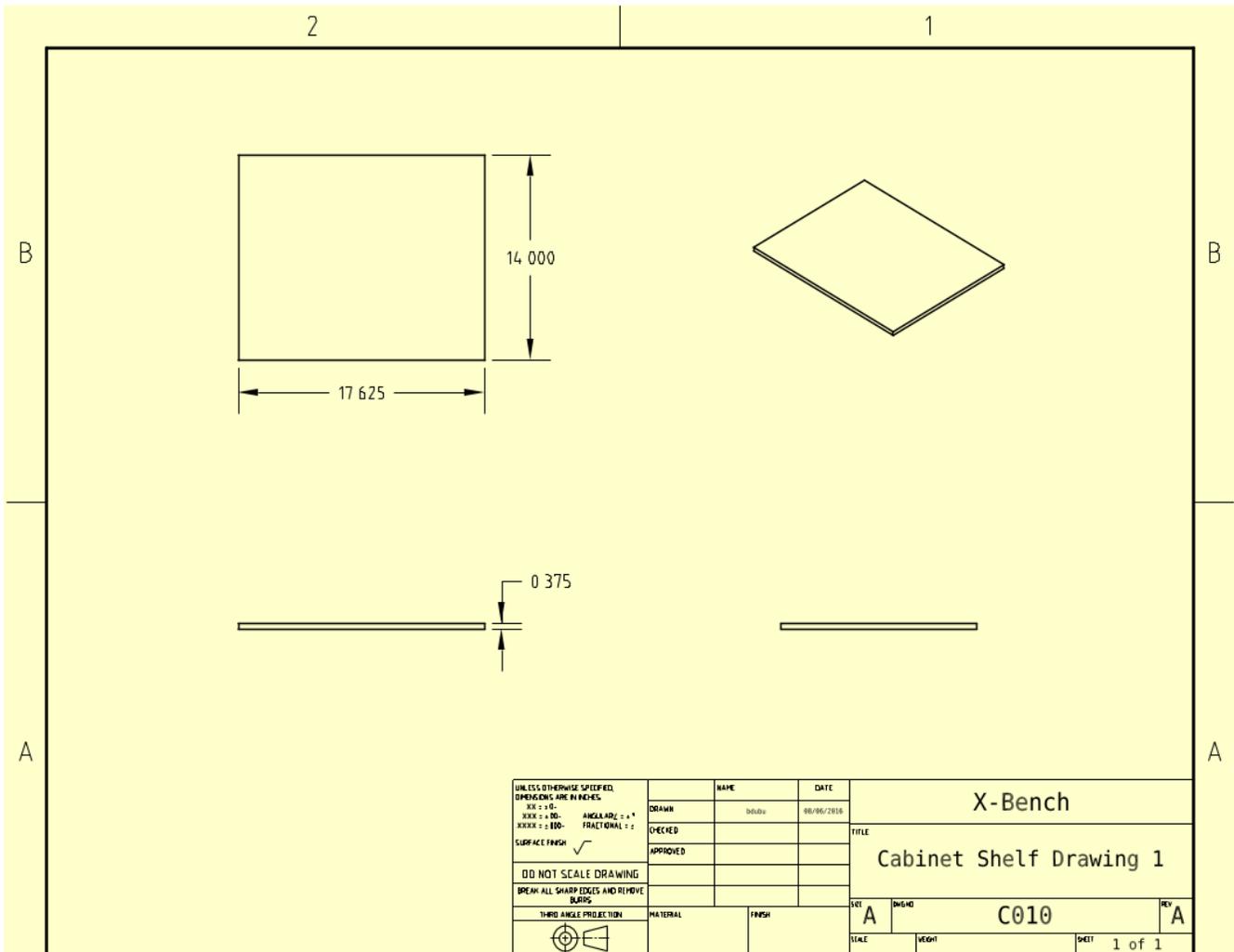


C9 – Cabinet Mid Drawer Front

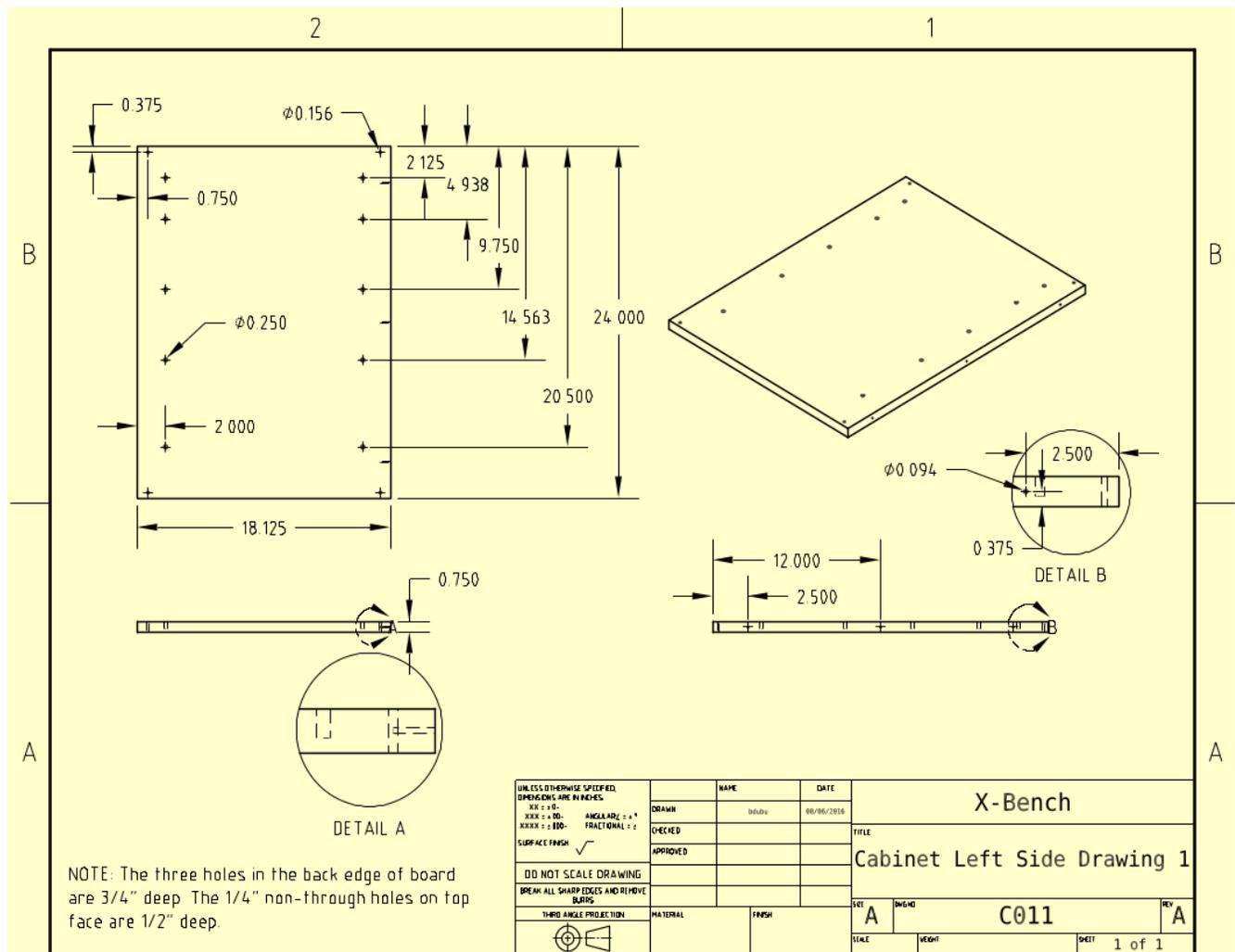


<small>UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES: XX = ±0. XXX = ±0.001 SURFACE FINISH ✓ DO NOT SCALE DRAWING BREAK ALL SHARP EDGES AND REMOVE BURRS</small>	NAME	DATE	X-Bench	
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	APPROVED			
THIRD ANGLE PROJECTION	MATERIAL	FINISH	SET	REV
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			SCALE	VEGT
				DELT
				1 of 1

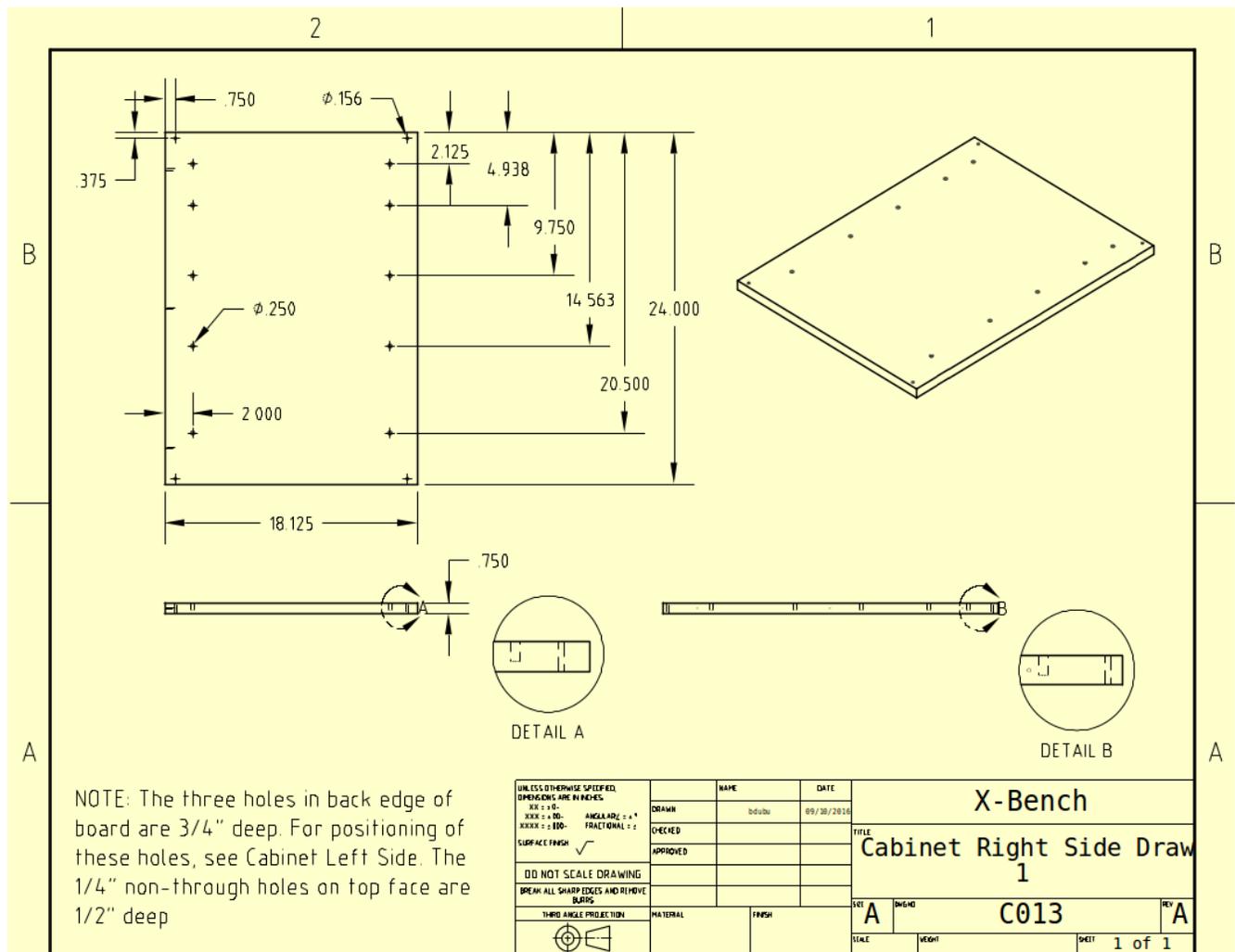
C10 – Cabinet Shelf



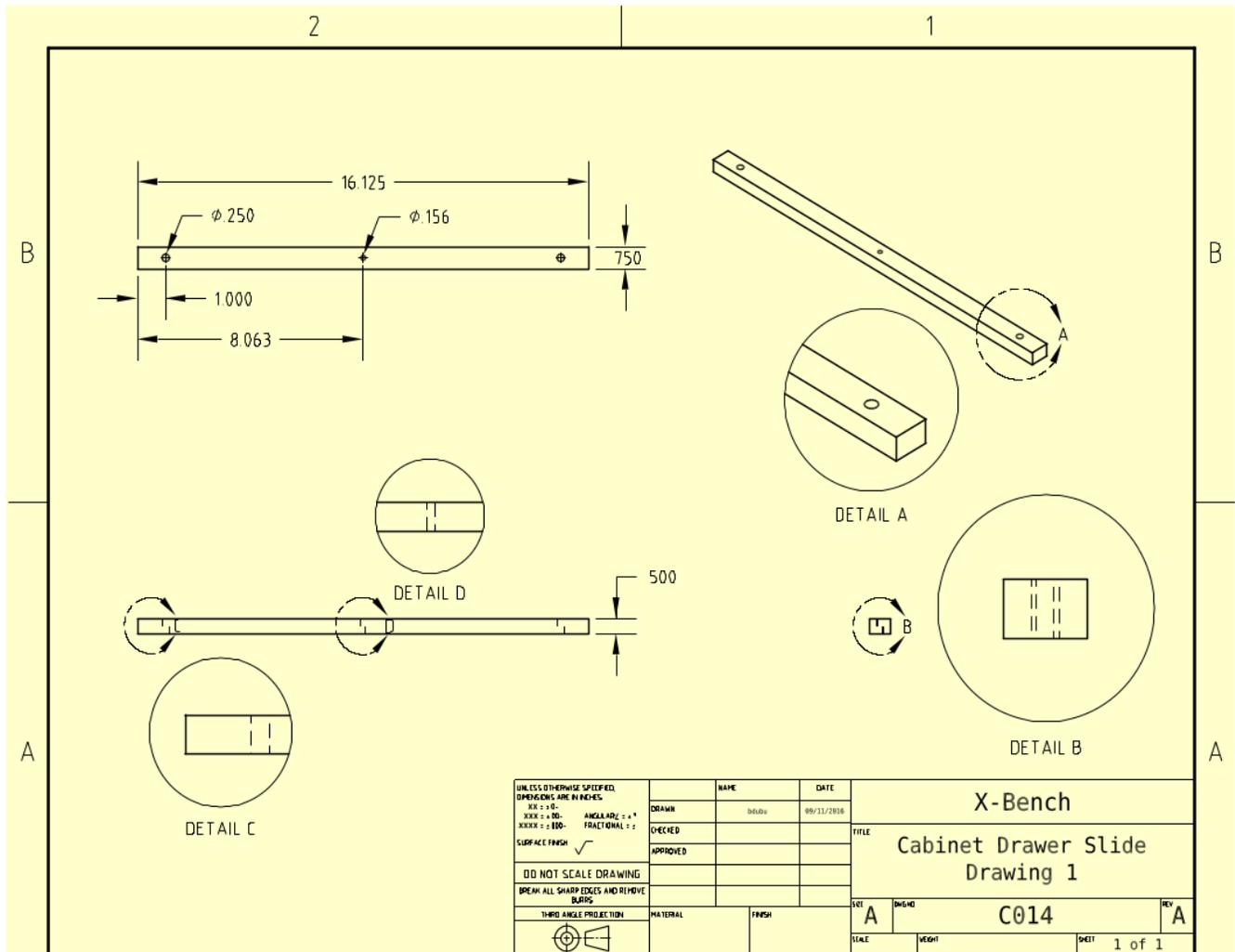
C11 – Cabinet Left Side



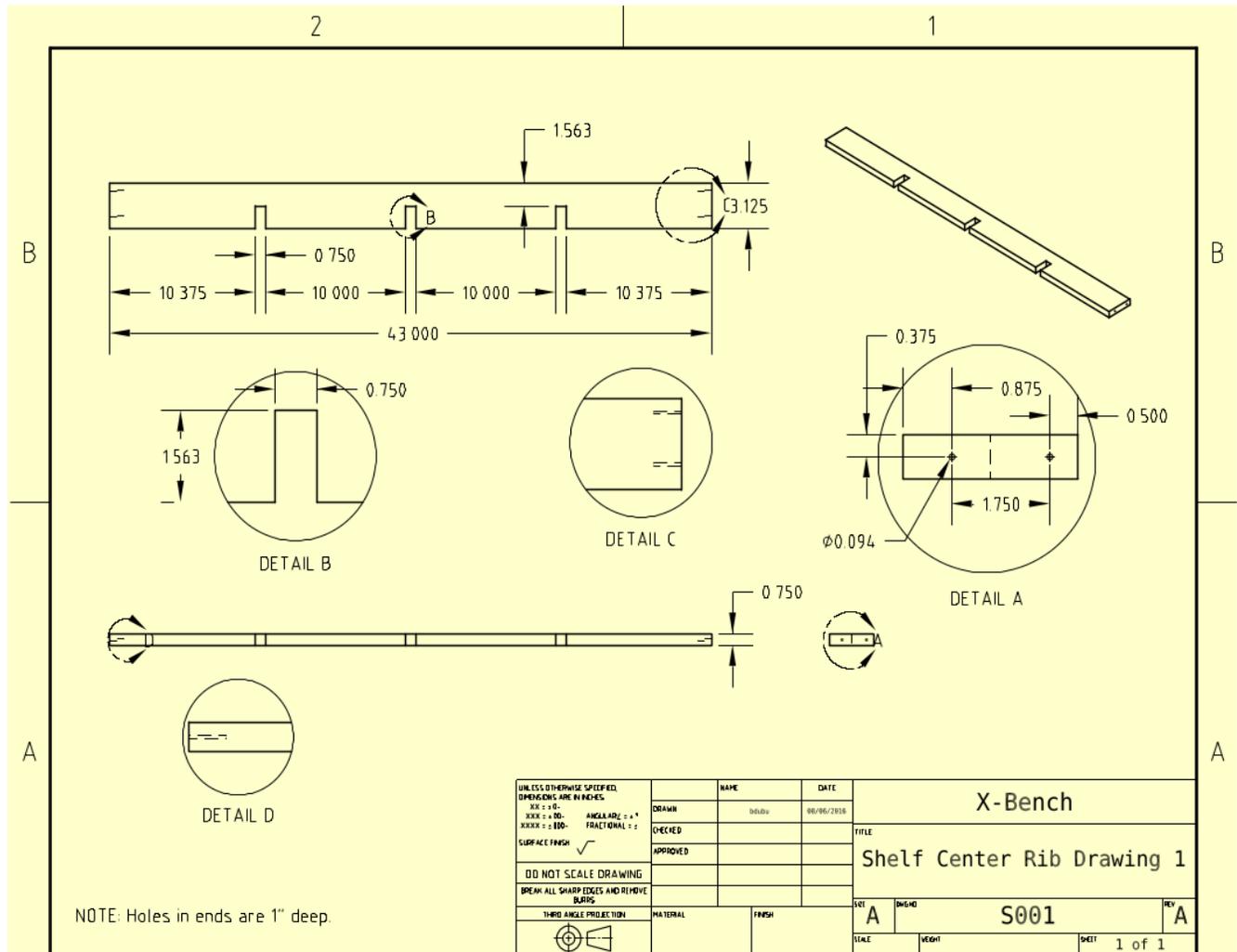
C13 – Cabinet Right Side



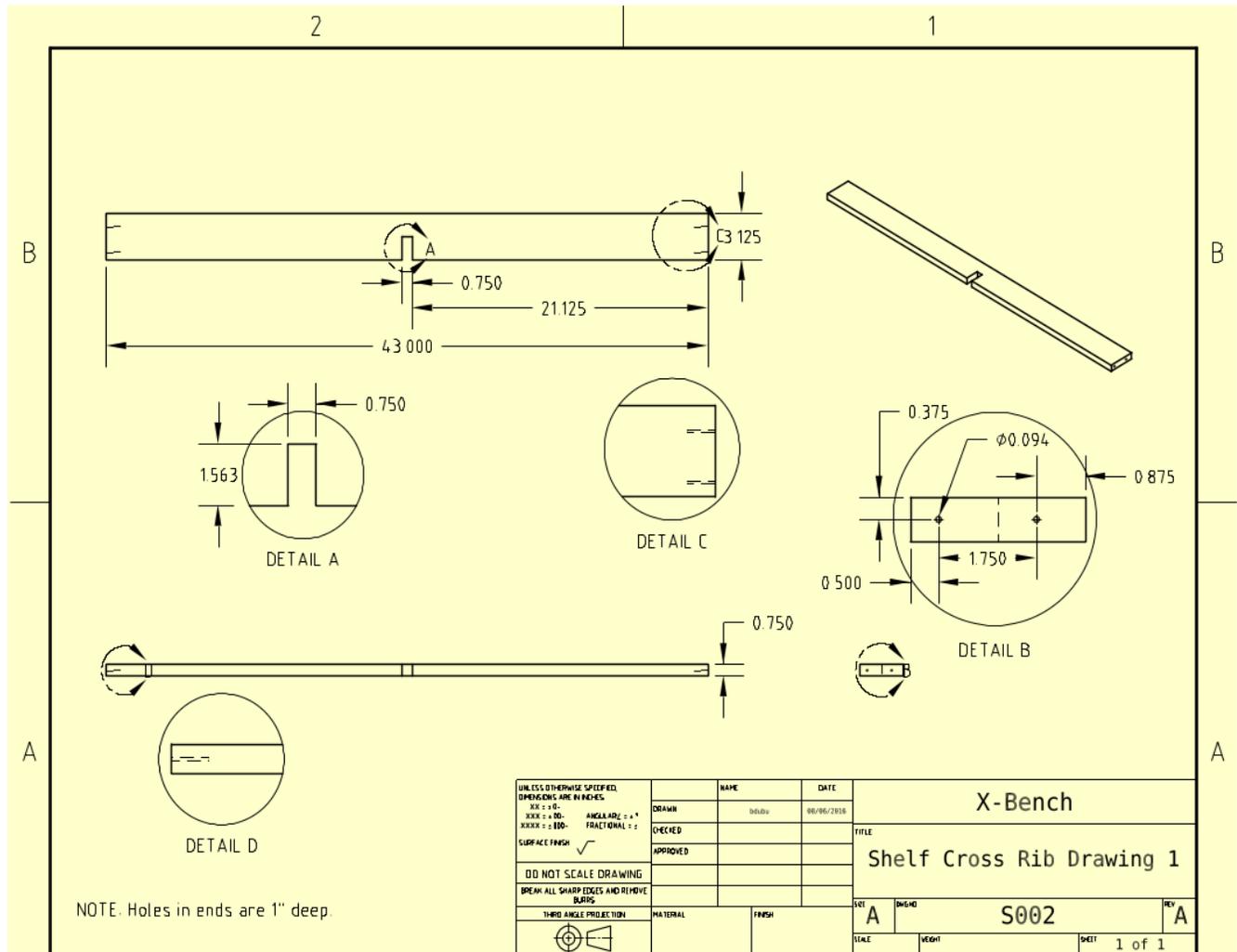
C14 – Cabinet Drawer Slide



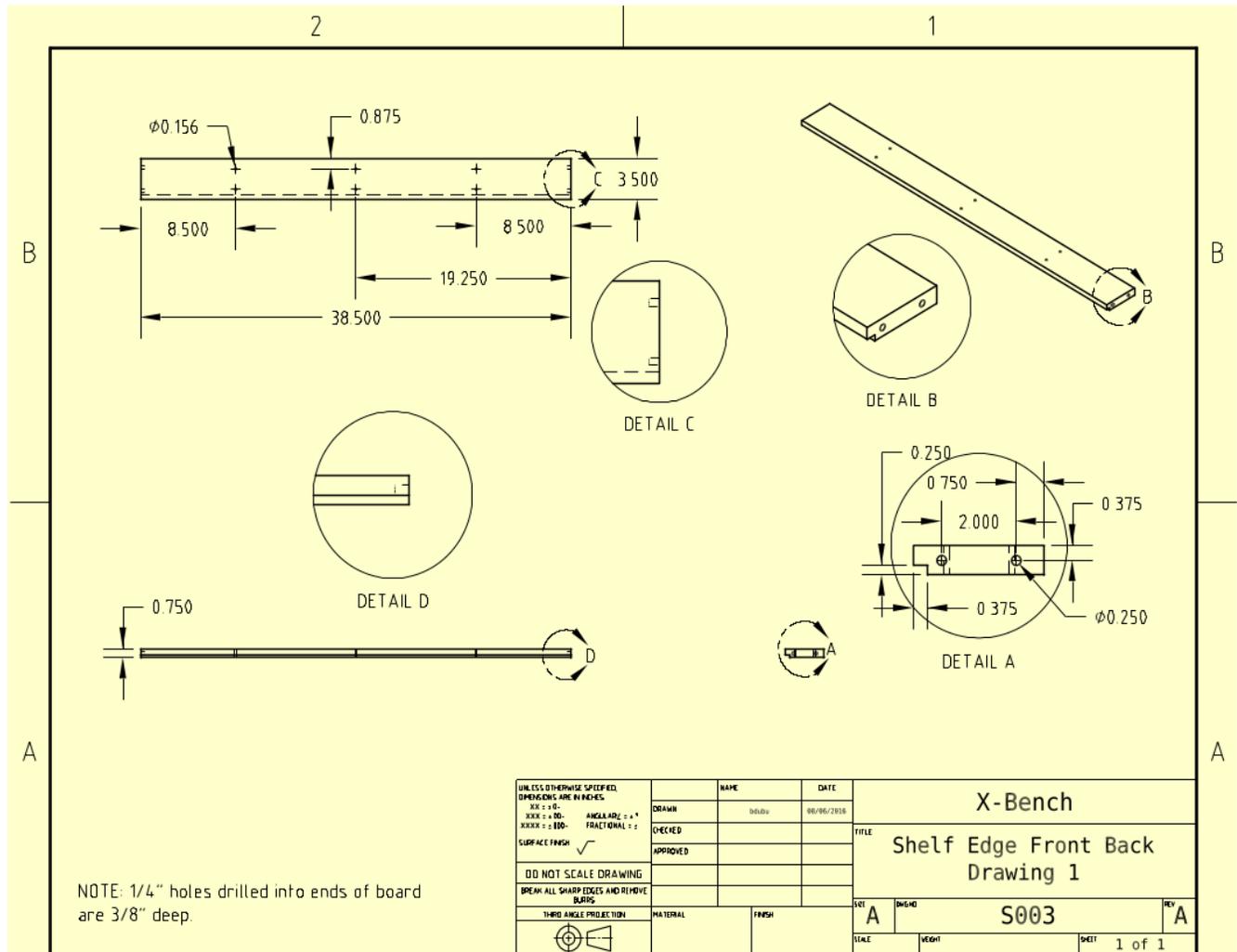
S1 – Shelf Center Rib



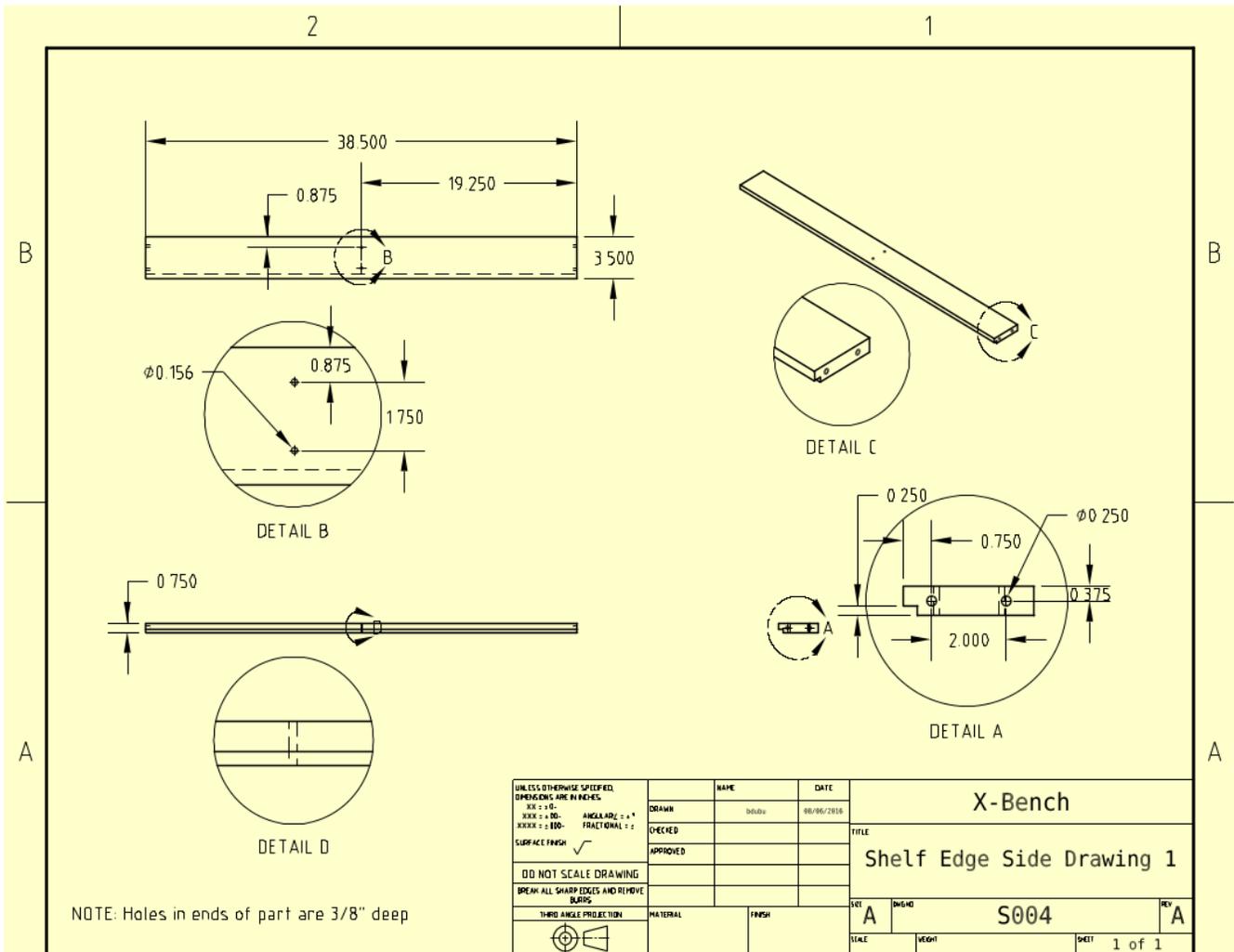
S2 – Shelf Cross Rib



S3 – Shelf Edge Front Back

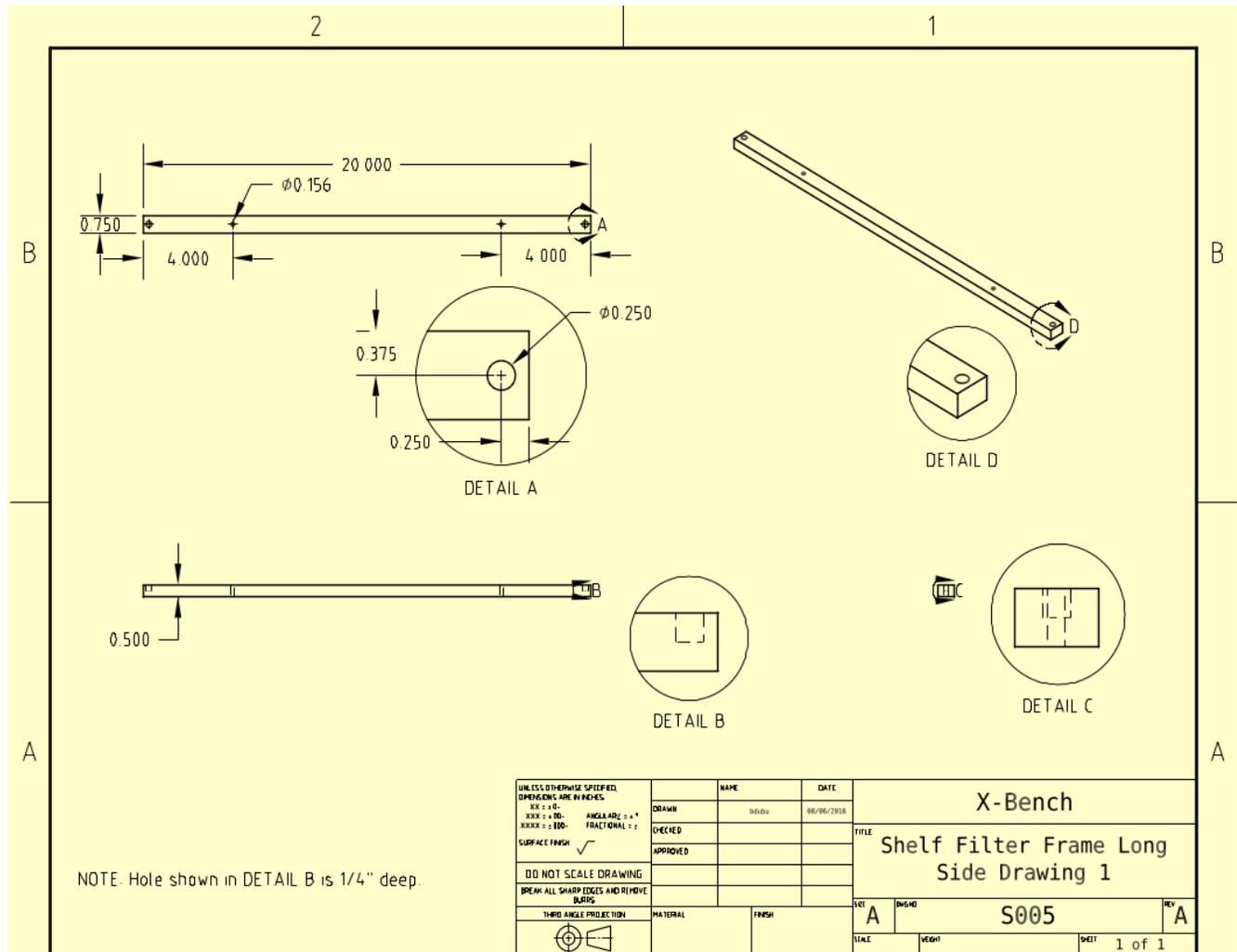


S4 – Shelf Edge Side

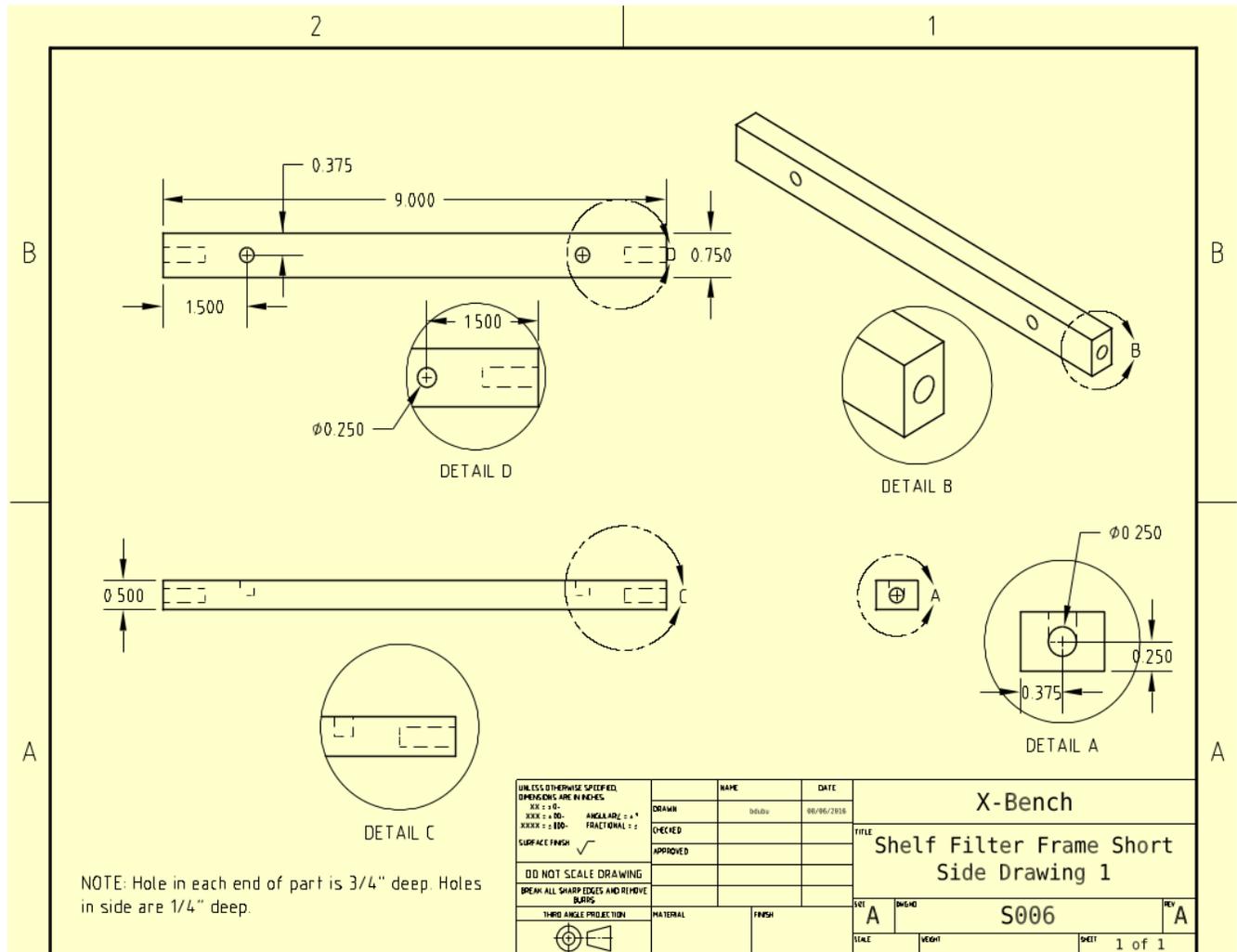


UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES: XX = ± 0.001 XXX = ± 0.0005 SURFACE FINISH: ✓ DO NOT SCALE DRAWING BREAK ALL SHARP EDGES AND REMOVE BURRS THIRD ANGLE PROJECTION		NAME	DATE	X-Bench	
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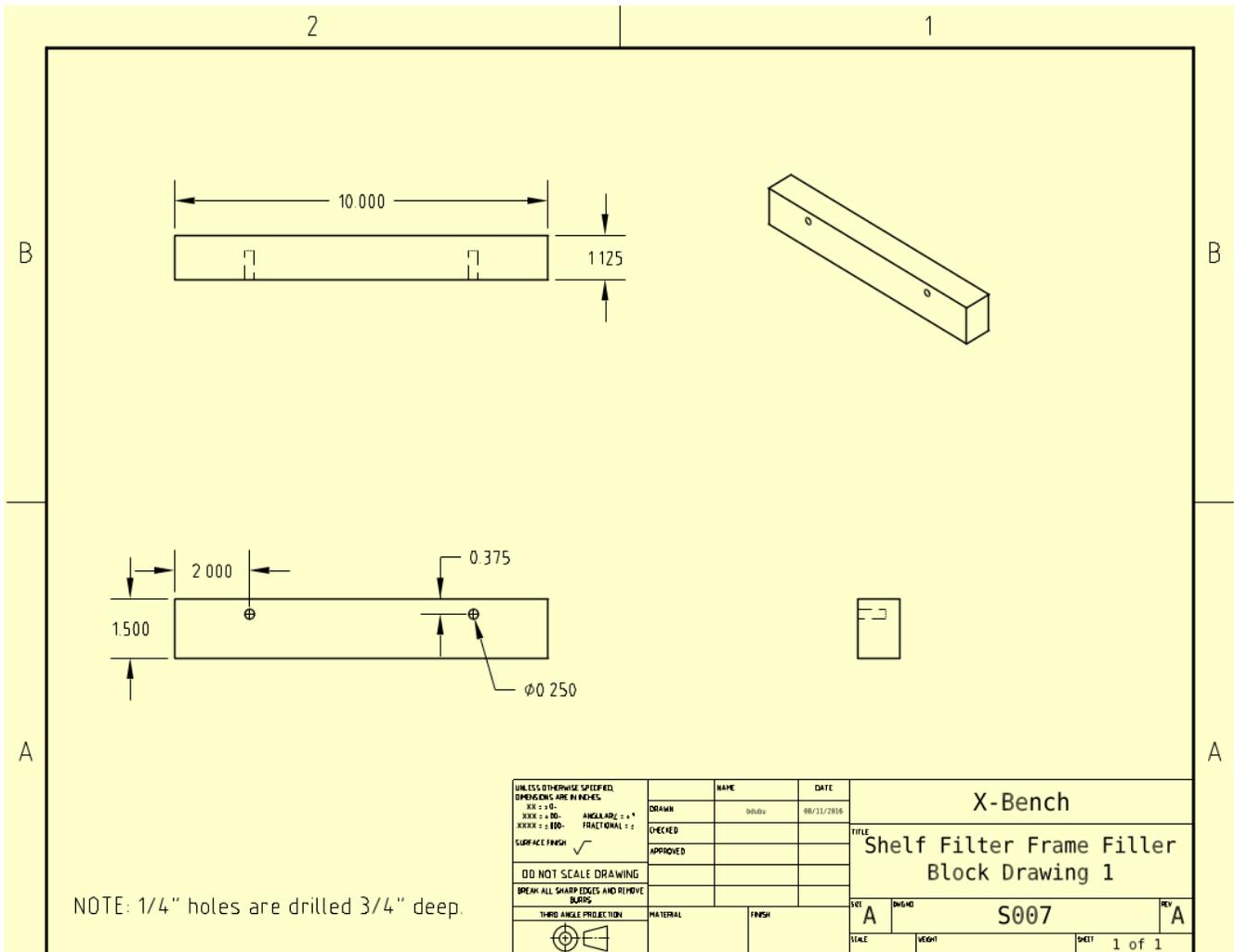
S5 – Shelf Filter Frame Long Side



S6 – Shelf Filter Frame Short Side



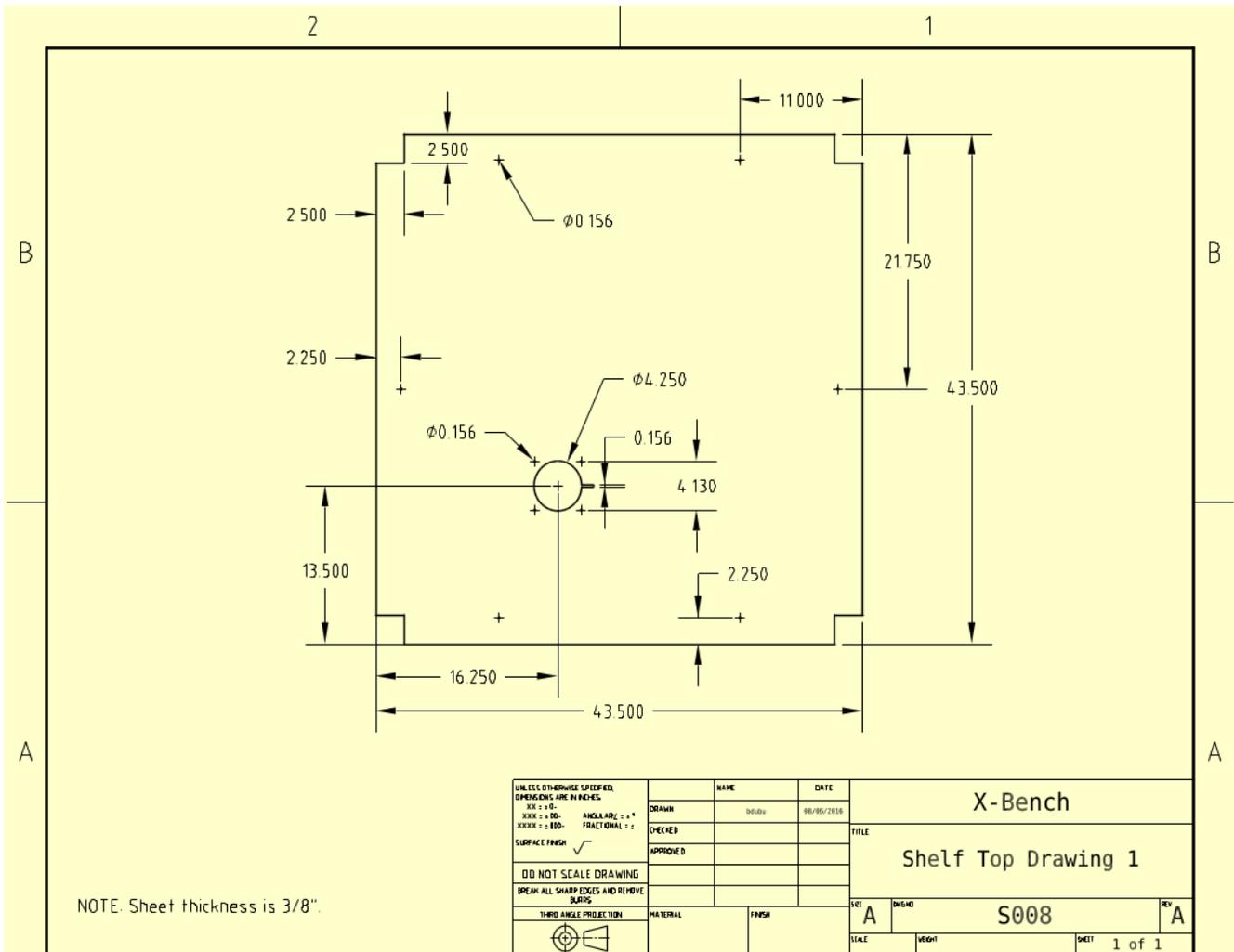
S7 – Shelf Filter Frame Filler Block



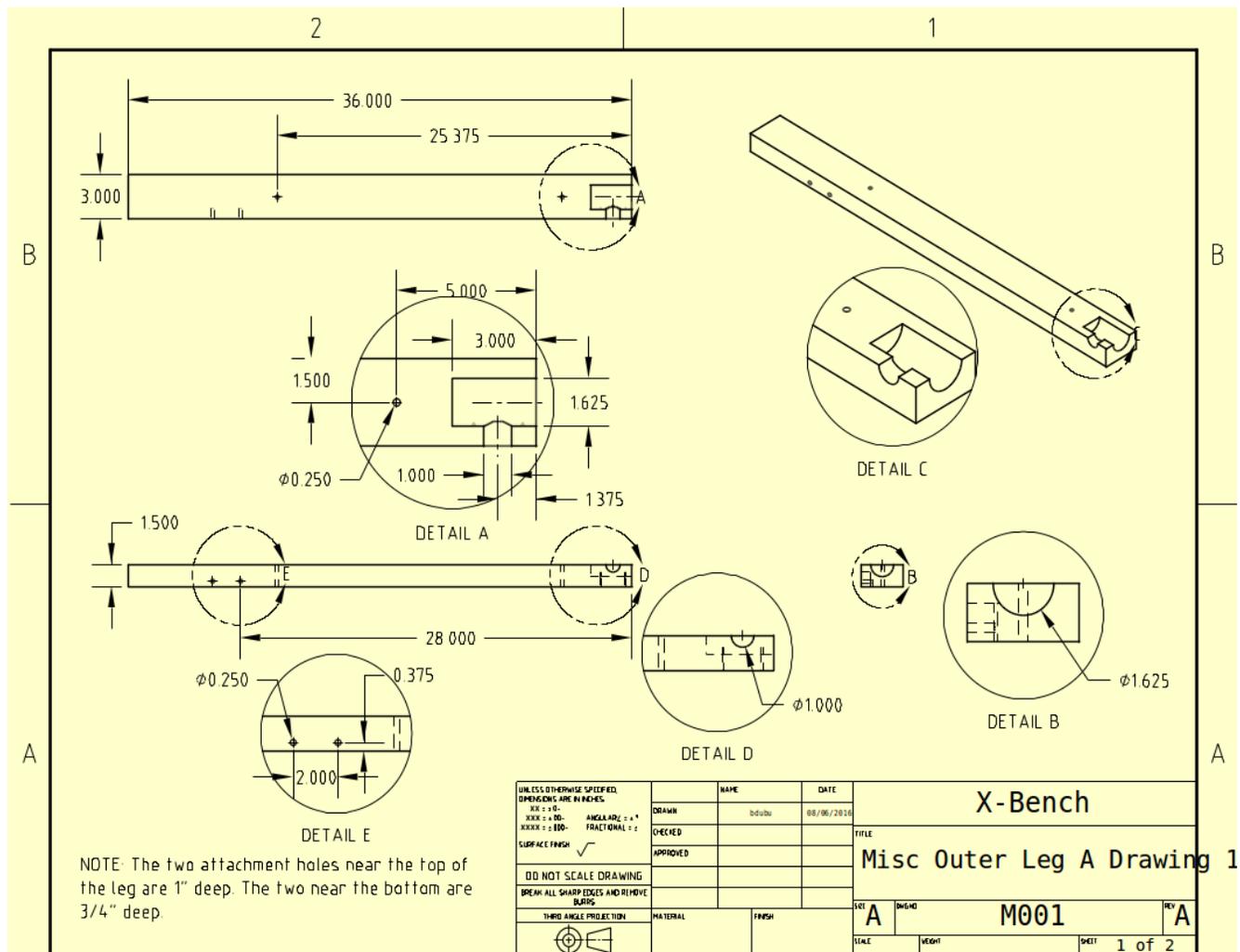
NOTE: 1/4" holes are drilled 3/4" deep.

<small>UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES: XX = ±0. XXX = ±0.001 SURFACE FINISH ✓ DO NOT SCALE DRAWING BREAK ALL SHARP EDGES AND REMOVE BURRS</small>	NAME	DATE	X-Bench	
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	APPROVED			
THIRD ANGLE PROJECTION	MATERIAL	FINISH	SET	REV
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			SCALE	VEGHT
				DEET 1 of 1

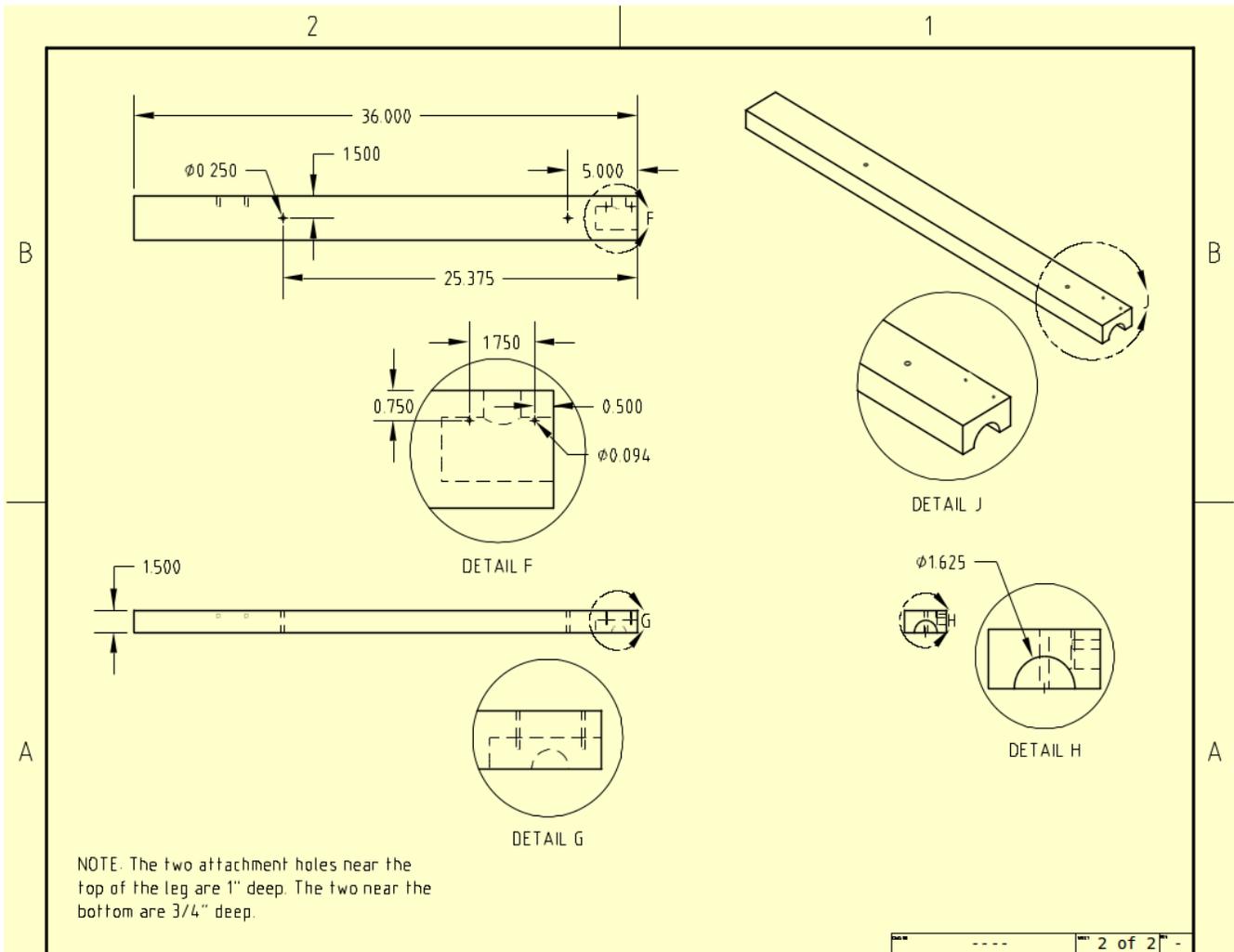
S8 – Shelf Top



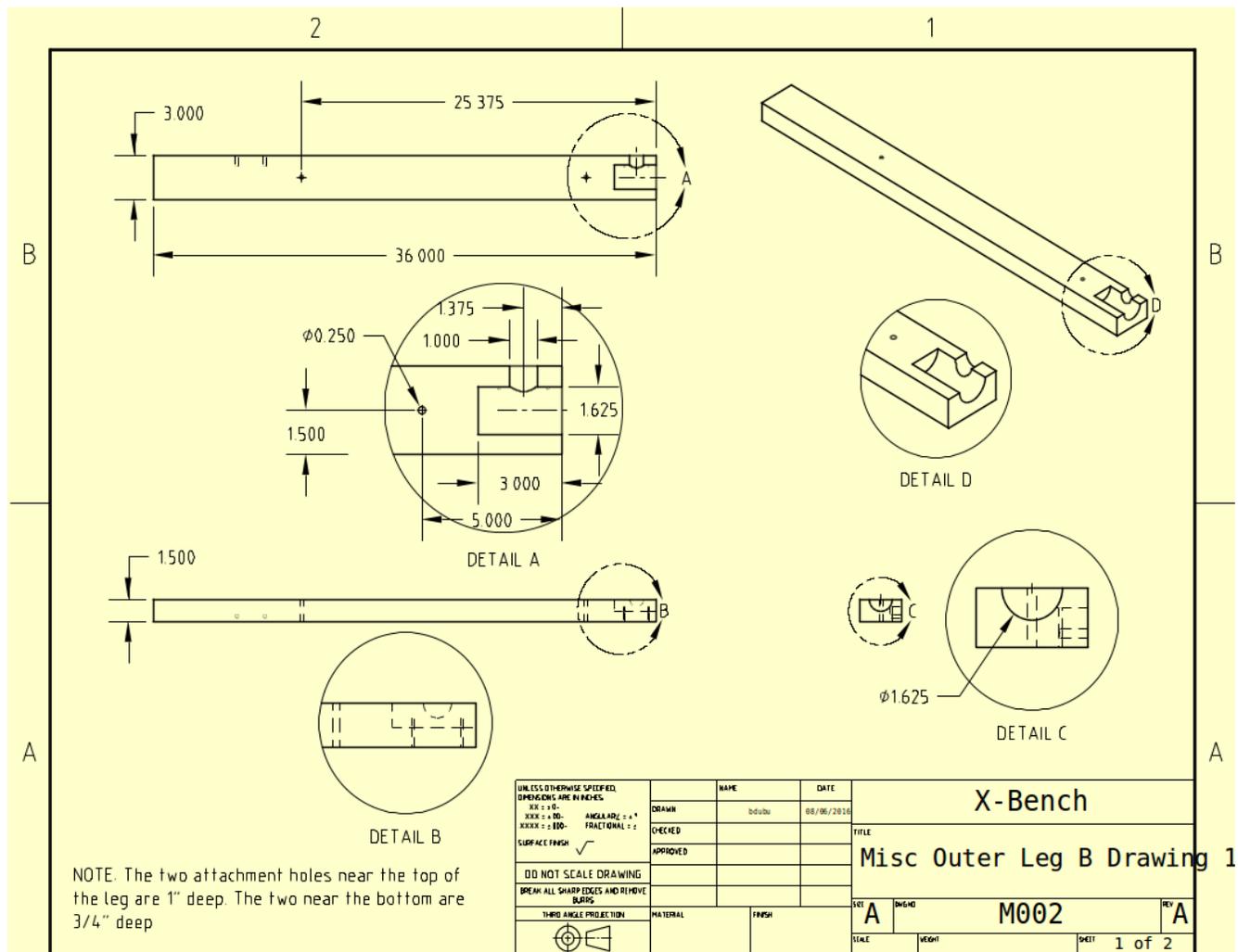
M1 – Misc Outer Leg A (1 of 2)



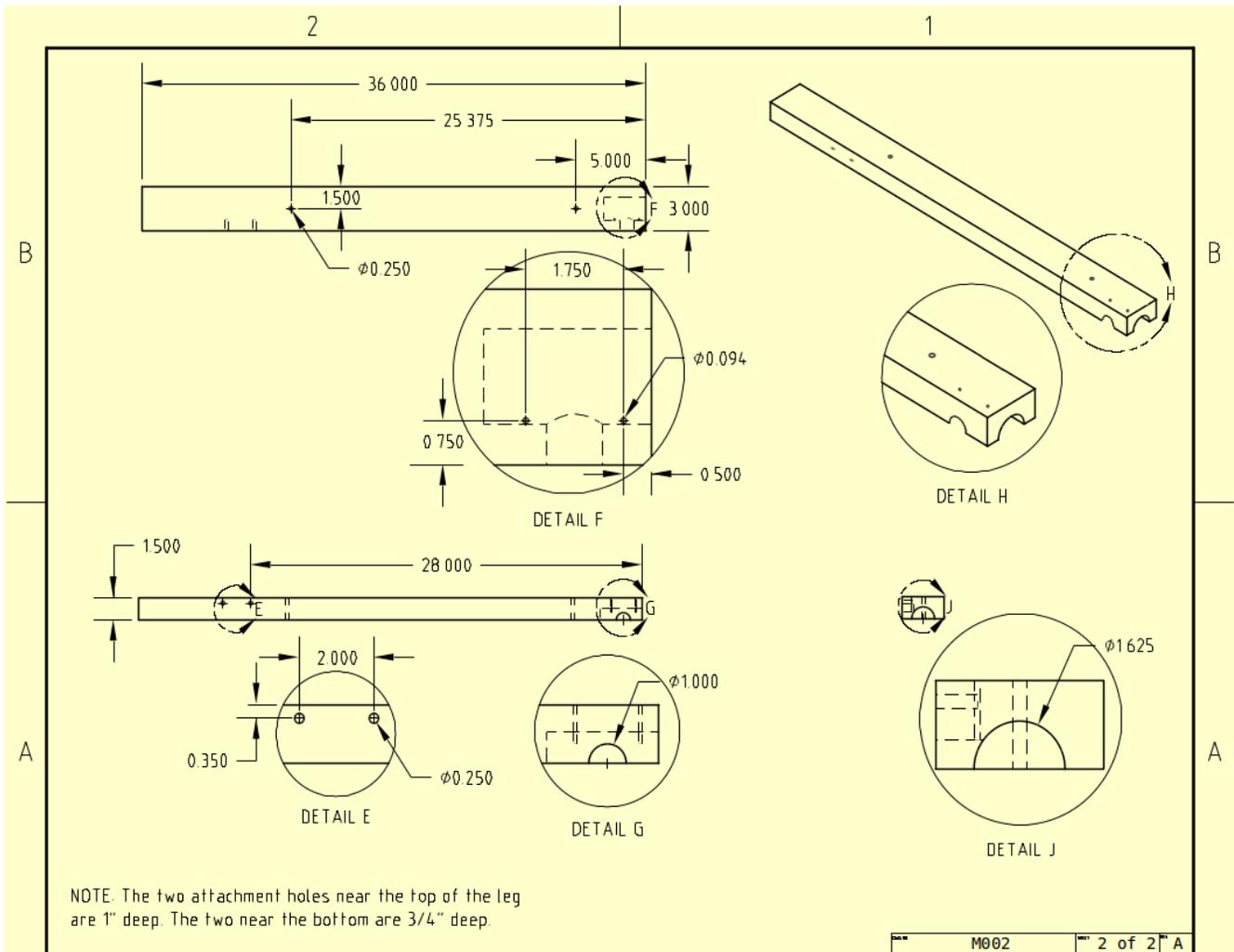
M1 – Misc Outer Leg A (2 of 2)



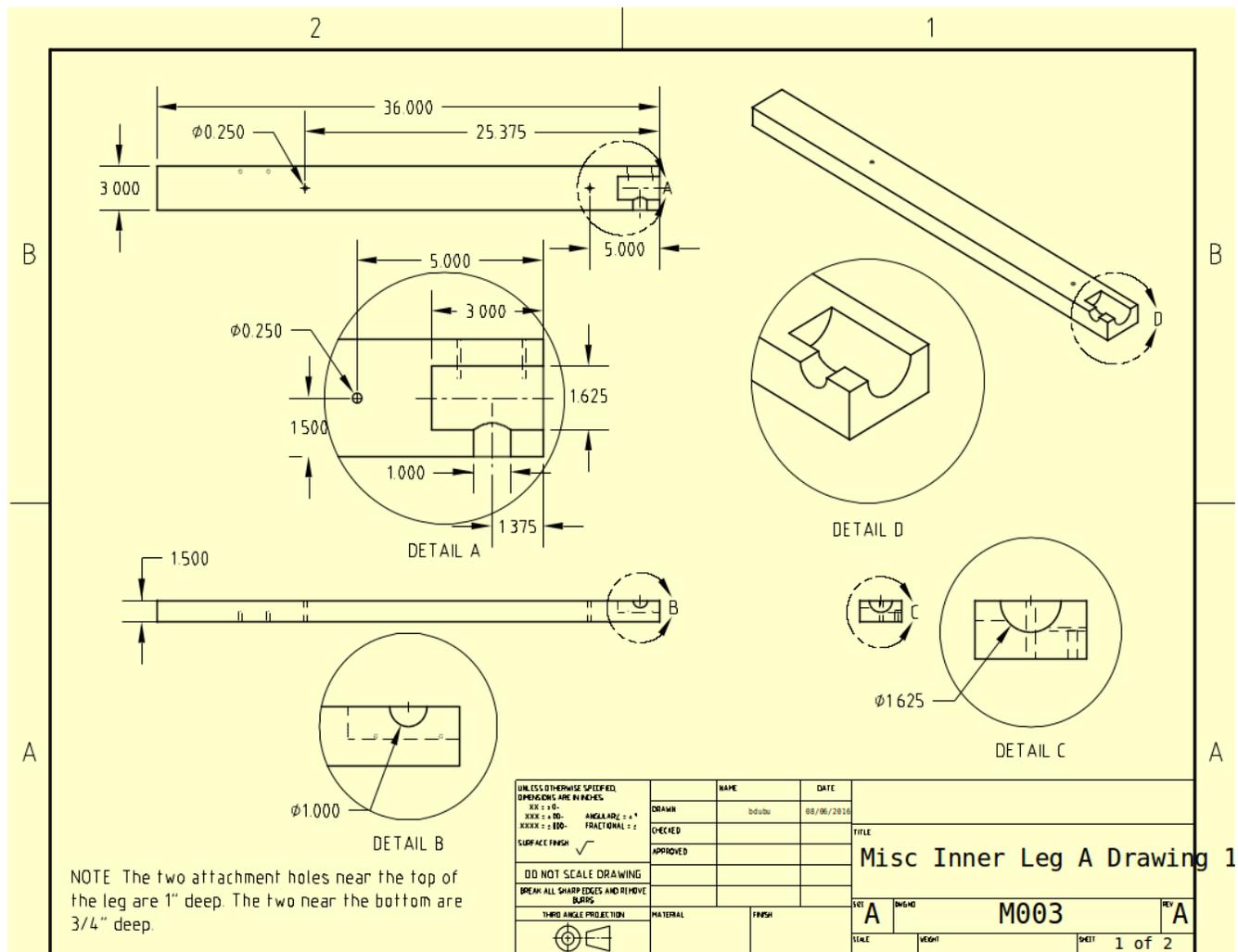
M2 – Misc Outer Leg B (1 of 2)



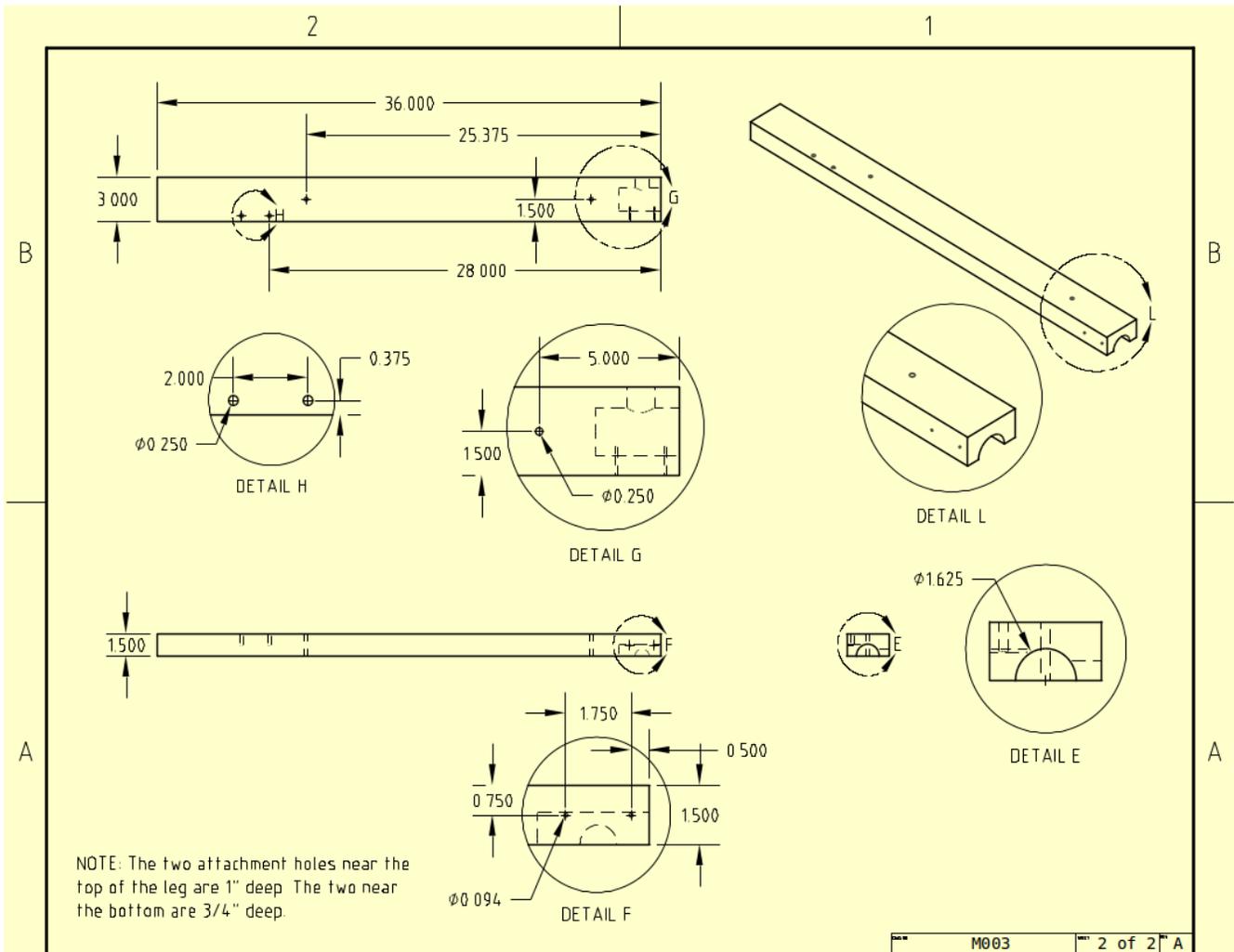
M2 – Misc Outer Leg B (2 of 2)



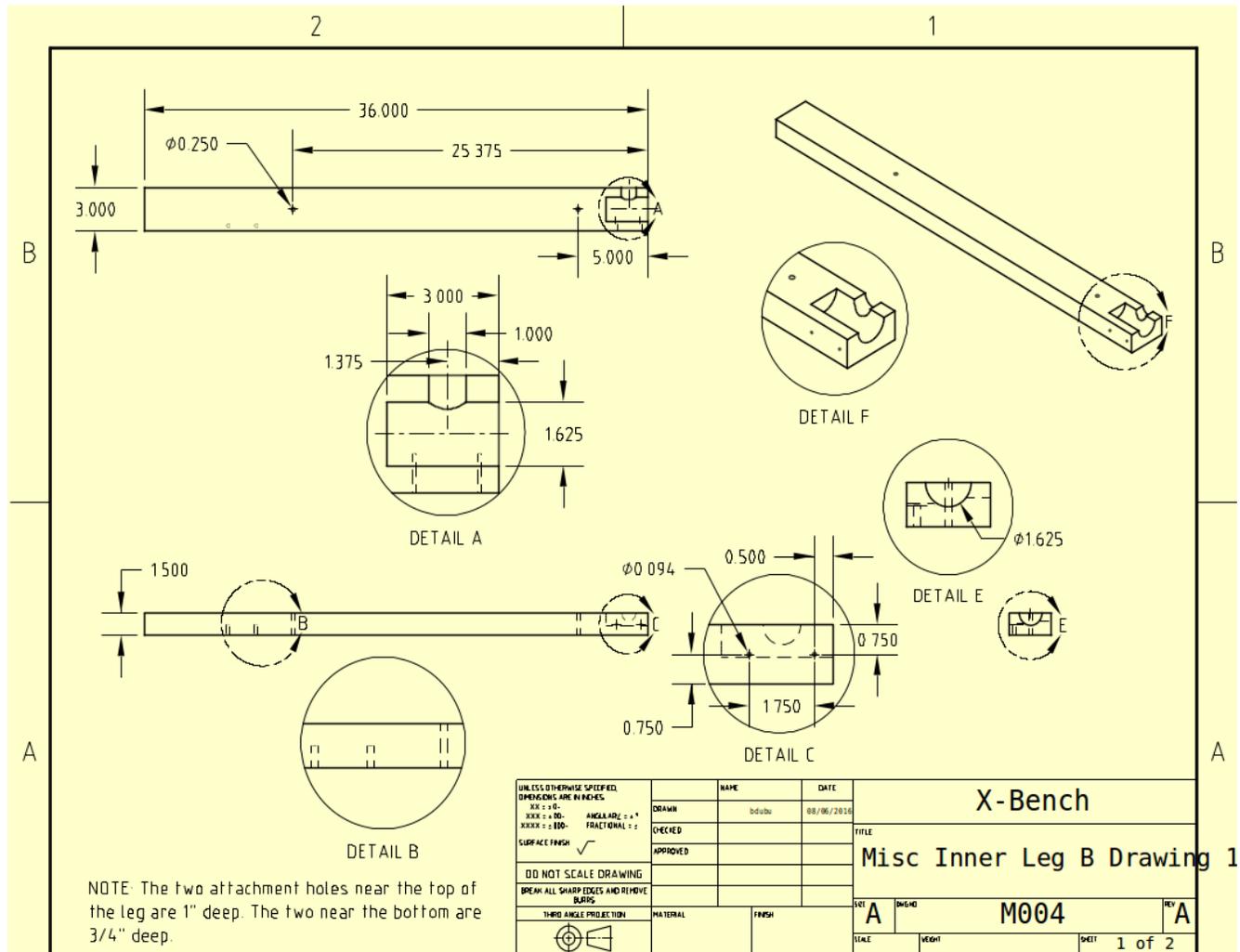
M3 – Misc Inner Leg A (1 of 2)



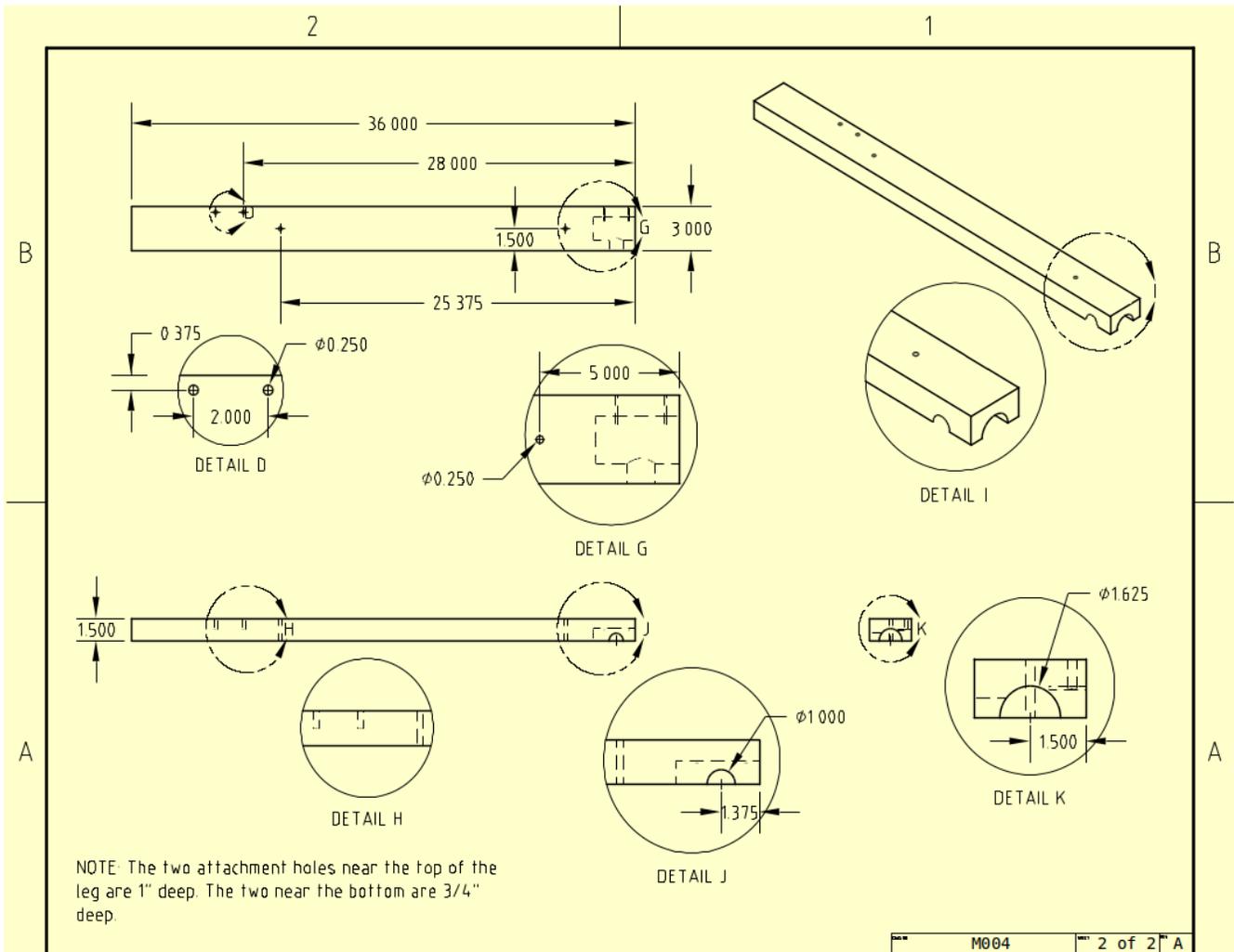
M3 – Misc Inner Leg A (2 of 2)



M4 – Misc Inner Leg B (1 of 2)



M4 – Misc Inner Leg B (2 of 2)

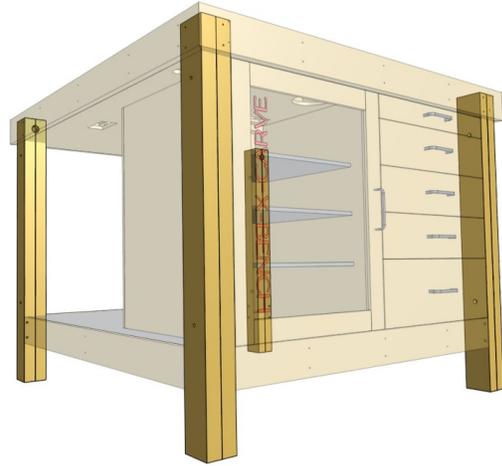


Assembling the X-Bench

In this section, you'll assemble the X-Bench's various sub-assemblies, connect them all together and then “finish out” the workbench by adding wiring, attaching the X-Carve, etc.

Leg Assembly

As noted earlier, each of the X-Bench's legs is comprised of two "half-leg" parts that are each created from a 2x4. These two parts must be bound together using two 1/4" hex-head bolts that are 3" in length. The head of each bolt (plus a washer) should be located on the *outside* face of the leg. As these bolts are the same length as a leg's width, T-nuts will be used on the inside face of



the leg (inserted into the 1/4" hole).¹⁴ Use of T-nuts here allows the cabinet unit to be slid into place between the two front legs without being obstructed.¹⁵ Use of T-nuts also makes it possible for a bench leg to be disassembled in-place, allowing you to re-route monitor (or other) cables through it.¹⁶

Be careful to correctly identify and pair the leg parts. As per *illustration 12* seen in the section *Building the Legs*, an "M1" part must pair with an "M4" and an "M2" must pair with an "M3".

If you have casters that you'd like to attach to the bottom of the legs, now is a good time to add them.

¹⁴ About 3/8" of this 1/4" hole will need to be slightly enlarged to 5/16" in order to accept the T-nut.

¹⁵ If a T-nut does interfere with sliding the cabinet unit into place, you may need to countersink it just a bit.

¹⁶ Such disassembly may be necessary if, for example, a monitor's power or data connector doesn't fit through the 1" hole on the back side of the leg.

Box Unit Assembly

The first step to assembling the box unit is to assemble its internal rib structure on a suitably large, flat and clean surface *upside down* as shown in *illustration 16*. All ribs running front-to-back should have their notches facing *upwards* and those running side-to-side should have their notches facing *downwards*. To aid you in identifying the box ribs, please refer to *illustration 10*.



Note that there shouldn't be any need to affix the ribs to one another using screws, etc. You should be able to align the notches and then just press the ribs together.¹⁷

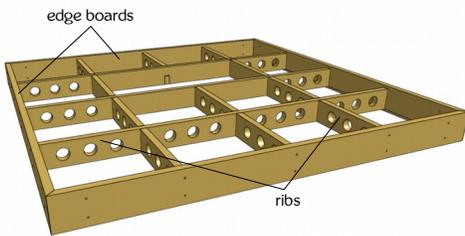


Illustration 16: box ribs and edge boards assembled

At this point, pay particular attention to how well each rib “joint” is assembled. Are the top surfaces of both ribs flush with one another? If not, then some debris might be trapped in one of the joints or a notch may have been cut too shallow.

Once you have what appears to be a good, flat, assembled rib structure, you can then proceed to attach the edge boards. As there are pilot holes pre-drilled into the ends of the ribs, attachment of the edge boards should be a simple matter with one caveat – as the rib structure itself is upside down, be sure to attach the edge boards upside down (the groove cut in an edge board should be facing down). Attachment of the edge boards to the ribs is done using 1 3/4" wood screws.

Once the edge boards are attached to the rib structure, you can then attach the box bottom. Be sure to orient the box bottom correctly. Firstly, make sure that its front is facing the same direction as that for the rib structure. Secondly, make sure that the box bottom is turned so that – in the completed X-Bench – the large *air intake vent* hole will lie above the side of the cabinet where you want the shelves to be. In other words, if you intend to build the X-Bench in the *default* configuration as show in all of the illustrations – that is, with the shelves on the left and drawers on the right – then the box bottom should be oriented on top of the rib structure so that its air intake vent hole *lies to the right* of the fore-aft center line. On the other hand, if you prefer that the cabinet shelves and drawers be reversed, then the

¹⁷ If a “joint” seems a little loose, it should be alright but if it's too tight, you may have to remove some material from the offending part.

air intake vent hole should *lie to the left* of the fore-aft center line.

Now, as there are no pilot holes drilled into the ribs for attaching the box bottom, you'll need to drill these; however, since the holes are already pre-drilled into the box bottom, you can use the box bottom as a guide to drill the pilot holes into the ribs.¹⁸ These holes should be 3/32". Once all of the pilot holes have been drilled, you can proceed to drive the 1" screws into them.

Now is a good time to attach the air vent panel which covers the long cut-out in the shelf bottom located just in front of the edge-routing port. You should be able to simply press the vent panel into place and then affix it using four small wood screws.

With the bottom attached to the rib structure, you can now flip the whole box assembly over. Afterwards, place the box top into position and go ahead and drill the pilot holes in the box ribs to attach the box top but don't attach it using the screws just yet. Remove the box top and place it out of the way for now. It will be attached later, once work on the box's internals is complete.

¹⁸ If the box bottom is constructed from two quarter sheets, this procedure should be basically the same as if it was constructed from a single piece of plywood. The only difference is that you *may* want to add two or three additional attachment holes along the seam that exists between the two halves.

Shelf Unit Assembly

The shelf unit is assembled in much the same fashion as the box unit except that it is assembled in its *working* orientation with the shelf top facing *upward*.¹⁹

First, you need to assemble the four ribs as per *illustration 17*. Again, the ribs need not be joined using any hardware. They can simply be pressed together until their notches “bottom out”.²⁰ Once assembled, the notches in the center rib (the one running left to right in the illustration) should be facing *downward*.

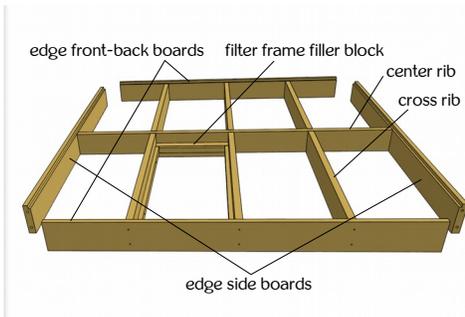


Illustration 17: shelf ribs and edge boards assembled

Next, attach the four edge boards. Remember that these come in two flavors – one that's used for the front and back of the shelf unit and the other for its sides. Note that the groove cut in each edge board should face upward. Attachment of the edge boards to the ribs is done using 1 3/4" wood screws.

After the edge boards are attached to the ribs, you can attach the filter frame. The filter frame is installed between the two ribs as shown in *illustration 17* – but only if you're not reversing the cabinet! If you are reversing the cabinet, then rather than the filter frame being attached to the *left* of the

fore-aft centerline, it should be attached in the space to the *right* of it.

As shown in *illustration 18*, the filter frame is assembled using six wood dowels. The four side parts are joined together and then the filler block (shown to the far left in the illustration) is joined to either of the short side members. Once the frame is assembled (no glue should be necessary), position it between the two shelf ribs and attach it to them using four small wood screws (the holes for which should be drilled into the two long frame members).

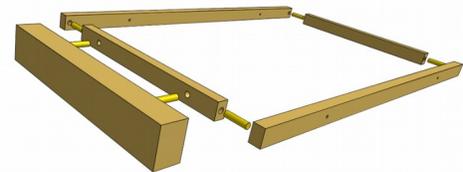


Illustration 18: filter frame assembly

¹⁹ If you're running low on bench or floor space, you can use the already assembled box unit as a work surface for assembling the shelf unit.

²⁰ Unlike box ribs, shelf ribs don't have an “air gap” to help ensure surface flatness (and nor is this really needed).

With its filler block attached, the filter frame should just fit into the opening between the shelf ribs.²¹ When properly positioned, the bottom of the filler block should be flush with the bottom edge of the shelf rib and the bottom of the filter frame itself will be 3/4" above that.

To complete the filter frame install, you'll want to affix a small piece of 1/8" MDF (or similar) to the bottom edge of the filler block so that when you slide an air filter into position, it won't be able to separate from the filter frame due to gravity. Likewise, you'll want to devise some sort of mechanism to keep the front of the air filter in place as well. I'll leave these details up to you, the builder. ;-)

The last step in assembling the shelf unit is to attach the shelf top. Once again, be careful to attach the shelf top in the correct orientation depending on whether or not you're reversing the cabinet. If you're *not* reversing the cabinet (and instead you're assembling it as per the illustrations seen in these plans) then the shelf top must be oriented so that the large air intake hole is located to the *left* of the shelf's fore-aft center line. Otherwise, it should be located to the *right* of this line.

As with the box assembly, there are no pilot holes in the tops of the shelf ribs to accept the wood screws and so you will have to drill these. Again, the location of these holes is easily determined by using the shelf top itself as a guide. These holes should be 3/32". Once you've drilled the six pilot holes you can then attach the shelf top to the rib structure using wood screws.

21 In the event that the frame fits too tight, you may have to sand it some.

Cabinet Unit Assembly

The four main structural components of the cabinet unit are its two sides, its spine and its back. Assembly begins by first attaching the two sides to each of the four left-right members. Be sure that the pilot holes that are drilled into the side board's edge are facing to the *rear* of the cabinet as these are used for attaching the cabinet back.



Each corner of a cabinet side is attached to an end of a left-right member using a single 1 3/4" wood screw. Note that you may need to leave out the top two wood screws on one side in order to make it easier to attach the spine.

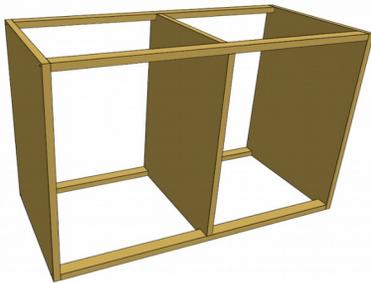


Illustration 19: cabinet sides and spine

To attach the cabinet spine, you'll first need to insert the four wood dowels – one per each corner of the spine. Then, work the spine board into position between all four left-right members. The four wood dowels should engage the holes drilled into the left-right members, thus securing the spine board in place. Afterwards, be sure that all eight of the wood screws are tightened. The result should look as shown in *illustration 19*.

Next, you can attach the cabinet back. It attaches using nine 1" wood screws – three each per side and then three for the spine.

With all of the main structural parts assembled, the next step is to “firm up” the cabinet structure by adding the eight cabinet corner braces (as can be seen in *illustrations 9 and 11*). Note that the four corner braces having the 1/4" hole drilled through their centers must be attached at the *bottom* of the cabinet.

Each corner brace is positioned in the corner between a cabinet side and a left-right member. Holding the corner brace firmly in place, use it as a template to drill pilot holes into both the cabinet side and left-right member. Afterwards, you can then drive pocket hole screws into both holes as indicated in *illustration 20*. *Be careful to not drive the pocket hole screws all the way through the cabinet side!*

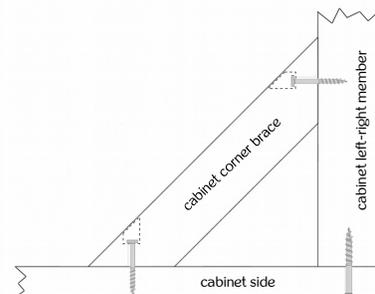


Illustration 20: attachment of corner brace

Next up is to assemble the cabinet door frame. The details of assembling it are dependent on which method of attachment you've chosen to join the frame members together. As the default method is to use wood dowels to join the frame members, I'll provide instructions for this method only.

Using wood dowels, assembly of the door frame is trivial. Simply insert a wood dowel into each of the 1/4" holes at each end of both door stiles and then press the protruding ends of the wood dowels into the end of a door rail. Be sure that the routed groove is on the same face of the door for all four frame members. After checking to make sure that everything fits ok (including that the frame is *planar*; that is, it sits flat when placed on a flat surface), re-assemble the frame using wood glue. *Illustration 21* shows the assembly of a corner of the door frame.

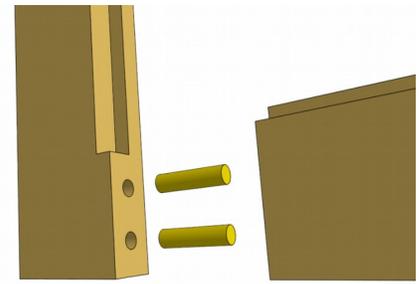


Illustration 21: assembly of a door frame corner

After the glue has set, you can then insert the door's glass/acrylic pane into the frame. Given that the pane is 1/8" in thickness, it should sit perfectly centered in the door frame (with respect to the door frame cross-section). With the glass pane seated in the routed groove, there should be about 5/16" of the groove remaining. This should allow for a number of ways to secure the glass pane; one being to drill small holes into the side of the groove that are flush with the glass surface and are capable of accepting small metal pins. These pins could easily be removed if the glass ever needed to be replaced. Another means of securing the glass pane is to affix a flat piece of metal to the inside face of the frame at each corner that presses against the glass and holds it firmly in place.

To attach the cabinet door to the front of the cabinet, you'll need to refer to the instructions for the particular type of "euro" style hinges used (again, you can likely find good videos on the web to help with this). These hinges typically require that you drill a "pocket" into the cabinet door frame to accommodate the hinge. Note that once the door is attached, its left edge should be flush with the left side of the cabinet and there should be a 1/16" gap between its right edge and the cabinet's vertical center line.²²

Pay particular attention to attaching the hinges as vertically symmetrical as possible; that is, the distance from either hinge to the top or bottom edge of the frame should be *identical* for both hinges. Likewise for locating the hinge attachment holes on the inside of the cabinet sides. This is all very important because, should you later decide to reverse the cabinet, the cabinet door itself will have to be "flipped" so that its hinges are now on the right side and if there is any variance in the location of the hinges, things might end up not lining up properly.

Next, you can attach the five pairs of drawer slides. If you've chosen to support the cabinet drawers using the default *wooden* slides (part C14), then each slide will attach to the rest of the cabinet using

²² This same gap will exist between the center line and the left edge of the drawer fronts too; therefore, when complete, the cabinet should have a total 1/8" gap between the edge of the cabinet door and that of the drawer fronts.

two 1" long 1/4" wood dowels (one on each end). The smaller diameter hole drilled into the *center* of each slide is for permanently attaching the slide to the cabinet side (or spine) using a 1" wood screw. This should keep the slide from working its way loose during use. As there is no corresponding pilot hole pre-drilled into the cabinet's side or spine for this purpose, you'll need to mark and drill it using the slide itself as a template.

If you've chosen to use purchased drawer slides instead of the default wooden ones, you'll need to locate and drill any necessary attachment holes (as the 1/4" holes specified in the drawings are meant only for use by the wooden slides).

Attachment of the shelf support rails and the drawer and door pulls won't be covered as part of these plans as both of these steps should be self-explanatory.

Main Assembly

With the major units all assembled, the next step is to connect them together. Start by placing the box unit on the floor *upside down* and then place the shelf unit on top of it, also *upside down*. Be sure that both units are oriented so that their fronts face the same direction.

Next, one by one, insert a leg assembly into a corner of the box unit and fasten it to the box edge boards using four 1 3/4"

wood screws. Before actually driving the screws however, be sure that the four attachment holes in the leg itself line up with those in the edge boards. Don't tighten the screws all the way – leave them a bit loose. The result should be what you see in *illustration 22*.

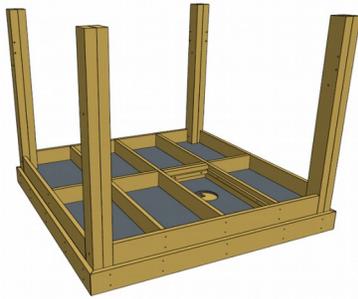
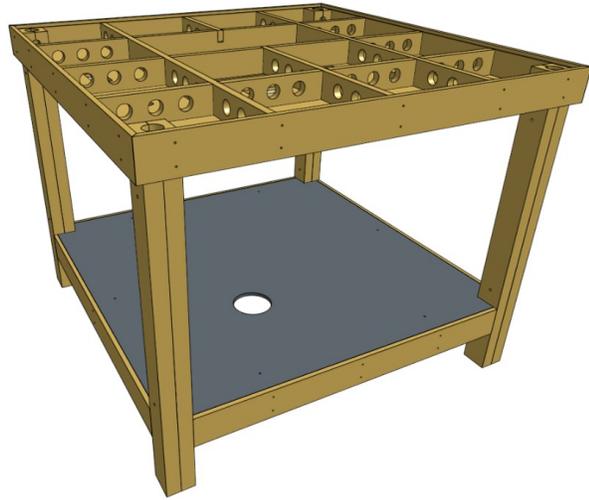


Illustration 22: beginning assembly

Next, rotate the entire assembly 90° so that it rests on its side. A piece of “one by” lumber should be placed beneath the ends of the two legs that are resting against the floor. This will help ensure that the whole structure is resting square to the floor. Now insert wood dowels into the four shelf alignment holes per each leg and work the shelf unit into position so that the wood dowels keep the shelf and legs in proper alignment.

At this point, to help keep everything together, a nylon strap or a piece of rope can be tightened around all four of the legs.

This will help to keep the legs good and steady as you attach the corner brackets (next).

Now, you're all set to permanently attach the shelf unit to the legs. To attach the shelf to a leg, first mark the location for any pilot holes that need to be drilled.²³ This is done by holding the corner bracket in place (between the leg and shelf edge board) and then using it as a template to mark and then drill the pilot holes. Be careful not to drill the pilot holes clear through the edge board!

Once the shelf corner brackets have been attached, the entire assembly can then be rotated to the upright position.

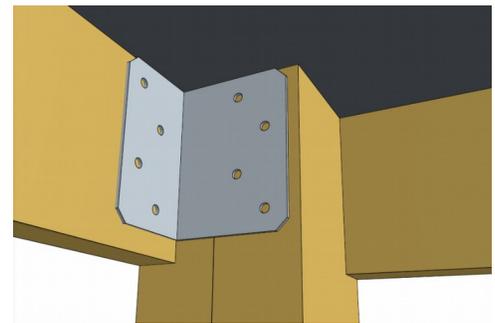
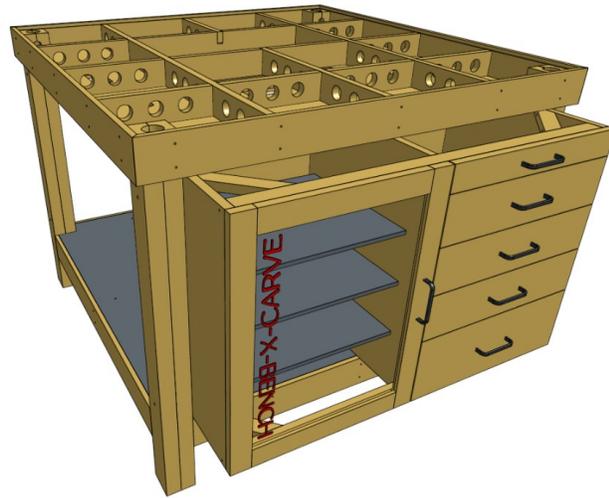


Illustration 23: positioning a corner bracket

²³ If you've chosen to use the Simpson Strong-Tie corner bracket, orient it so that the long face of the bracket contacts the leg assembly and the narrow face contacts the edge board (as shown in *illustration 23*).

Adding the Cabinet Unit

Once the box, shelf and legs are all assembled and joined together, you can then attach the cabinet. The cabinet is sized smaller than the opening for it in the workbench by 1/16" on either side so that it can more easily be slid into place. Once positioned, you'll need to shim the cabinet so that the overall 1/8" gap is evenly distributed side to side. Once done, the cabinet should be perfectly centered on the shelf's fore-aft center line.



With the cabinet's horizontal positioning on the shelf fine-tuned, you can now "lock it in". This is done by drilling four 1/4" holes through the shelf top using the 1/4" holes in the four bottom corner braces as guides. Once these holes are drilled, drop a 2" long, 1/4" carriage bolt into the hole for each of these four corner braces, pressing it down until it engages the shelf top. This should prevent the cabinet from horizontally shifting its position during use.

Just like with the cabinet's width, the height of the cabinet is also 1/8" shorter than the space allowed for it.²⁴ To evenly distribute this gap, insert a 1/16" thick fender washer beneath each of the four cabinet corners as well as the front and back of the spine.

As indicated in the list of features, the cabinet unit is meant to be mostly air-tight so that dust stays out of your electronic equipment. As such, you'll want to eliminate any gaps around its edges (including those just created by shimming the cabinet into place).²⁵ That said, the air circulation fan will be positioned so that it blows air *into* the cabinet rather than vacuuming air *out* of it. As a result, even if there are minor openings around the cabinet edges, the fan should maintain *positive pressure* inside of the cabinet thus helping to keep dust out.

²⁴ Actually, this vertical gap is 1/16" larger as both the box bottom and shelf top pieces (which are of 3/8" nominal thickness) should each have an actual thickness of 1/32" less.

²⁵ There are likely better ways to vertically shim the cabinet than using fender washers that don't result in air gaps. One possibility might be to apply a 1/16" thick veneer (or similar) around the bottom edges of the cabinet.

Wiring the Box for Power

The next step in the process is to wire up the X-Bench for power. The X-Bench has three electrical outlets that make it convenient for you to power the X-Carve and related equipment. One of these is dedicated to the electronics cabinet and is needed for powering your computer, monitor, controller, etc. The other two outlets are mostly just provided for convenience. You can use these auxiliary outlets to power a light, a vacuum, etc.

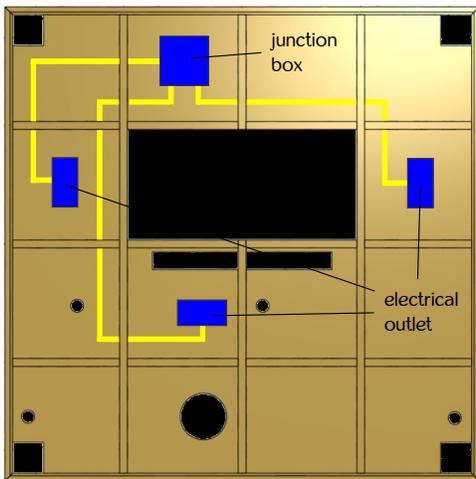
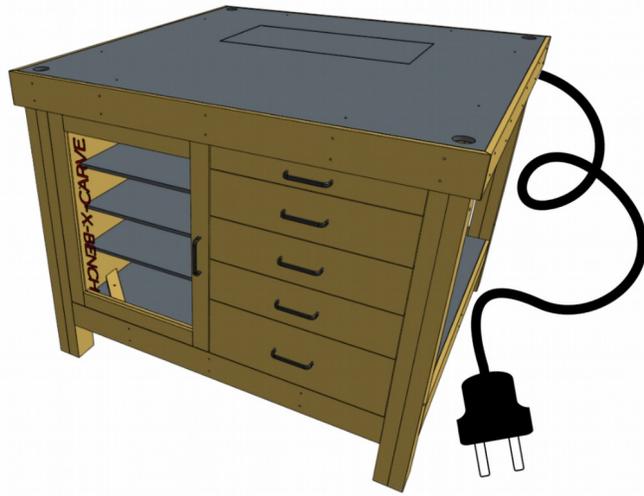


Illustration 24: electrical wiring

Each of these electrical outlets is wired directly to a common junction box that is used to bring mains power into the X-Bench's box unit. The mains power is brought in through the hole beneath the junction box. The wiring connecting each of these components is schematically shown in *illustration 24*.

All splicing of wires should be done inside of the junction box itself. Be sure to use electrical wire of a suitable high gauge so that it can handle the electrical loads anticipated. You can use an electrical extension cord as both the lead-in cord itself as well as for the internal wiring just so long as it is once again of high enough gauge to handle the electrical load.

WARNING: If you don't feel qualified to safely wire your X-Bench for power, find someone who can help you. Incorrectly wired electrical outlets can result in property damage, bodily harm and even death.



Adding the Electronics

Next, you need to attach the 120mm fan across the large opening in the shelf top. The mounting holes should have been drilled into the shelf top to allow for attaching it. If not, you will have to mark and drill these using the fan unit itself as a template. Note that the fan can be mounted *above* the cabinet floor or *below* it, with the latter likely being preferred as the fan is then hidden from view and the opening in the cabinet floor (shelf top) can then be covered with a fan grill (see materials list). If you choose to mount the fan below the cabinet floor, the narrow channel that is cut into the right side of the 4 1/4" hole can be used to route the fan's power cord through the shelf top. Note that regardless of whether you attach the fan above or below the cabinet floor, *the direction of air flow must be into the cabinet!*

You can now place the electronics equipment onto the shelves in the X-Bench cabinet. In the process you may find that the the standard X-Carve control wiring is too short to reach the controller located in the cabinet. To remedy this problem, you will need to extend those wires that are too short. This can be done by attaching “extension” wires to the controller and then routing them out of the cabinet, into the box and then up through the hole in the left front leg. Since the idea is to make it easy for you to disconnect the X-Carve when necessary, the control wires exiting the box should be terminated with appropriate connectors. Hopefully when done, very little wiring should be visible on top of the workbench.

Connecting the computer should be mostly a matter of routing its video cable to the computer monitor and routing the keyboard cable to the keyboard situated on the keyboard drawer. As with the X-Carve control wiring, these two cables may need to be extended in order to reach the computer inside of the cabinet.

If your computer requires an ethernet (direct network) connection, the area between the box ribs just to the right of the one housing the electrical junction box (as seen in *illustration 24*) is a good location for bringing an ethernet cable into the X-Bench box. At that location you could mount a wall plate having an ethernet jack on it. This would enable you to easily disconnect the network cable in the event you needed to re-locate the X-Bench elsewhere in your shop.

Likewise, if you'll be needing to regularly access the USB ports on your computer, these can similarly be extended to the outside of the X-Bench. I plan on doing this possibly by routing a small rectangular opening in the front box edge board that can accept a 1/8" piece of MDF as a “front panel”. On this panel could be mounted switches, USB jacks, an emergency stop, etc.

Attaching the X-Carve

Now it's time to attach the X-Carve. Before doing so, you'll need to "close" the box by adding the box top onto the workbench. Don't attach it using wood screws just yet.

Next, place the X-Carve onto the X-Bench. Attaching the X-Carve to the box top should be just a matter of centering it and then fastening it down using screws (possibly in combination with small brackets). That said, note by default the center member of the X-Carve's base frame will lie *across* the edge routing port. If you don't intend to edge-route boards that are wider than about 10", this shouldn't be a problem. On the other hand, if you need to route boards that are wider than this (up to about 20"), you'll have to modify the X-Carve's base frame so

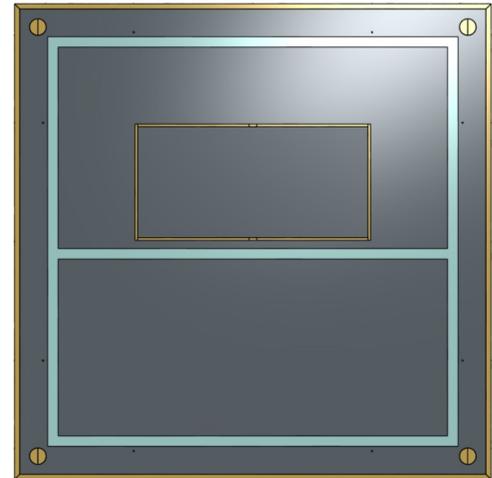


Illustration 25: modified x-carve base frame

that this center member is attached between the base frame's sides as shown in *illustration 25*.²⁶ Note that in addition to turning the center member 90°, you can optionally add additional support members. These can be either additional pieces of 20x20 extrusion or simply pieces of wood that have been carefully ripped to the exact same height as the existing frame members.

Regardless whether you make the above modification(s) to the base frame or not, a cut-out of some sort must be made in the X-Carve's wasteboard to provide access to the edge routing port. This cut-out can be made using the X-Carve itself. The size of the cut-out can theoretically be as large as that of the underlying edge routing port, but a slot about 2" in height and perhaps 10" or 12" inches wide should be more than adequate for most applications. Bear in mind that the smaller the cut-out, the less intrusive it will be with regards to normal routing operations. And speaking of which, there's nothing to prevent you from making this cut-out in your wasteboard so that it is turned 90° and is roughly aligned with the far left or far right edge of the edge routing port opening. Doing this might further ensure that the cut-out made in the wasteboard doesn't interfere with normal routing operations.

The final step is to connect the X-Carve's control wiring. If you've extended the wires from the controller inside of the cabinet to the box top surface (and terminated them with connectors), this should be a simple matter of mating the two connectors per each pair of wires.

The only thing that remains is to test the operation of the X-Carve. If all goes as planned you should be able to fasten the box top using eight 1" wood screws.

Happy X-Carving!

²⁶ This looks to be just a matter of shortening the cross-member and then re-attaching it.

Usage Notes

Any unused holes in the X-Bench box should be capped so that dust can't enter them. For example, each of the four corners of the X-Bench top has a hole drilled in it for mounting a computer monitor. You'll likely need to use only one of these mounting holes at any given time. The other ones should be capped using an appropriate plug (see materials list).

A box edge board can be removed to allow you to more easily re-route wiring (while leaving the X-Carve in place on top of the X-Bench).

If you're unable to route a monitor cable through the hole in the back of a leg because the cable connector is too large, you can remove that side's box edge board and then remove the “outer” leg part (by removing the two 1/4” leg bolts).

Note that the X-Bench top is designed to support the weight of a 1000mm X-Carve in addition to that of a workpiece, etc. As such, it's not recommended that the X-Bench be used for any purposes other than this (such as using it as a convenient ladder to replace a burned-out light bulb in an overhead light fixture, for example).

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How to Contact Me

If you have questions or comments regarding the X-Bench or you find errors in this document, feel free to contact me. I can be reached at bwb@fireflysoftware.com. As an alternate, I can also be contacted through the Inventables forum. There, my user name is “bdubu”. Just send me a PM.