

Harness Drawing & Construction

Any project that involves a MotoHawk controller will also involve a wire harness, or, as our friends in England like say, a wire loom.

The harness, or loom, is nothing more than that spaghetti of wires running from the controller out to the interesting vehicle components. Believe it or not, the harness is one of the most complex components of your design and can easily make or break the progress of your project. If you learn nothing else:

“Bad harnesses mean bad results.”

This segment of our training will focus on designing a harness, documenting it properly, and then building it.

If you are lucky to work for a big organization, this task may take several people and involve all manner of 3D cad tools, technicians, sophisticated braiding machines, and exotic tools.

Don't worry. All of this is do-able with Visio, a couple of good crimp tools, and a well-stocked connector drawer.



The Basic Steps

Before starting, gather up all of the sensor and actuator datasheets you can find. New Eagle has all this information available on our Wiki Site. If you cannot find it on the Wiki, contact New Eagle.

1. **Create a block diagram of the system.** This simply shows the controller at the center of the system and all of the electrical connections necessary to all of the various sensor and actuator pins.

Splices are one of the most important details on the block diagram — do not overlook them!

Begin assigning connector names (e.g. C1, C2 or J1, J2) to the various connectors.

Assign wire numbers and wire colors at this point, if possible.

2. **Do a physical layout drawing of the harness(es).**

Stretch string around your vehicle or machine to approximate lengths.

Draw a physical layout on a 1:1 drawing and plan on plotting it full size.

This will make construction far easier down the road.

3. **Create a point-to-point drawing showing all connectors, wires, and splices.**

4. **Start constructing S/N 1.**

- *Test as you go.*
- *Label as you go.*
- *Fix the drawing when issues arise.*
- *Spend extra time on splices.*

Let's look at each of these steps in detail.

Creating a Block Diagram of the System

Visio Primer Notes

If you don't have Visio, go get the evaluation version at:

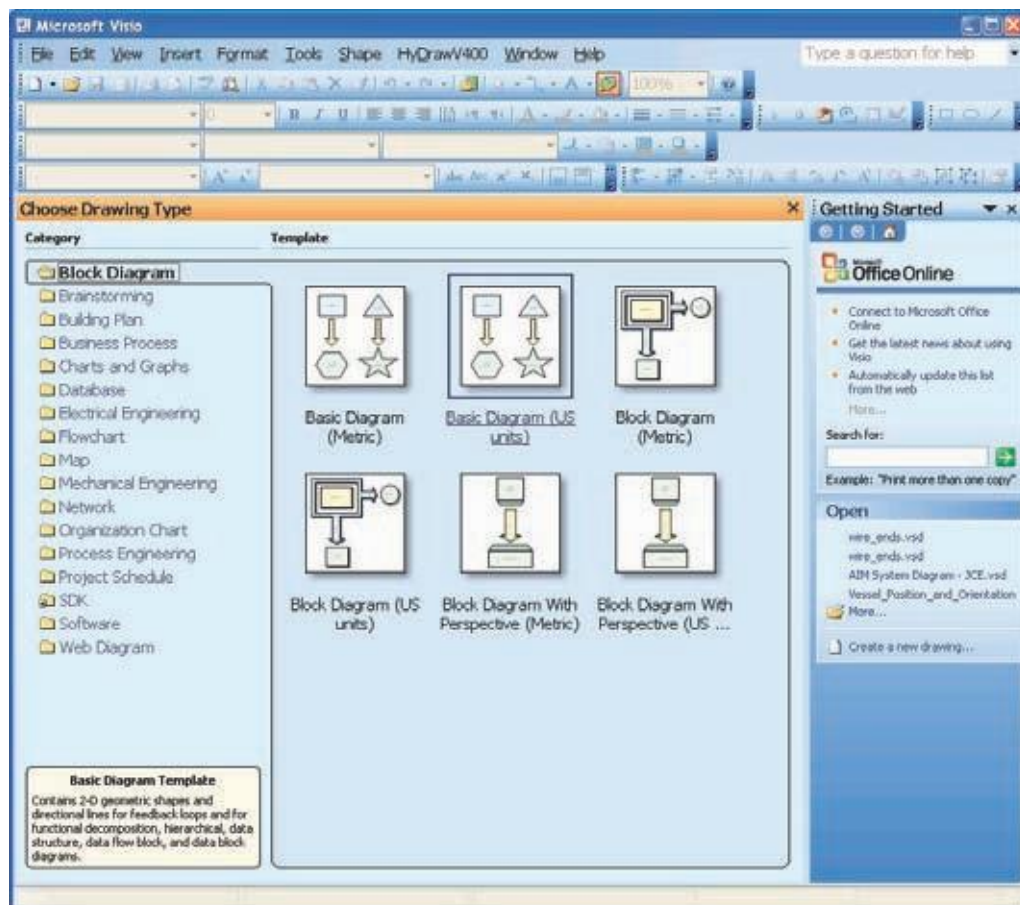
<http://www.microsoft.com/office/visio/prodinfo/trial.msp>.

Is Visio the "Premier Harness Design Tool"? No. But, those programs are very expensive, Visio can do the job.

Visio has a cool metaphor for making diagrams. Remember those ubiquitous green stencils that everyone had in their drafting kits for Tech Drawing 101?



Visio put those stencils into a computer program. Basically, you can choose shapes out of the stencil, drag them onto the page, and maybe even connect them together with lines.



Visio is an “object” based drawing program, rather than a tool or line based program. This means that a shape in Visio contains artwork like lines, files, etc. It also contains parametric information like height, width, and rotation for each shape.

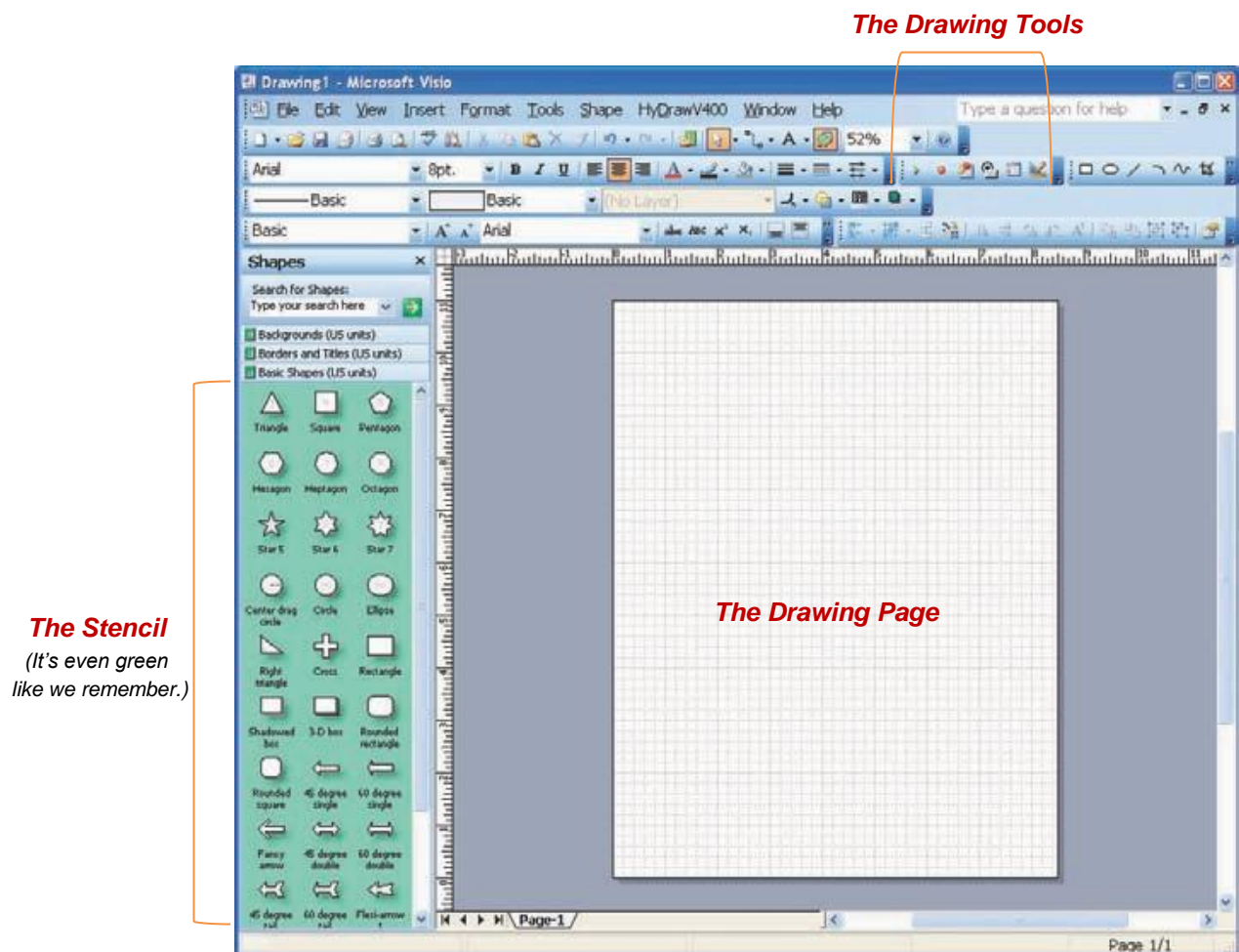
Each shape, has hidden beneath it a “shape sheet” that contains what looks like an excel spreadsheet. The spreadsheet allows you to make the parameters be functions of one another.

For instance, if you want to make a square...you could enter an equation like $\text{Height}=\text{Width}$ for the shapes to obey the rules of a square.

One of the most powerful features of Visio is the ability to connect shapes to wires.

USE THIS FEATURE! Learn how to make Visio connections well and you will be forever revered by your peers.

Let’s take a quick look at Visio. Crack open Visio and create a new blank drawing:



1. Drag our friend the Square on to the page.
2. Drag out another one. (Or control-click and drag the first one to make a copy.)
3. Select File/Shapes/Visio Extras/Connector (US Units).
4. This will add another stencil to the palette on the left.
5. Add a dynamic connector to the page.
6. Pull the ends to the little blue 'x' on the squares. Connect the squares.

Notice how the connector routed itself to look nice. "Nice" might be a stretch depending upon how you thought the wires should have run. Visio tries — but you may need to adjust the routing yourself.

7. Now drag one of the squares to different spots on the page. Notice how the wire stays connected.

You could have created this same drawing by selecting the Rectangle tool, drawn the square, selected the Line tool, and created the wire segments.

However, there is about a 2% chance that you would have discovered the connection point tool and made the wire actually connected to the square rather than just drawn to end at the edge of the box.

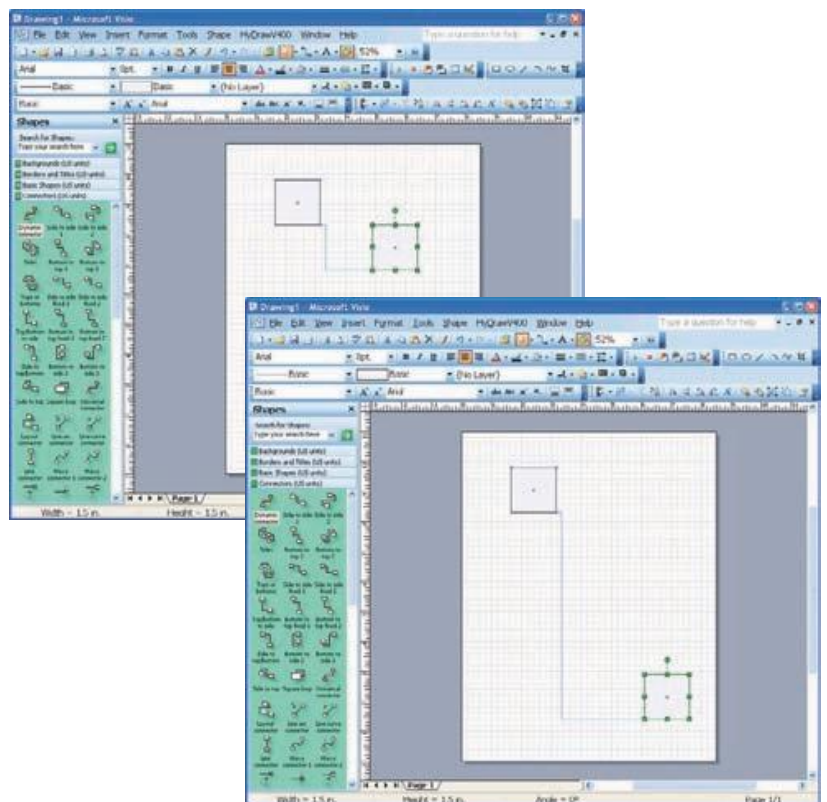
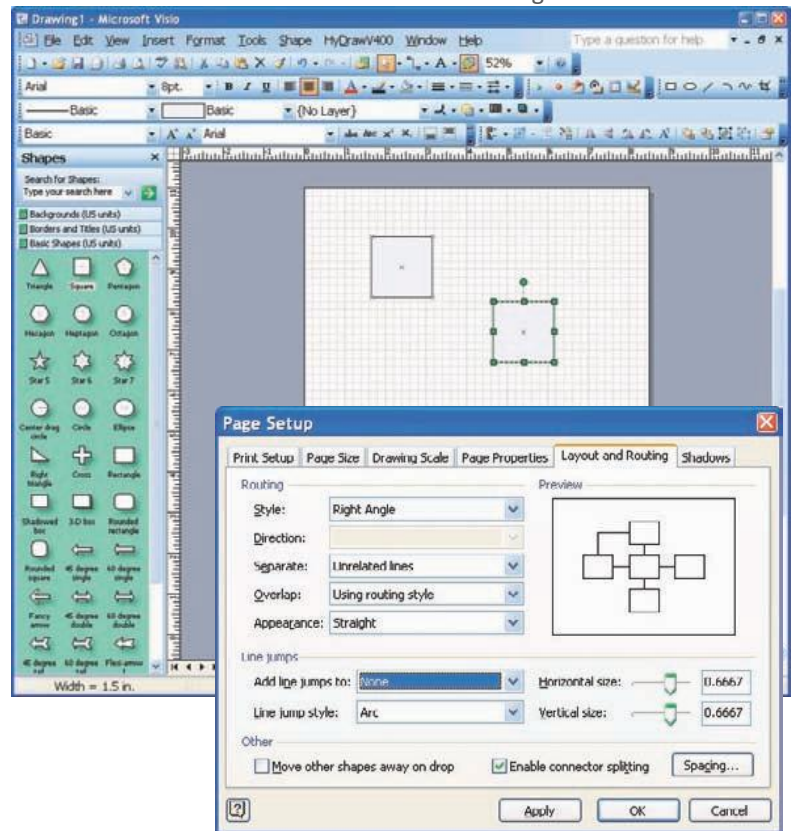
The probability is even lower that you would have made the line somehow reroute itself.

NOTE: Never make a drawing like this where lines and boxes are just drawn in proximity to one another.

Having Visio route wires for you can be a frustrating endeavor. TIP: Go to File/Page Setup/Layout and Routing.

8. Set the "Add Line Jumps to:" setting to "None".

Believe it or not, you are now as skilled as 94% of all Visio users. Plop boxes (or any of the 100's of shapes on the stencils), connect them together, and boom you have a Space Shuttle drawing or a map to your kid's school.



The Shape Sheet

Time for some advanced techniques...

1. Click on one of those squares.
2. Go to Window/Show Shapessheet. It looks like an Excel spreadsheet.

For those of you that don't know, you can actually use equations in cells of Excel and it will calculate the values, it's not just a column based editor.

Tour the cells and notice how some have fixed values while others have equations. Visio actually parses and interprets these cells for each shape on your page every time that it needs to re-render the display.

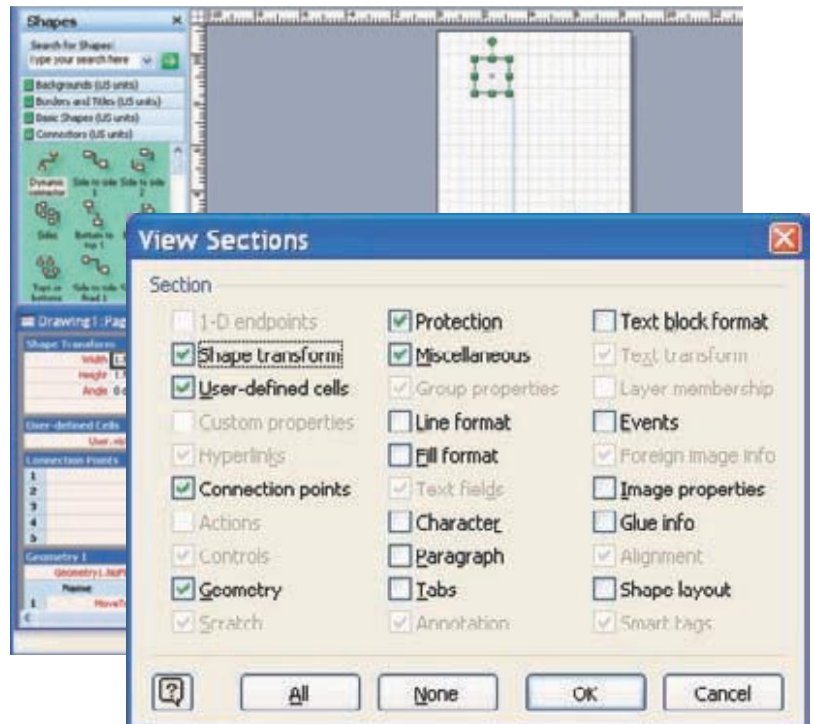
3. Right click in the grey area of the shape sheet and select "View Sections".

There are probably a bunch of sections that are not even displayed.

Or, Right Click/Insert Sections.

If a shape doesn't already have a connections section (which will put the little blue x on the shape) you can add that section here. This will become incredibly useful down the road.

For now, close the shape sheet.



Basic Visio Techniques

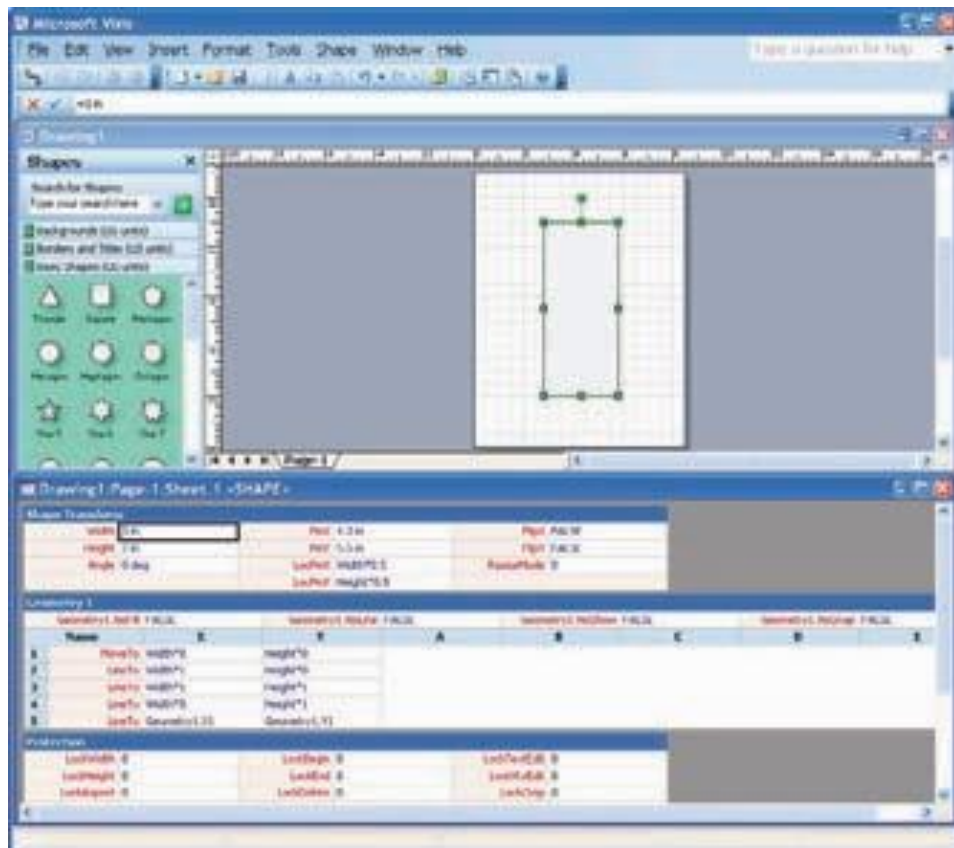
If you learn no other tricks from this class, learn these:

- Plopping and Connecting Shapes in Visio (OK, that was easy.)
- Adding connection points to a shape via the shapesheet
- Creating Line ends that represent connectors

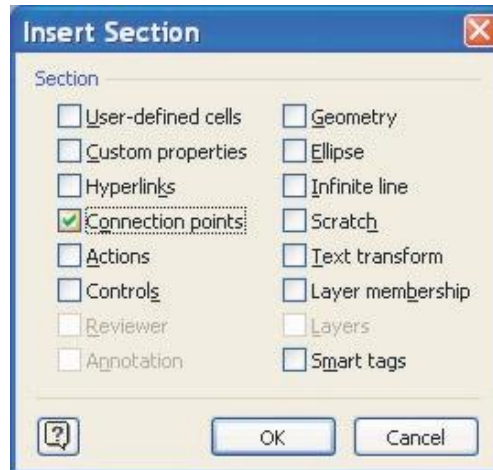
Visio tries to make connections too easy with a “Connect Shapes” tool that will automatically create connection points for you. Unfortunately, these connection points disappear when disconnected.

You can add connection point to shape that will actually be permanent via the shape sheet. Here's how.

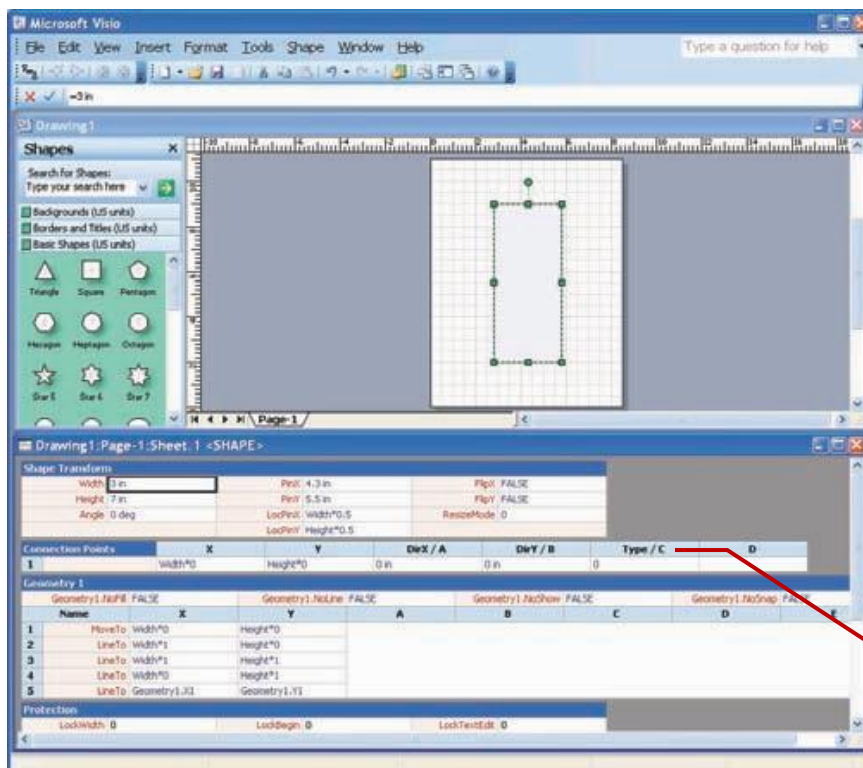
1. Get a shape or create one. For now just create a rectangle. Open the shape sheet for the newly created shape.



- Right click and Insert Section: Select Connection Points and OK.

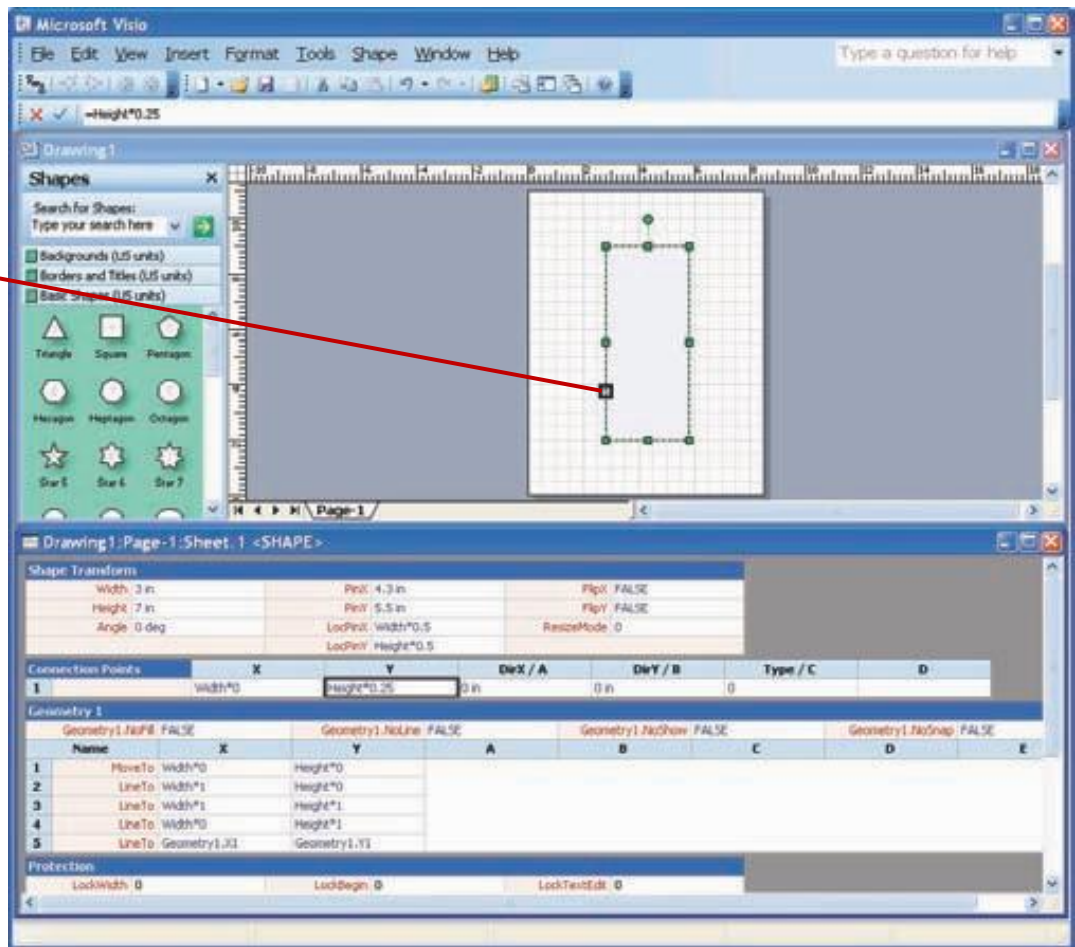


- Change the equation in the Y column to be $\text{Height} * 0.25$. Notice that the connection point is on the left side of the rectangle, 25% up.
- Let's add another point on the other side. Right click the row, "Insert Row After".
- Enter $\text{Width} * 1$ in the X column and Connections. Y1 in the Y column.
- Don't worry about the other columns for now. However, if you are interested, select a cell in any column of the shape sheet and hit F1 to get the help description about the meaning of that column.



Notice the new connection points section

Our
connection
point



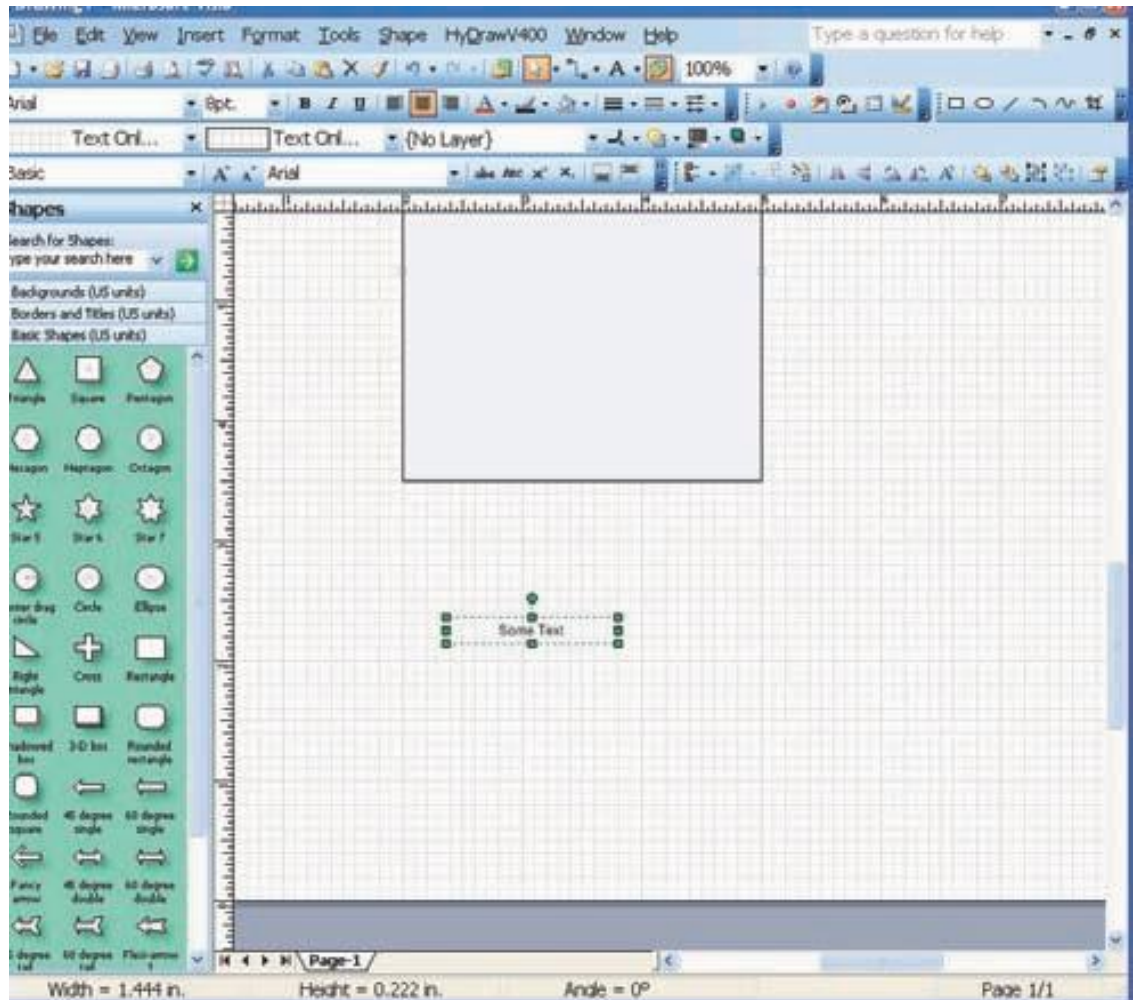
Believe it or not, you are well on your way to a good and proper block diagram. For a 48 pin module, you only need 46 more connection points, for a 128 pin, 126 more.

I need to manually enter all those points?

Never fear, some handy templates are included that has shapes already built with all of the connection points.

Let's build one more handy shape. This time we'll make a label that you can attach to a connection point.

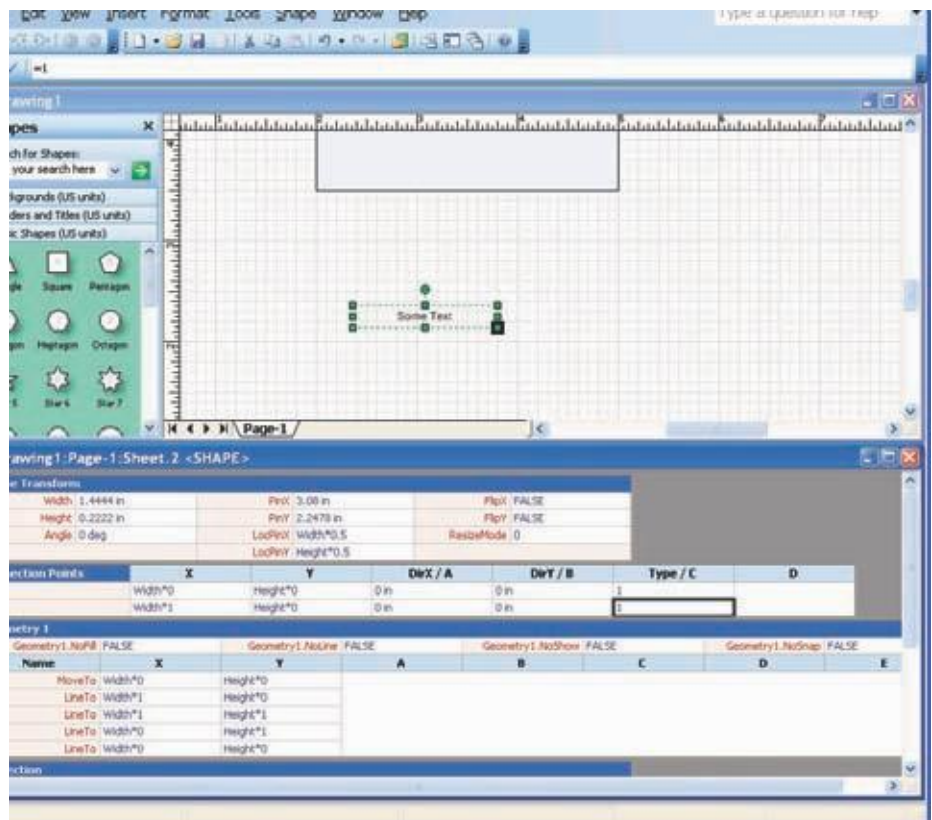
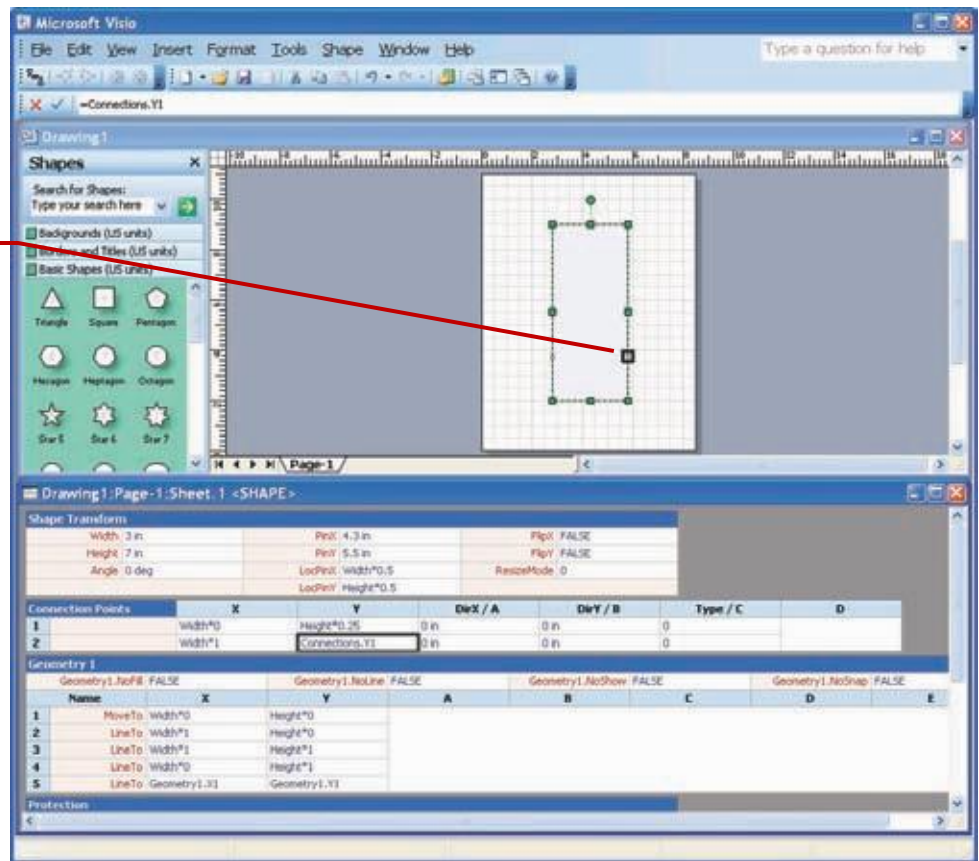
1. Select the text tool (The “A” button). Click anywhere in the page and type some text.



2. Open the shape sheet.
3. Add a pair of connection points on the bottom of each side. But, this time, set the Type to “1” which means an outward connection point.

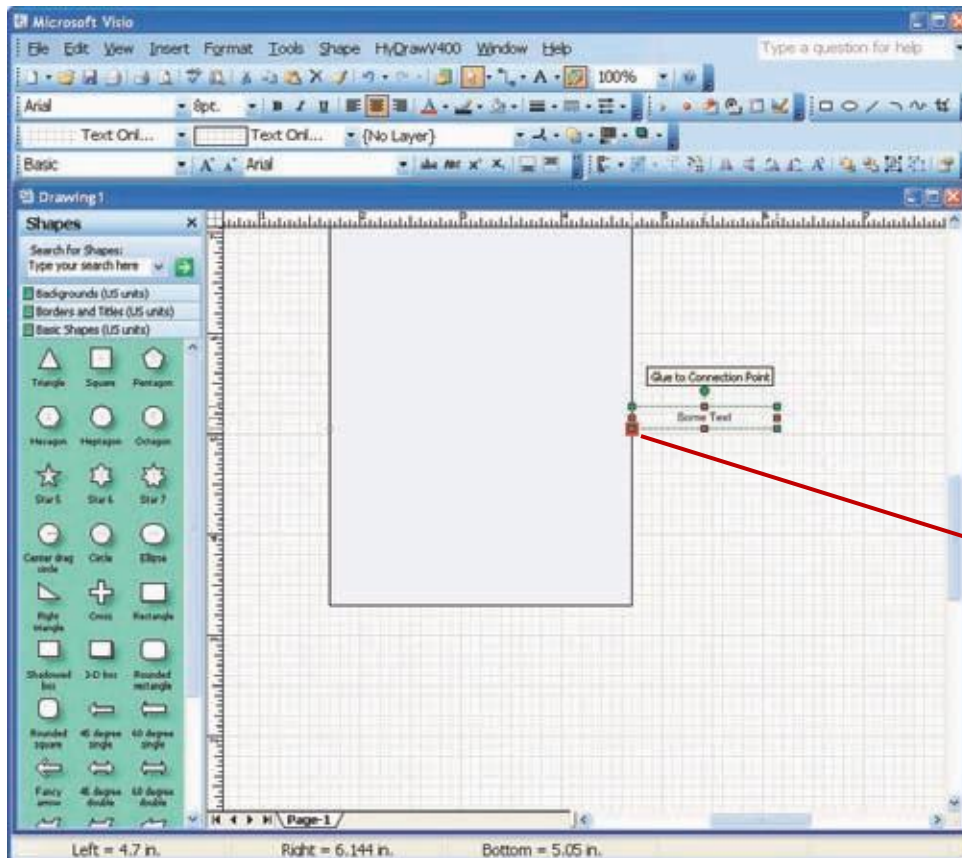
An outward connection point simply allows you to connect to an inward connection point (the little blue X).

Another
connection
point

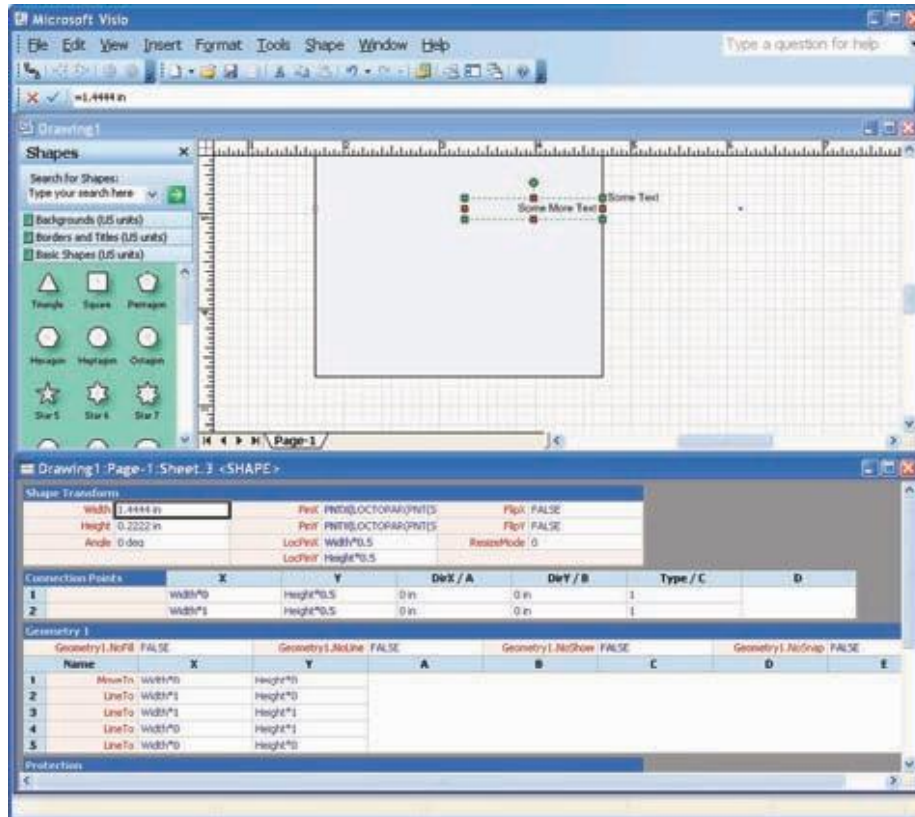


Let's build one more:

1. Create a text label and add the connectors, but this time put the connection points 50% vertically.
2. Now move the shape over to one of your connection points, and if you grabbed it by an end near the connector, you should see the magic red glue indication.

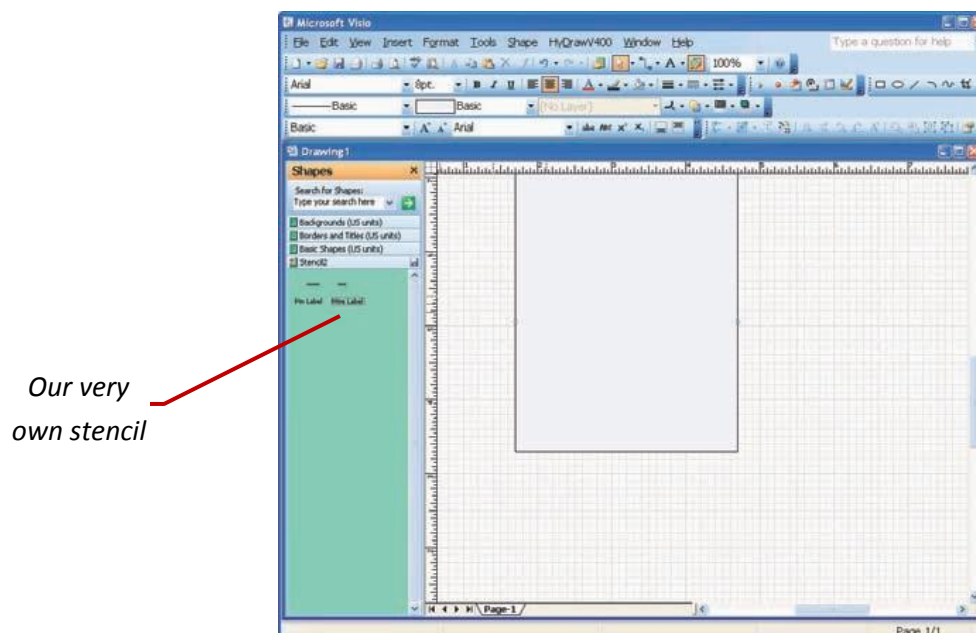


*RED means
it's glued*



Now you have two labels that will keep themselves connected to a point on your block. You can now move the block and all of the labels will move with it.

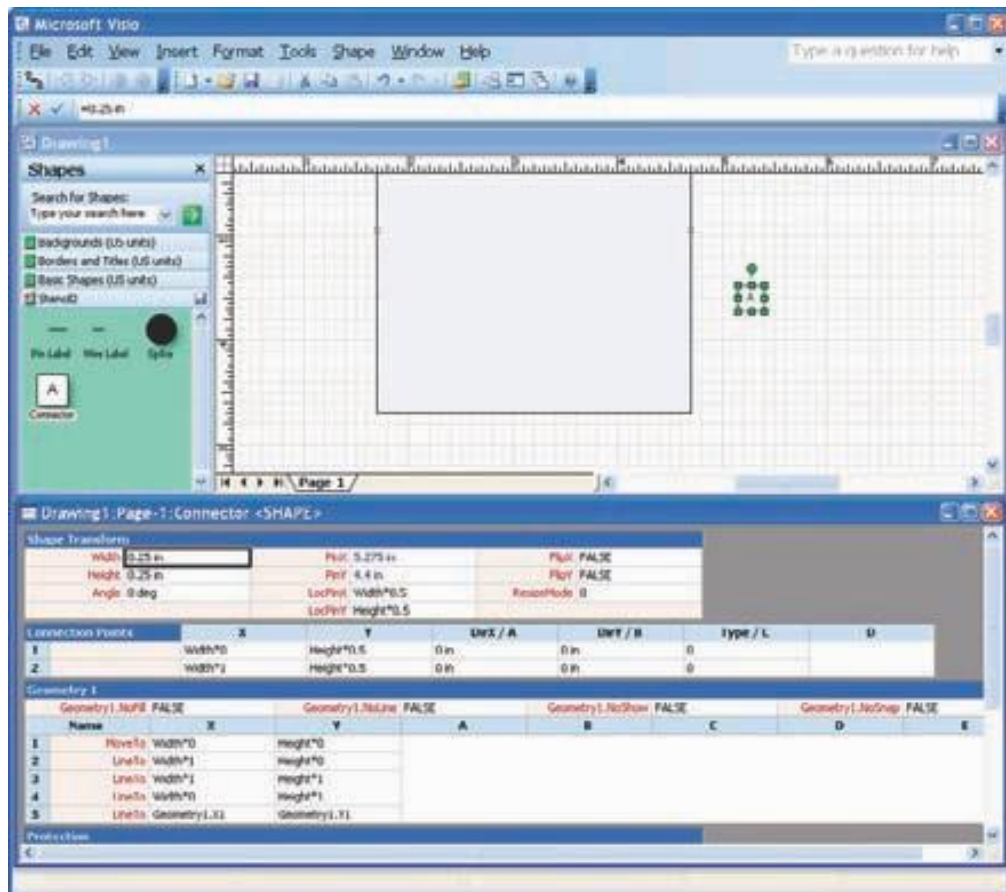
Useful Tip: Create your very own stencil by selecting... *File/Shapes/New Stencil (US Units)*. Pull the two labels that you just created onto that stencil and name them something useful.

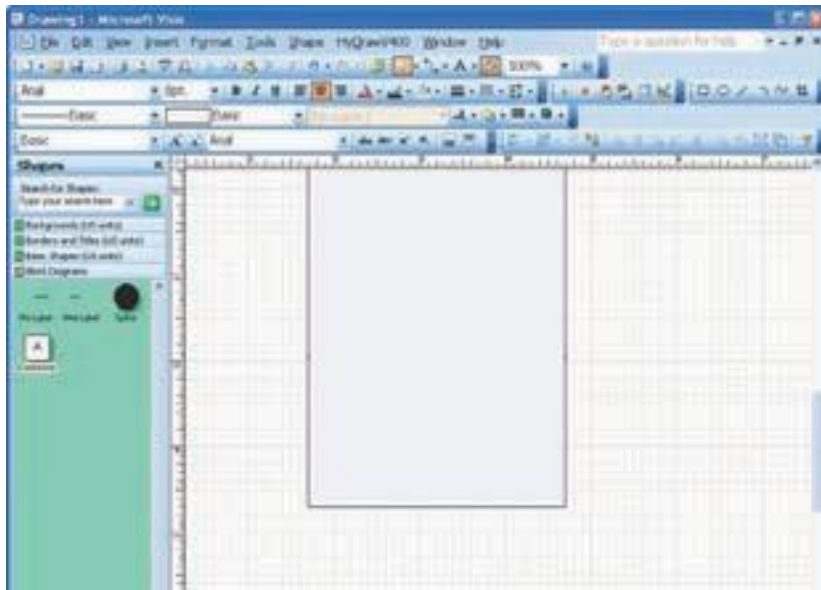


Now you can reuse the shapes in all of your future drawing endeavors.

To help make our lives simpler, create two more shapes:

1. Create a $\frac{1}{4}$ inch square box with connection point on either side at 50% altitude. This will represent a connector pin.

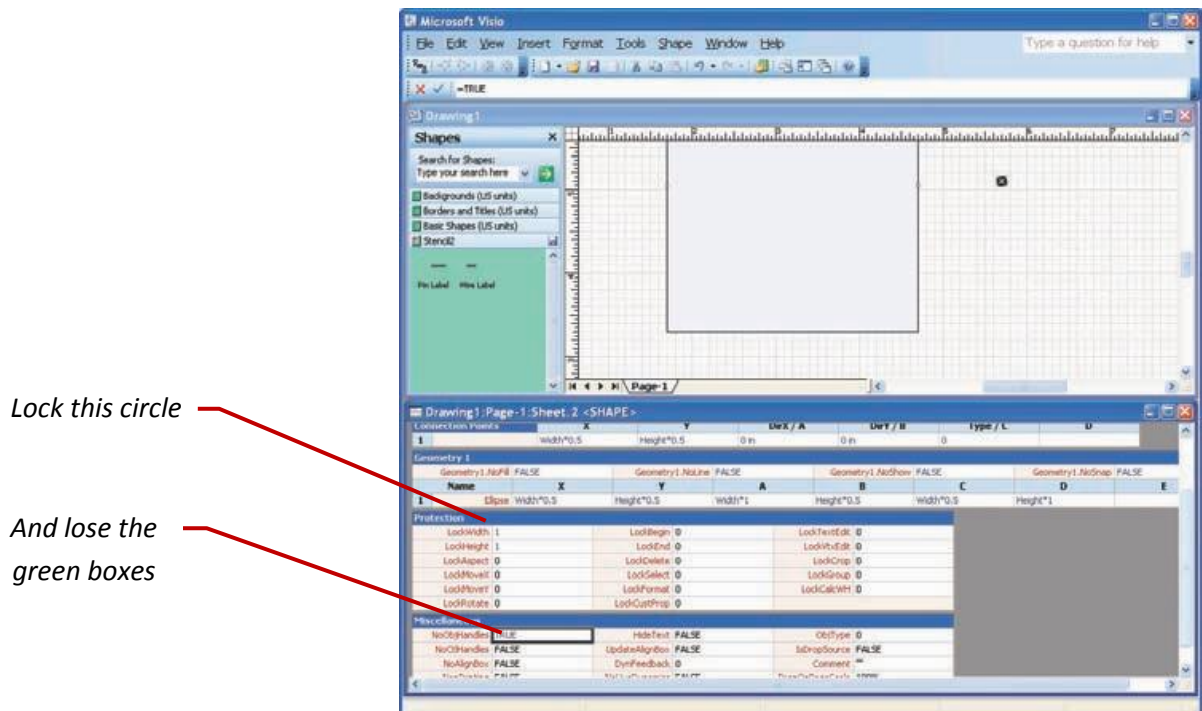




2. Create a black filled 1/8 inch diameter circle with a single connection point in the center.
This will be a splice.

Useful Tip: Find the Protection and Miscellaneous section. Set the LockWidth, LockHeight, and NoObjHandles. This will make the circle size unadjustable and remove the little green adjustment squares.

3. Right click the little green stencil with the red star and save your stencil someplace memorable. If you leave it in the default My Shapes directory, then Visio will always have this stencil on your path and can open it from the menus.



Proper Block Diagrams

A good block diagram shows the sensors, actuators, power, and datalink connections to your controller. A block diagram usually is drawn controller centric meaning that the controller is the center, the sensors are on the left, the actuators are on the right, power is in the top left, ground is on the bottom right, and serial links are on the bottom left.

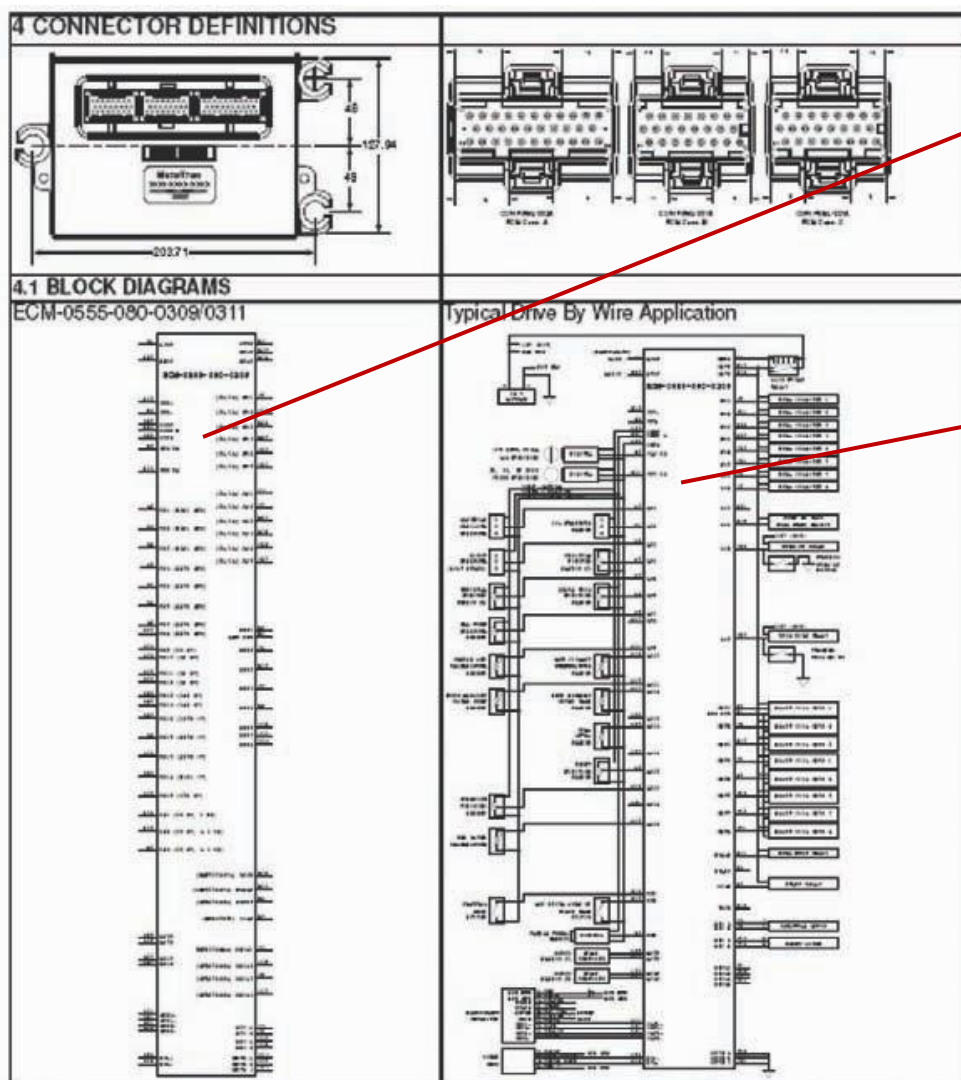
- This drawing is the single most useful drawing for your MotoHawk developer to set up his IO.

Where to start? Get your handy module data sheet. Look near the end, there should be a very empty block diagram showing the module, its pins, and the standard harness that ships with each kit. The key to a good block diagram is to show as much information that you possibly can. Connectors, wire numbers, colors, etc.

The more, the better. If push comes to shove, this may be the only drawing that you get done but it MUST be done. Otherwise, you just can't get your job done.

- See aim-interconnect-1.vsd in your examples directory of a fairly significant block diagram.

Notice in this example, the splices are shown with a different symbol and an associated splice number. Feel free to be this fancy if you like.



An example
block diagram

The blank
block diagram

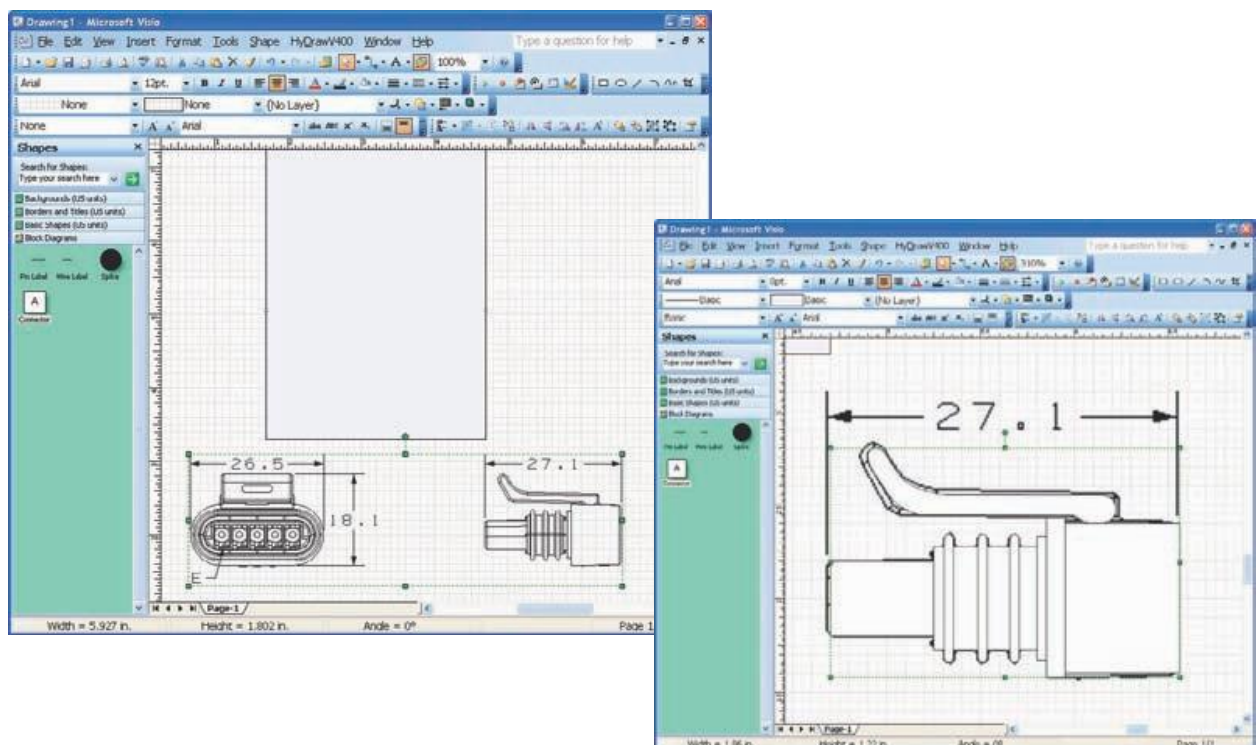
Layout Drawings

Layout drawings show the physical properties of your harness like lengths, locations of branches, and type of over-braiding. The point of the layout drawing is to convey what the harness should look like rather than its electrical connectivity. Of course, Visio is our weapon of choice so let's get ourselves squared away:

Visio Line Ends

The key to a good layout drawing is showing proper connectors depictions at the end. The more your drawing looks like the finished product the better. Here are steps to making this easy in Visio:

1. Get an image of you connector. This should either be available on the wiki, or contact New Eagle and we can obtain it.
2. Select Insert/Picture/From File.
3. Grab the line drawing from your data directory for the Metripack connector (LD12162825.gif). Unfortunately, Visio will not let you use images for line ends. And, Visio won't trace an image for you so you are stuck tracing it yourself.
4. Start drawing over the shape to create a rendition of the connector. Once you have all of the little details, group the shape with the Shape/Grouping/Group command.
5. Crack open the shapesheet. We need to get the dimension accurate. Since they only gave us the overall length, we'll need some shape sheet magic to keep the aspect ratio correct. Look at the width and height cells and not the current values.



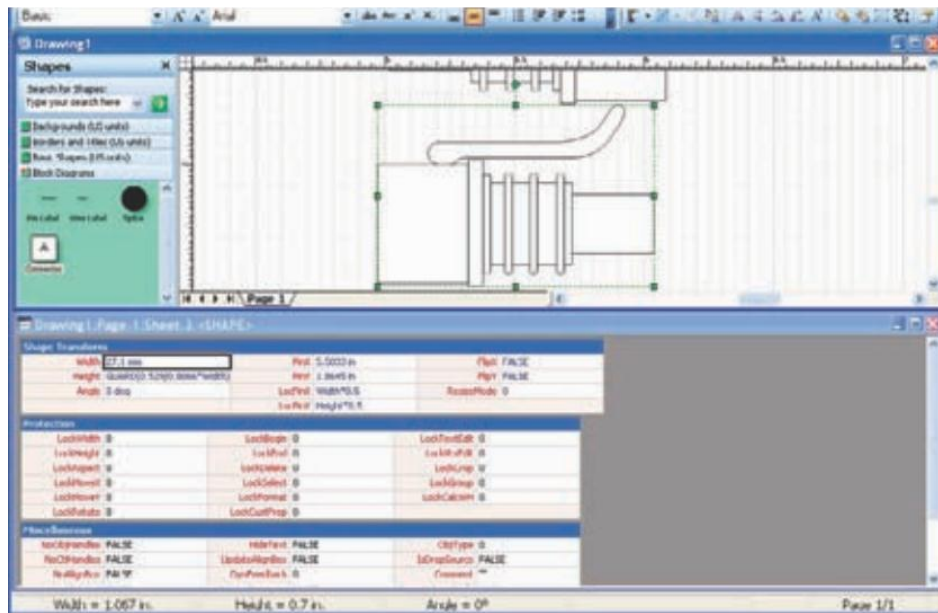
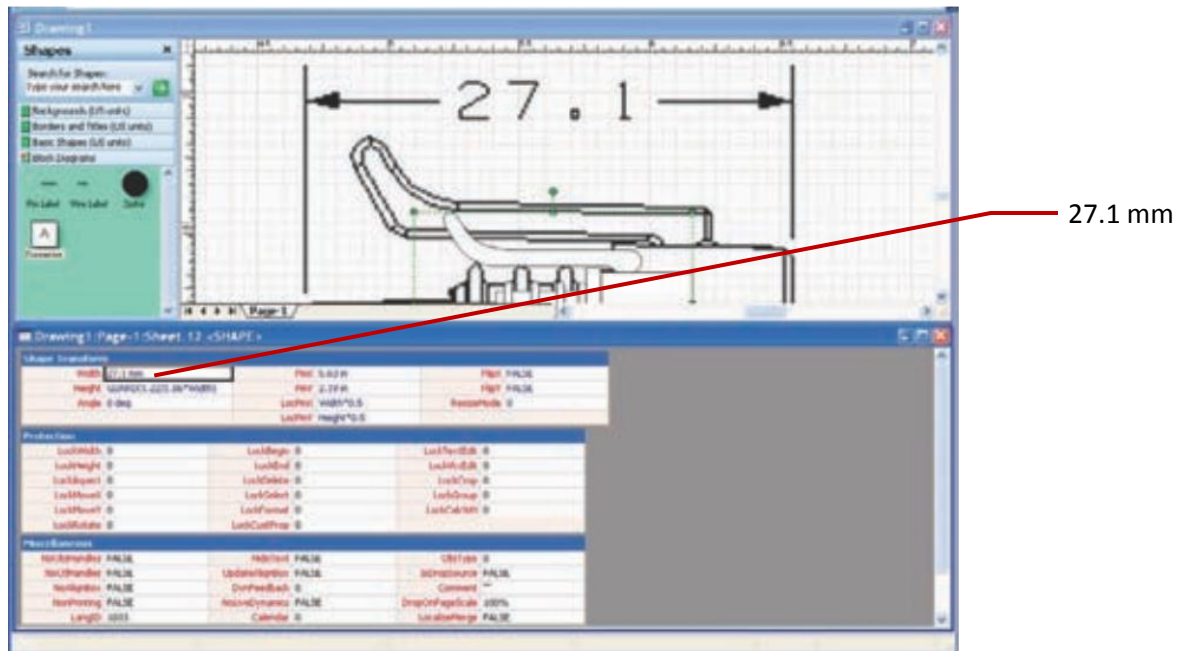
- Then we can enter the proper dimension shown in their drawing for the width. Note you can use a unit suffix and let Visio do the conversion for you.

- Select your shape. Edit/Copy, Edit/Paste Special/ Picture (Enhanced Metafile), Shape/Rotate or Flip/ Flip Horizontal, Shape/Grouping/Ungroup which will convert it back to a shape.

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- The screenshot displays the AutoCAD software interface. The top window is titled 'Drawing1'. On the left, the 'Properties' palette is open, showing the 'SHAPE' properties for the selected object. The 'SHAPE' section is highlighted, and a red arrow points from this section to the drawing area. The drawing area shows a cross-section of a mechanical part with a curved top and vertical supports. The 'Properties' palette also shows the 'Transform' and 'Section' sections, with various properties like Width, Height, Angle, LockWidth, LockHeight, LockAspect, LockMoveX, LockMoveY, LockRotate, LockBegin, LockEnd, LockDelete, LockSelect, LockFormat, LockCustomProp, LockTextEdit, LockVtxEdit, LockCrop, LockGroup, and LockCalcVtx. The 'Section' section is also visible, showing properties like LockWidth, LockHeight, LockAspect, LockMoveX, LockMoveY, LockRotate, LockBegin, LockEnd, LockDelete, LockSelect, LockFormat, LockCustomProp, LockTextEdit, LockVtxEdit, LockCrop, LockGroup, and LockCalcVtx.

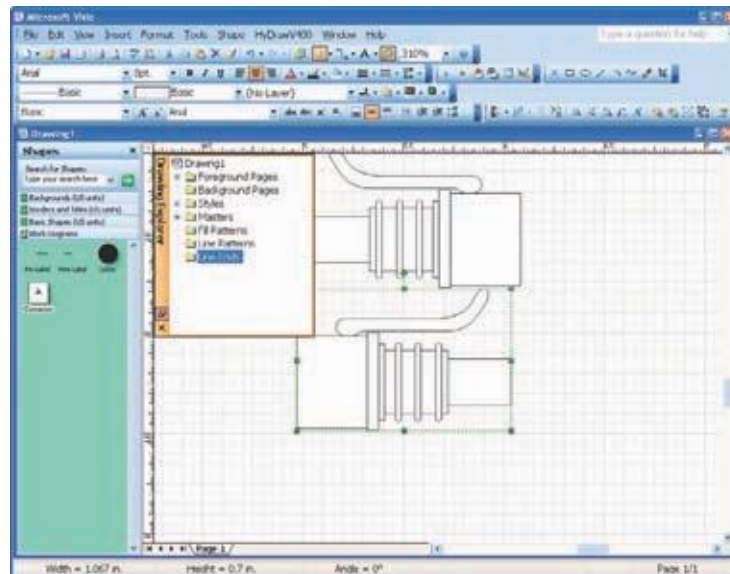


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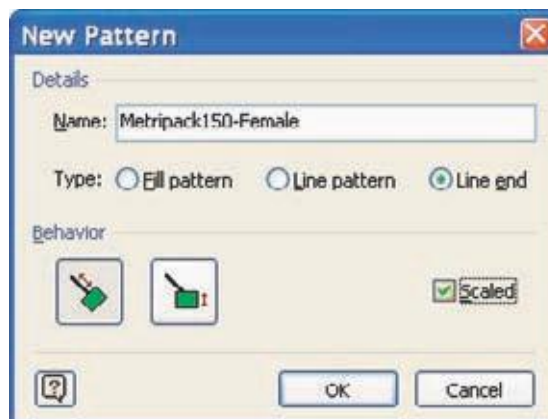


Now its time to make a line end.

1. Select View/Drawing Explorer Window.
2. Right click on the Line Ends folder.

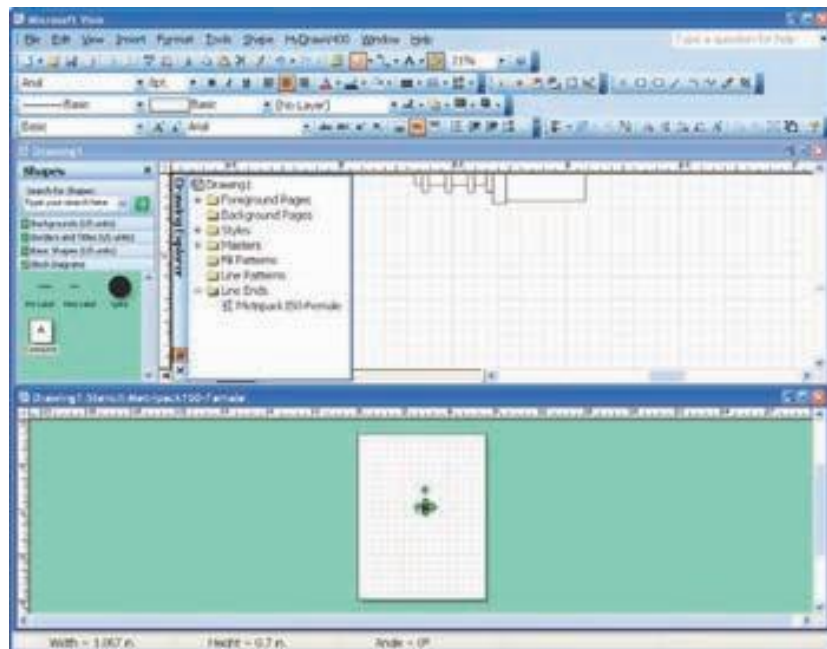


3. Choose New Pattern.

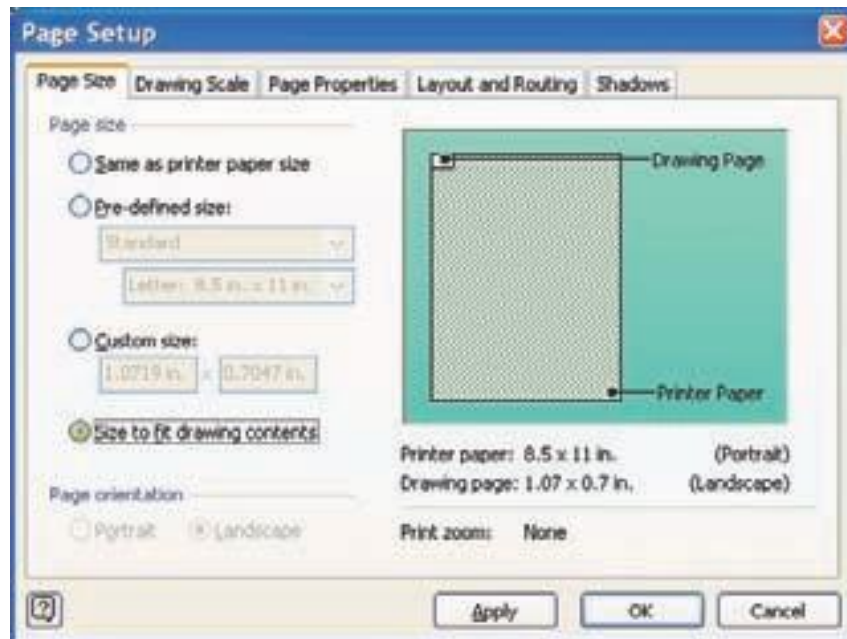


Give the line end a useful name, choose the behavior box on the left, and select the scaled checkbox.

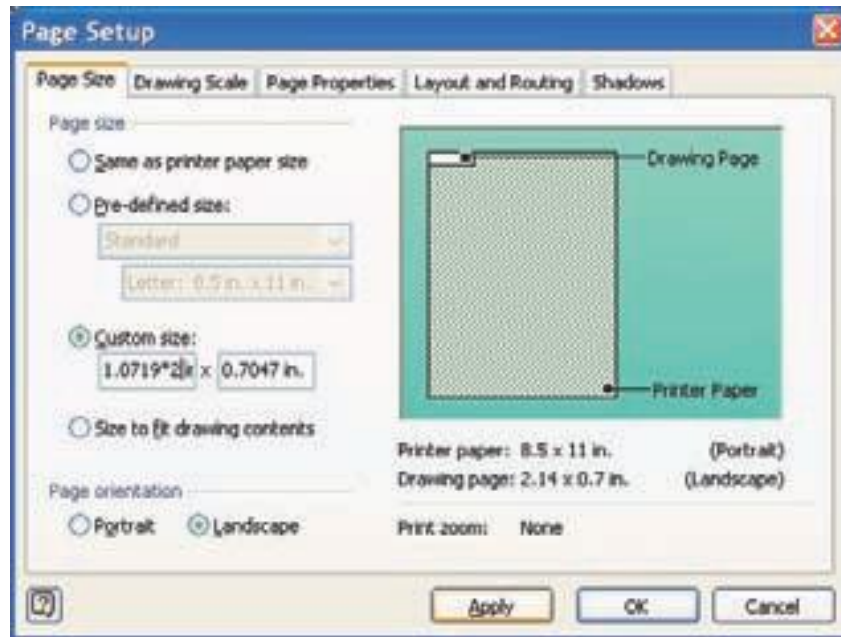
4. Right click on the new pattern Edit Patten Shape. Pull your right hand facing connector onto that new page.



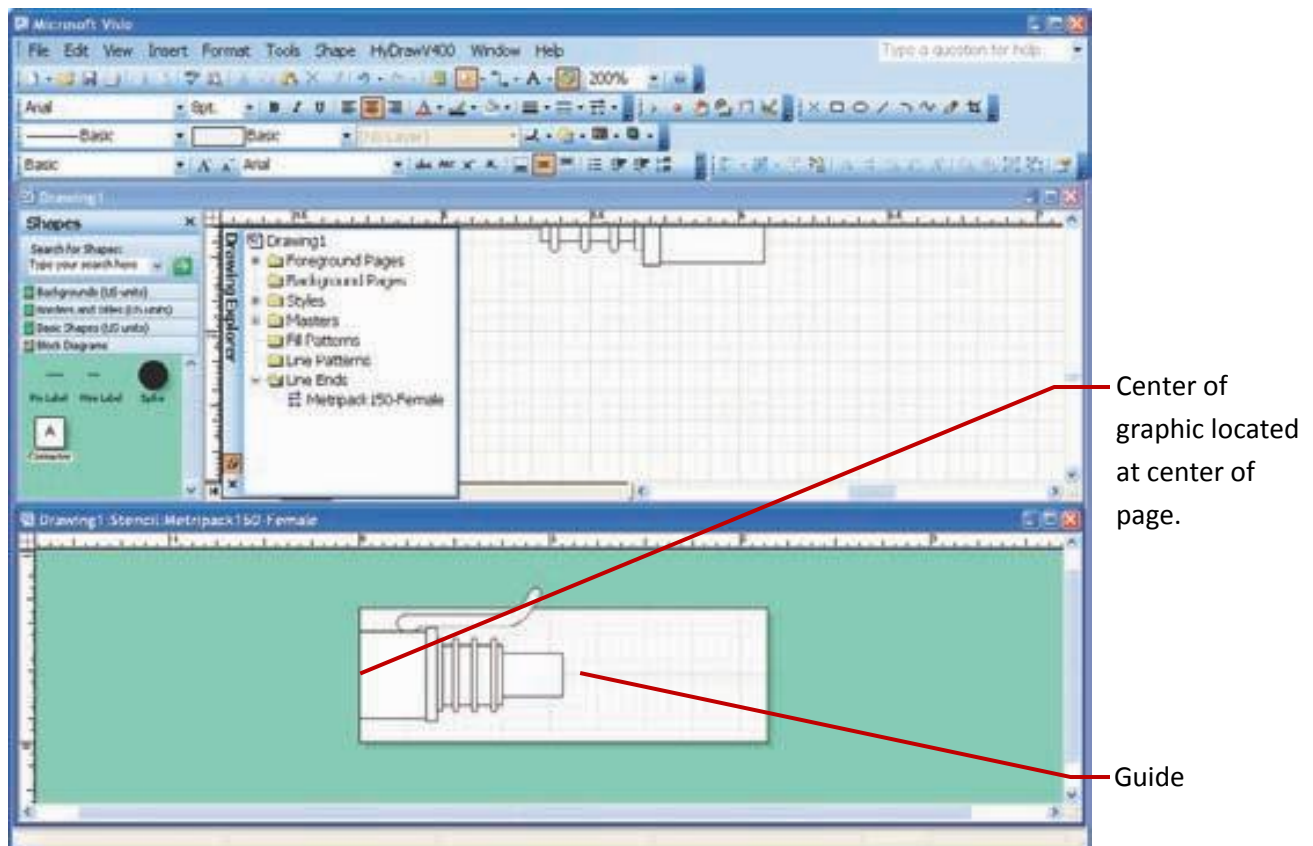
5. Go to File/Page Setup/Page Size and select the “Size to fit drawing contents” radio button.



- Next, select the Custom size radio button, and add *2 to the left number.



Chances are, your connector is way off the page somewhere. Zoom out, find it, and move it down to your very small page.

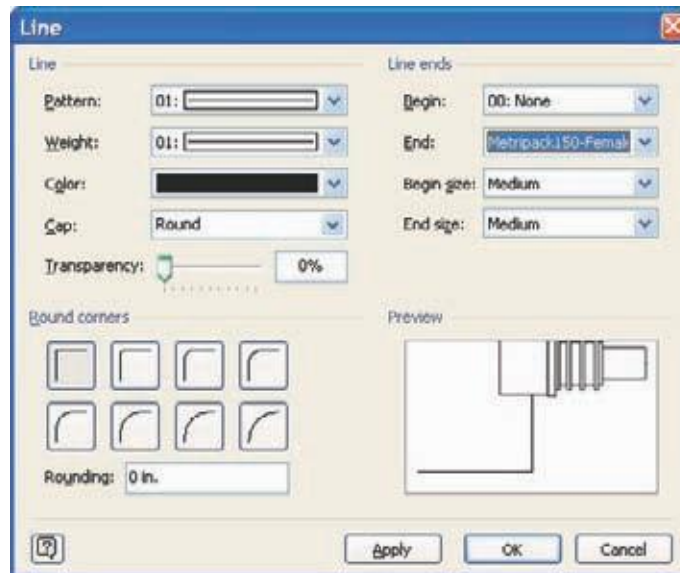


Why did we make the page twice the size of the connector?

Visio will put the actual end of the wire at the midpoint of the line end's page. This way, the end of the wire will be exactly at the end of our graphic. And, the wire will enter the line end at the 50% altitude of the line end page.

We need to move our graphic up so that the wire is centered in the graphic at the midpoint. (The blue line is just a guide to show where the mid height point is. You can get a guide by simply clicking on the ruler above and pulling a guide onto the page.)

1. Close the line end by clicking the Red
2. Now, create a line on your page and see if we can get the line end on it.
3. Select the line tool, draw a line, and then Format/Line.



4. Select the end style of either end to be the line end that you just created.

We have built several common line ends and patterns for you, so have a look at wire_ends.vsd for some common connectors that we use.

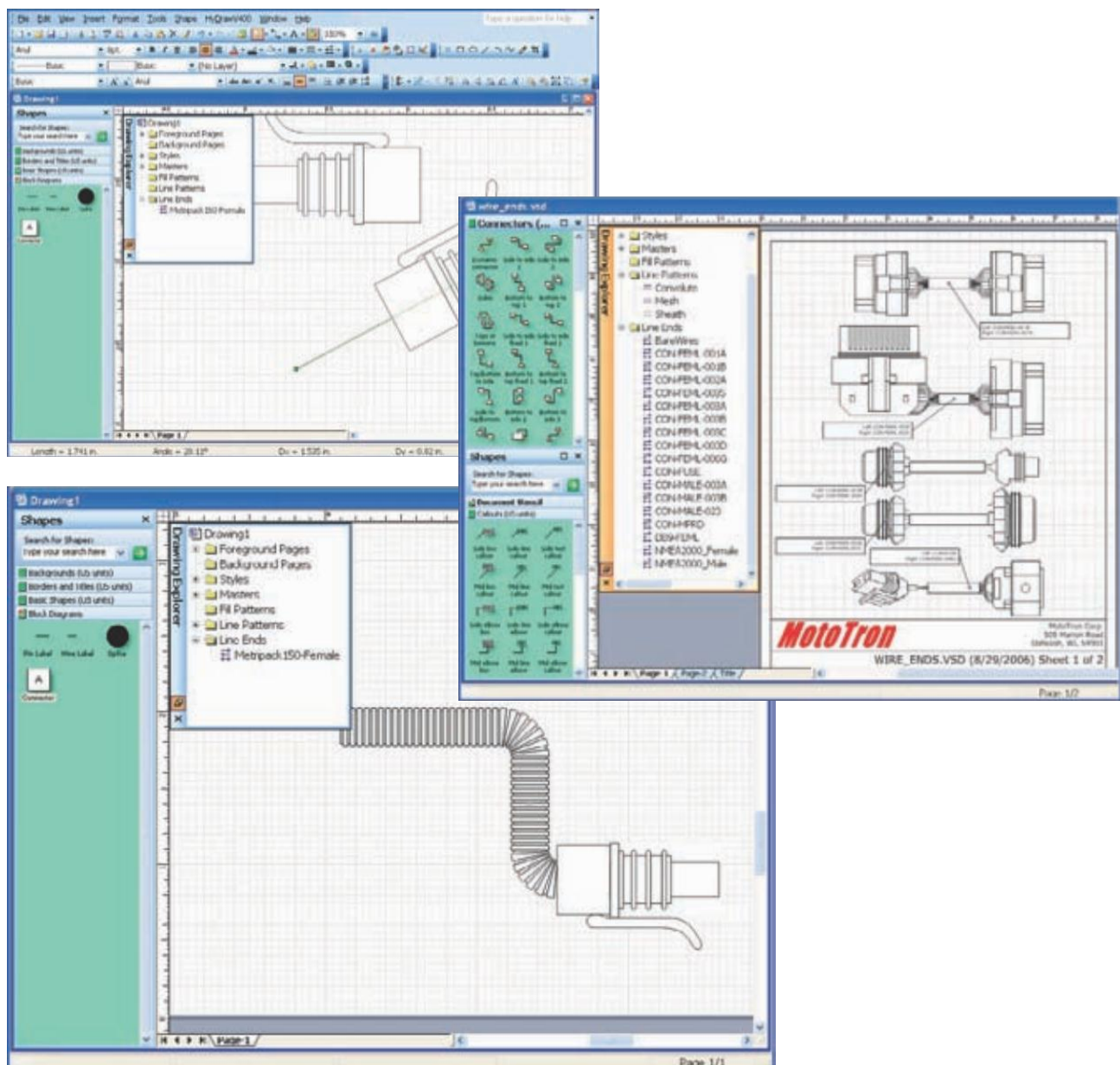
Perfect. You just made a nice looking line with an end that looks like the real thing. Note that there are some Line Patterns in that drawing that will show your harnesses with the proper overbraiding.

Visio doesn't make it easy to put line ends and line patterns into a stencil. However, if you pull a wire with the correct ends from another drawing, Visio will automatically add those new ends and patterns to your new drawing.

Always keep a master drawing of all of your connectors and line ends and pull from that into your local drawings.

When drawing multi-segment wires, use the corner rounding feature to get nice looking corners.

If nothing else, your friends will be amazed at how long it must have taken to draw those bends in the convolute.



Layout Drawings

The key to a good layout drawing is getting the dimensions correct.

Some harness shops like to measure relative to the pin of the connector and some like to measure to the end of the connector. Pick your poison.

Whatever you do, adjust the line ends so that Visio's end of the wire lines up with the reference point that you choose. This way, you can make use of Visio's built in dimensioning capabilities to help make your drawing.

Point to Point Drawings

Point-to-point drawings are simply harness centric views. The controller and devices are usually left out of the picture and only the connectors of the harness and the wires between connectors are shown.

Stencil: Point-To-Point.vss This has the "proper" shapes that you will need.

Bill of Materials
Double-Click to refresh.

| Item | Connector Name | Manufacturer Part# | Vendor | Vendor Part# | Qty | Ter |
|------|----------------|--------------------|--------|--------------|-----|-----|
| 1 | 9002 300 A | CONTROLLOC | TYCO | 6-LESTER7-6 | 1 | |
| 2 | 9002 300 B | CONTROLLOC | TYCO | 6-LESTER7-6 | 1 | |
| 3 | 9002 300 C | CONTROLLOC | TYCO | 6-LESTER7-6 | 1 | |

Notice how this drawing contains the layout and point-to-point. This drawing is incredibly useful as you can see the physical layout and the schematic in one place. ALWAYS HAVE THIS DRAWING UP TO DATE AND AVAILABLE FOR TROUBLESHOOTING!!

This is the view that a harness builder will want so that he can check the connectivity between the pins. This diagram needs to call out all of the wire parameters except for length. The layout diagram shows the length. Wire numbers, wire type, wire color, wire size, and actual splices need to be shown, along with all of details of a connector including pins, seals, locks, blanks, etc.

Harness Diagrams Made Easier

Of course, you shouldn't plan on creating drawings by hand. On your CD is a drawing, PCM80_ReprogrammingCable.vsd, that has some nice macros in it to automatically generate the net list

The screenshot displays a Microsoft Visio window titled "PCM80_ReprogrammingCable.vsd". The main drawing area shows a harness diagram with two ECUs, "ECU A" and "ECU B", connected to a "SMARTCRAFT" connector. Wires are labeled with IDs like W0001 through W0007. The "SMARTCRAFT" connector is a multi-pin connector with pins labeled A through K. Each pin has a corresponding wire label: A (18AWG, TXL, RED), B (18AWG, TXL, BLACK), C (18AWG, TXL, ORANGE), D (18AWG, TXL, GREEN), E (18AWG, TXL, YELLOW/BLACK), F (18AWG, TXL, PURPLE), G (18AWG, TXL, YELLOW), H (18AWG, TXL, BROWN), I (18AWG, TXL, WHITE), J (18AWG, TXL, BLUE), and K (18AWG, TXL, BLUE). The diagram also shows other components like "ECU A", "ECU B", "CAN1+", "CAN1-", "CAN2+", "CAN2-", "XDRIG", "ESTOP", and "BATT".

A red arrow points from the "Connector" label to the "SMARTCRAFT" connector. Another red arrow points from the "Pins" label to the "Pins" section of the "Custom Properties" dialog box. The "Custom Properties" dialog box is open, showing fields for various connector details:

- Connector Name: SMARTCRAFT
- MotoTron Part Number: CONFEML003G
- Vendor: PACKARD ELECTRIC
- Vendor Part Number: 15326842
- Terminal Quantity: 5
- Terminal Part Number: 12160223
- Seals Quantity: 5
- Seal Part Number: 15366021
- Plug Quantity: 5
- Plug Part Number: 15305171
- Lock Quantity: 1
- Lock Part Number: CONLOCK008
- Cover Quantity: 0
- Cover Part Number:
- Strain Relief Quantity: 0
- Strain Relief Part Number:

The "Prompt" section at the bottom of the dialog box shows "Connector Name".

Connector
Double-Click to record the BOM details.

Pins
To build a connector, glue the center point of a pin to the connector's line.

Splices

Splices within the point-to-point diagram need a bit more definition than just a simple dot that all of the wires hook to. Think about a physical splice — sometimes all of the wires come from one direction and you simply solder them together. However, most splices have wires coming and going from two different sides.

You will notice that the splice shape has an A and B side. Typically, you would think of the A side meaning the left side of the splice and the B side as the right.

You would then show on your point-to-point diagram which side of the splice that you want the wire to approach from.

Basically, you want to think about what will make the wire lay nice in the harness and avoid turning the wire 180 degrees after the splice. This puts stress on the splice and will break it.

That's it! The design is ready to be built. Get your crimpers greased up!

