

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:

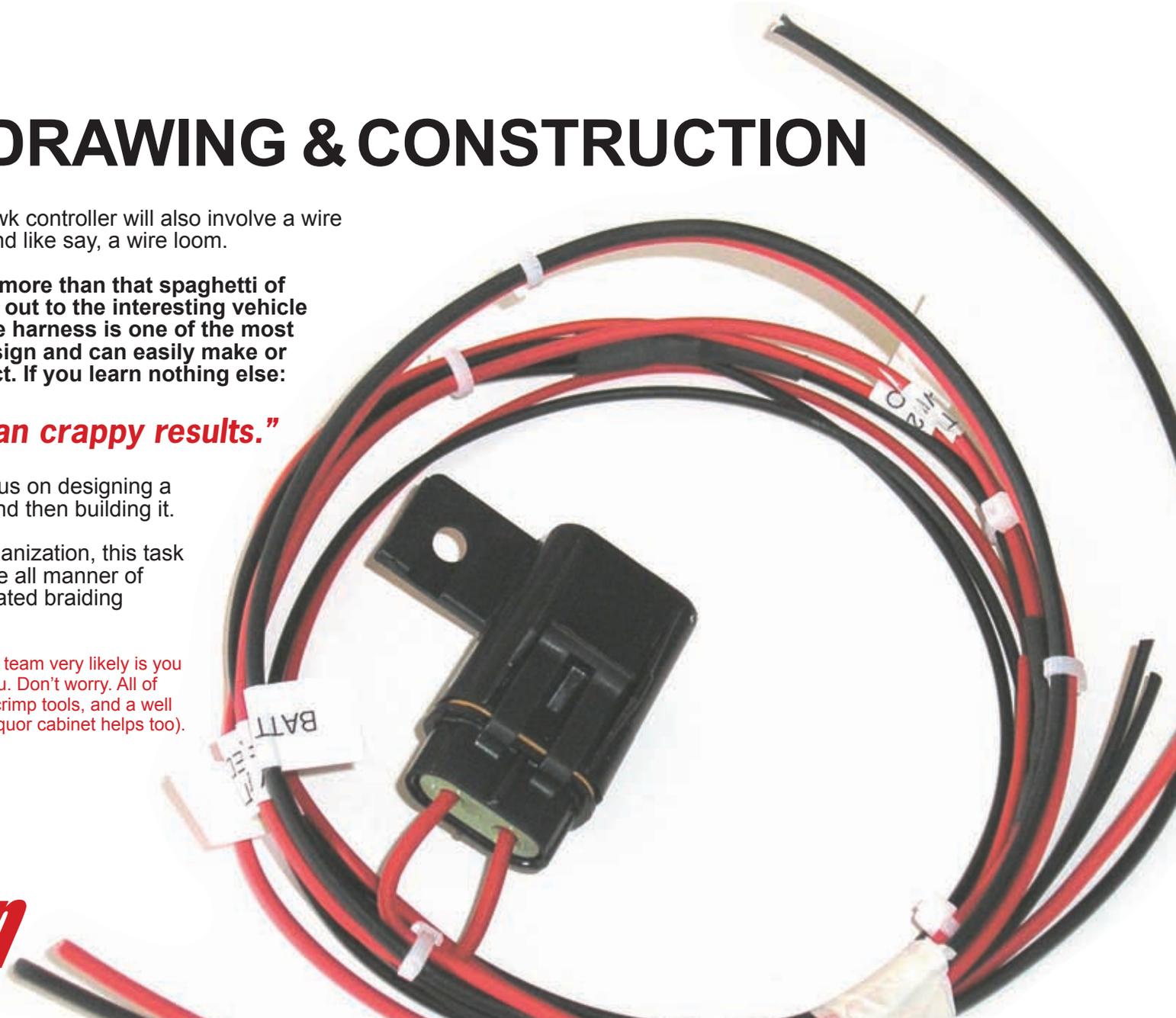
“Crappy harnesses mean crappy results.”

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.

Too bad if you work for MotoTron where the team very likely is you and the guy in the mirror looking back at you. Don't worry. All of this is do-able with Visio, a couple of good crimp tools, and a well stocked connector drawer (a well stocked liquor cabinet helps too).

MotoTron



The Basic Steps...

- 1 Gather up all of the sensor and actuator datasheets you can find.** If the datasheet doesn't show the physical connector, call the manufacturer and request a drawing. Get a connector description along with an appropriate mating connector and manufacturer.

The manufacturers will be companies like Deutsch, Packard (PED), Delphi, Amp, Tyco, Sumitomo, etc.

- 2 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.

- 3 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.

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

- 5 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.

Sensor and Actuator Datasheets

Of course it can't be easy, but every sensor or actuator with a built in connector should have a drawing or manual that describes the appropriate mating connector to be used.

This drawing tells you some interesting information like...

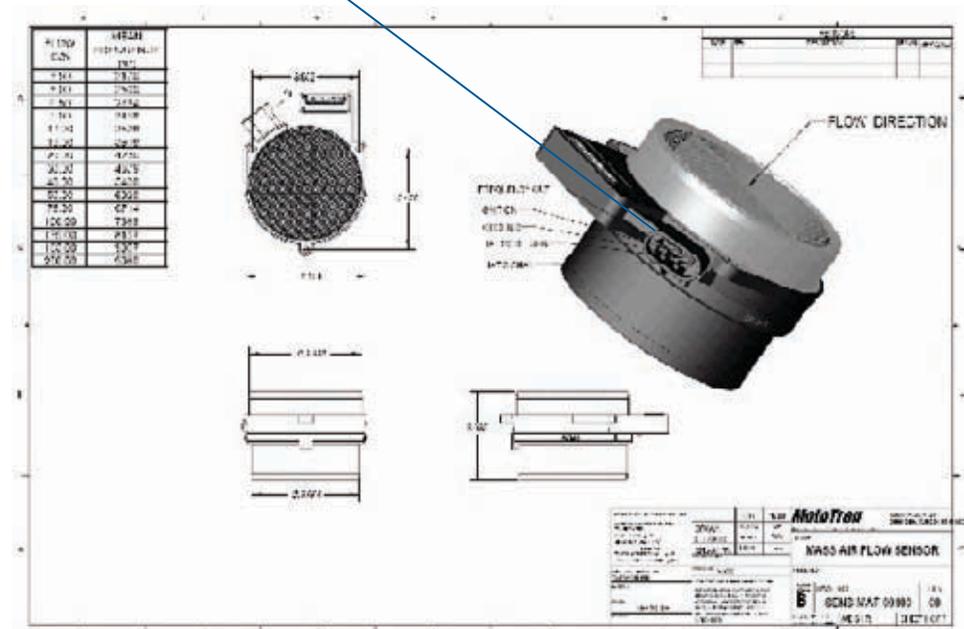
- ___ how to convert the frequency to airflow,
- ___ how big the diameter is,
- ___ and even the mounting hole locations.

But, guess what, not one mention of the appropriate mating connector.

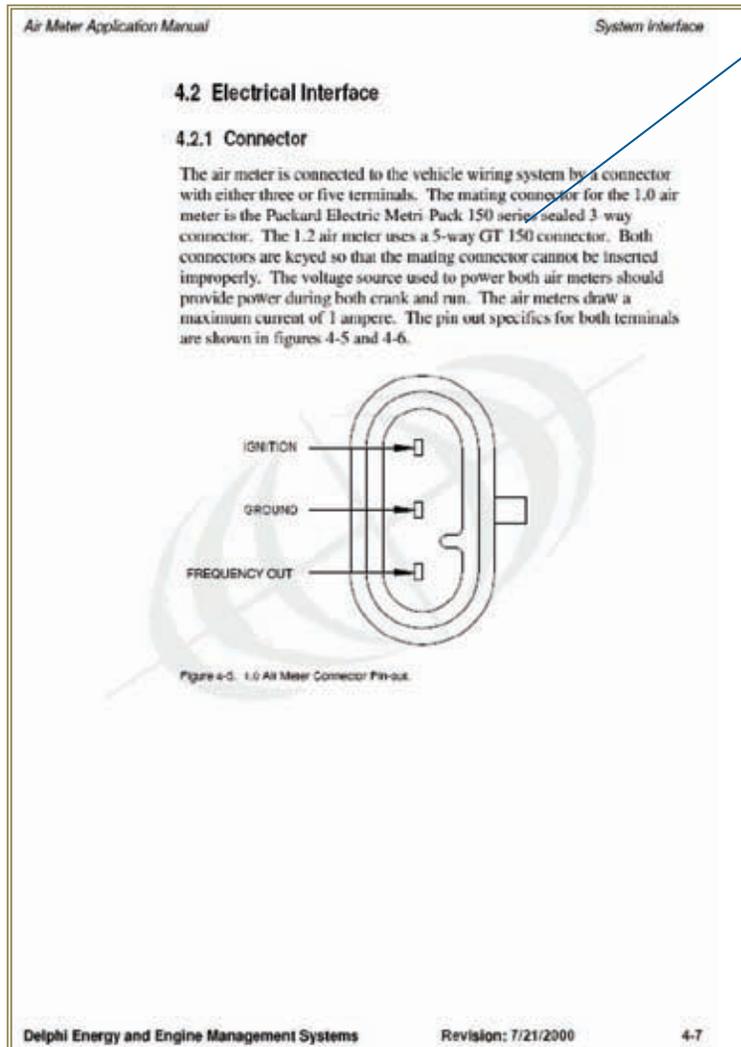
So we can bolt it into the engine but can't for the life of us hook up any wires.

Never fear, conveniently located on page 4-7 of the manual, they gives us a hint:

What the heck is this connector?



Example 1: Mass Air Flow Sensor



Aha. How come that's not on the drawing?

Great. One connector down, 400 to go! Hang on though. I better figure out what a Packard Electric GT150 is.

Hmmm.... I know, www.powerandsignal.com is a good bet.

Power and Signal distributes all of the "GM" based connection systems: Packard and Delphi.

Search on GT150 under the keyword option. DRAT! "No Results to Display".

Try Product Lines / Connection Systems / GT Connection Systems / (150 Catalog) or <http://www.powerandsignal.com/docs/Catalog/gt150.pdf>.

Alright, this should be easy, let me just go to the page that says "5-way GT150 connector."

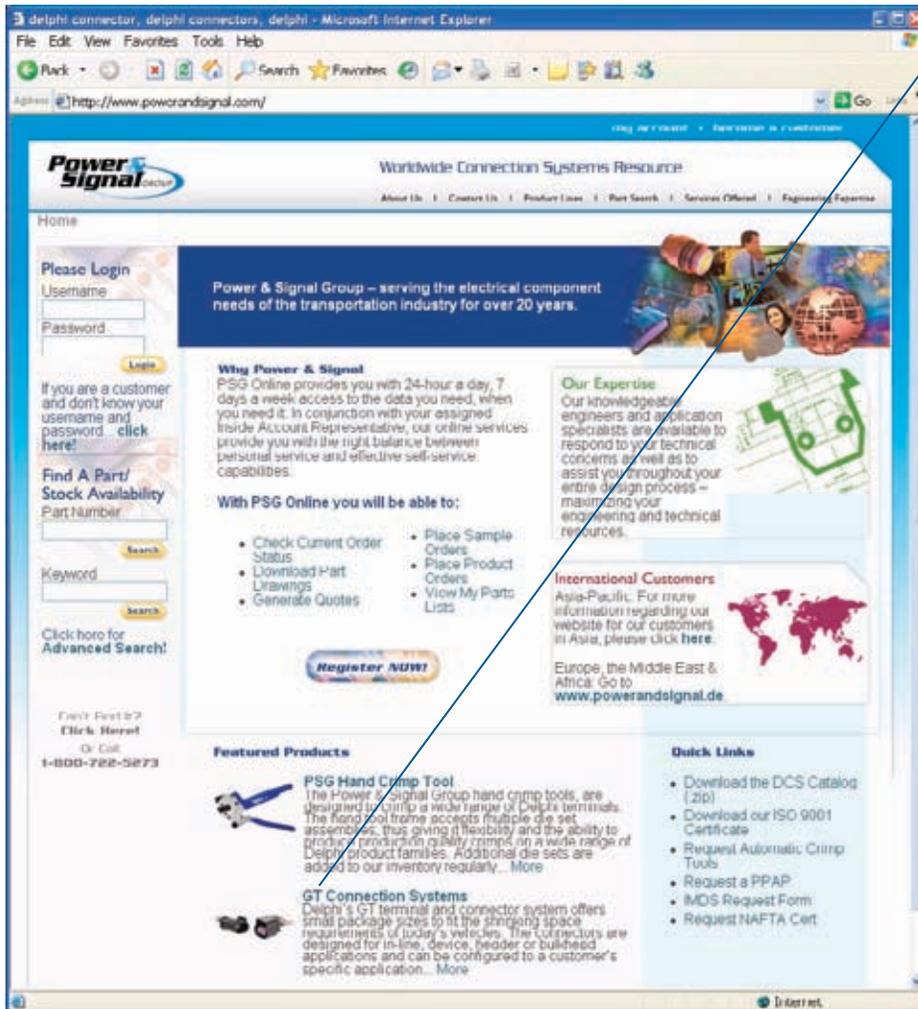
.....uhhhh, there isn't one of those pages.

(I should have been a physicist; they never have to actually build stuff, they just argue about dark matter and Dominos pizza).

OK. Cut to the chase... Go to the "Sealed" version of the connector. Unsealed connectors are cheaper and easier to put together but don't keep the fluids out.

Under the Sealed connectors, look for the female version. I only know this because our not-so-helpful drawing above at least showed male pins.

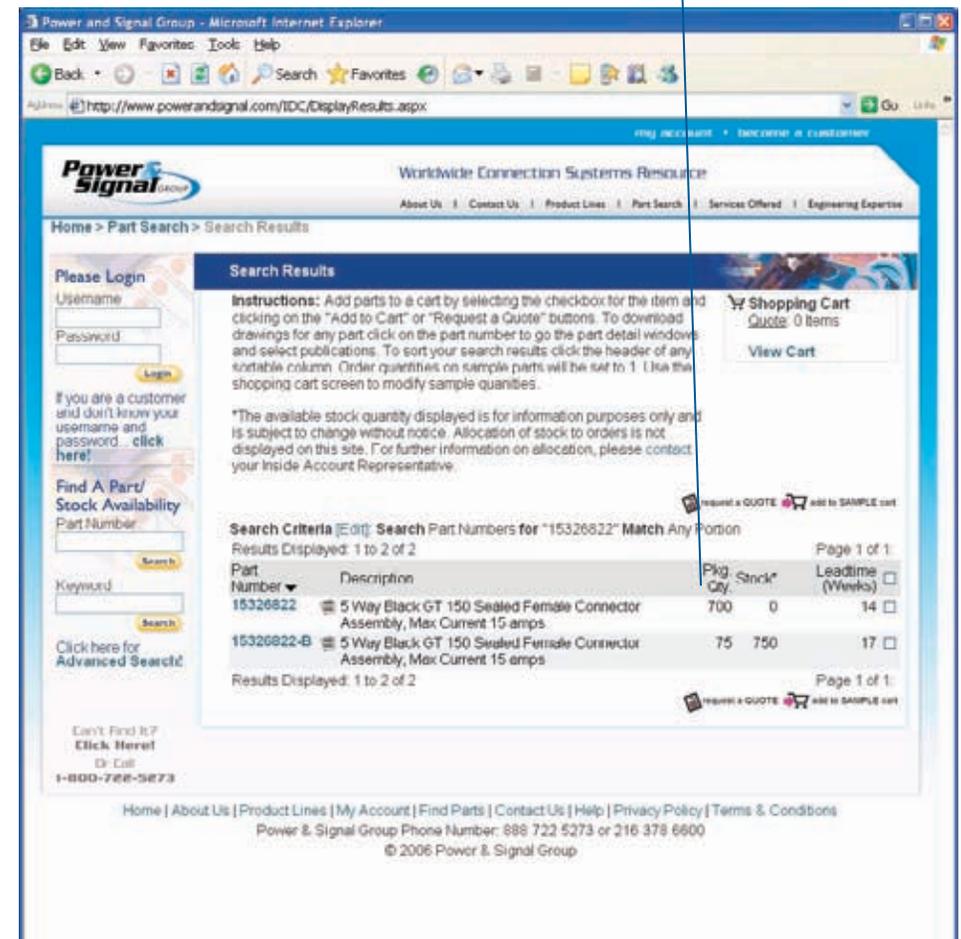
Look for the appropriate number of cavities, in this case 5. The part number, 15326822 is what you are looking for. Punch that into the Part Number field of the website.



GT. That looks familiar

Looks like I can buy 75 or 700 at a time. Oy!

Click on one of the part numbers, then go to "Prints, documents, etc."



Create a directory named “Manufacture-Type-Circuits-Gender-ObscurePartNumber
 So, in our case: **PACKARD-GT150-5WAY-FEMALE-15326822**

Download into that directory:

- 2D PDF
- 3D IGES
- Assembly Instructions
- Product Image
- Representative Image
- Technical Literature

You will need all of this information further down the road.

One Last Issue:

The connector described in the application document as a GT150, the one that we just downloaded all of the information for, the one that we finally thought we had done:
IT'S THE WRONG \$\$\$@#\$\$@#\$\$ CONNECTOR.

The MAF sensor actually uses the Metric-Pack 150 Series not the GT150. AAARGGGGG!. Repeat the steps above for part number 12162825. Never, and I mean never, trust the component documentation!

Always get a sample of the connector and see if it fits.

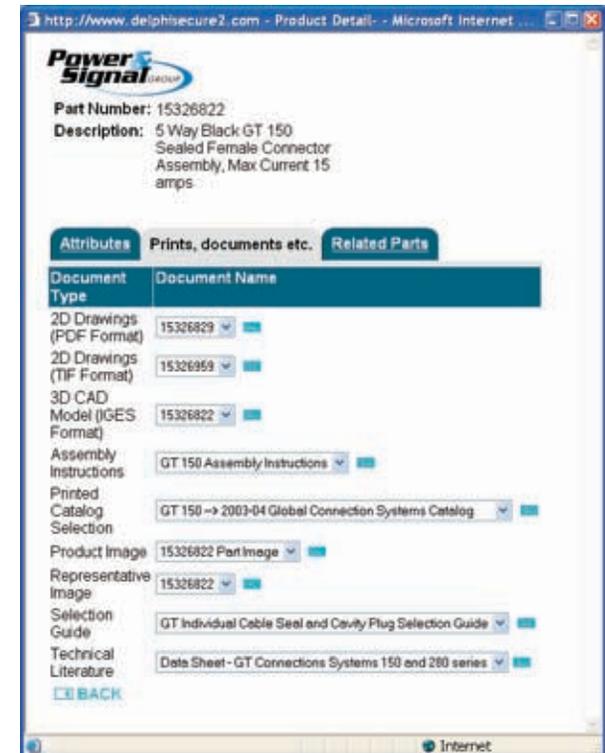
This is a “Pull to Seat” connector. “Pull-to-seat” is Latin for “Betterus Getus Rightus Firstus Timus”. If you have design control and can avoid “pull to seat”, please do. Your family and co-workers will thank you.

Now, we have all of the information for one of the connectors in our system. Repeat this for each and every sensor and actuator you have. Yes, even the Sumitomo* ones.

*The world’s most obscure connector according to my limited research.

Oh, and if you don’t want to buy 700 connectors at one time — you better learn the MotoTron part numbers:

PED	12162825	MOTOTRON	CONFEML011D0
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Handy websites for connector information

- <http://www.deutschipd.com/>
- <http://www.tycoelectronics.com/>
- <http://www.sewsus.com/welcome.html>
 (Sumitomo can’t even put their name in their website)
- www.powerandsignal.com
- <http://www.waytekwire.com>

Block Diagrams

But First, a Visio Primer...

If you don't have Visio, go get the evaluation version at <http://www.microsoft.com/office/visio/prodinfo/trial.msp>.

Or twist your IT departments arm to get a copy.

Is Visio the “Premier Harness Design Tool”? No.

But you can't afford that tool and that tool can't also create an organization chart that is apparently a required skill to be in upper management. Visio can, so look at it as a vital part of your career growth along with the added bonus of creating a handy drawing of your harness.

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.

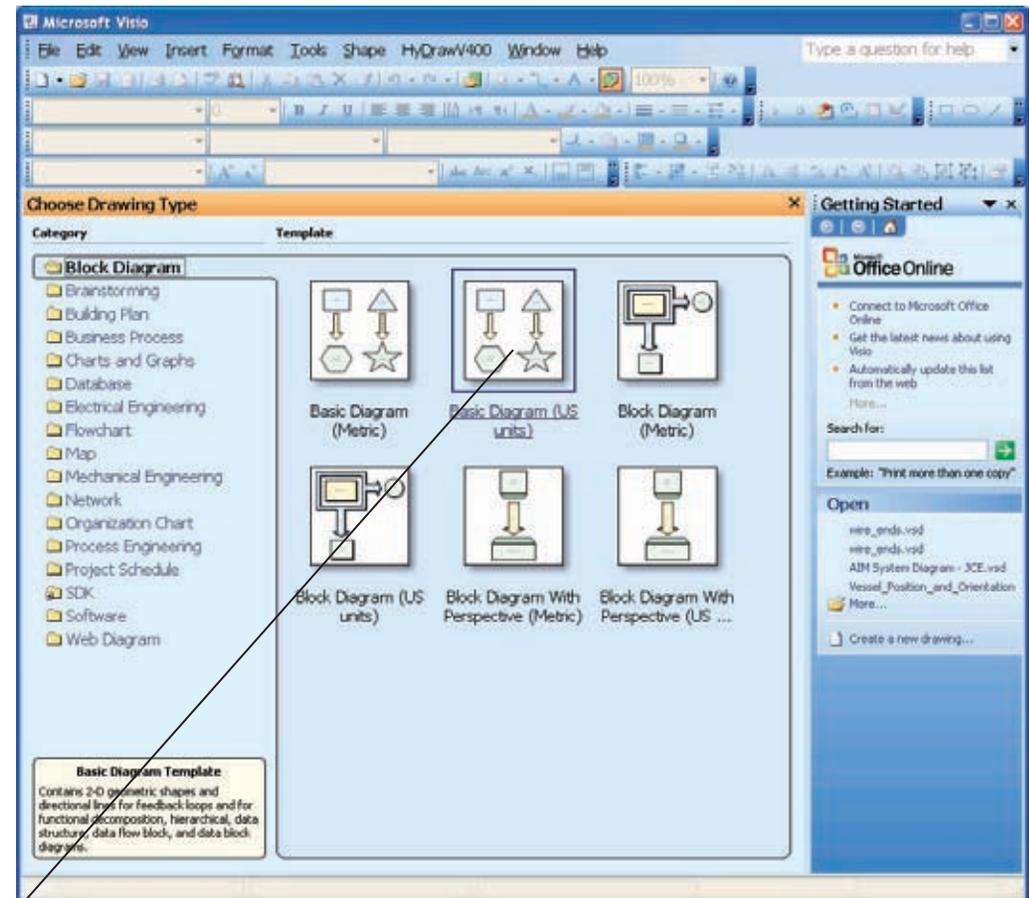
Each shape, has hidden beneath it a “shapesheet” that contains what looks like an excel spreadsheet. The spreadsheet allows you to make the parameters be functions of one another.

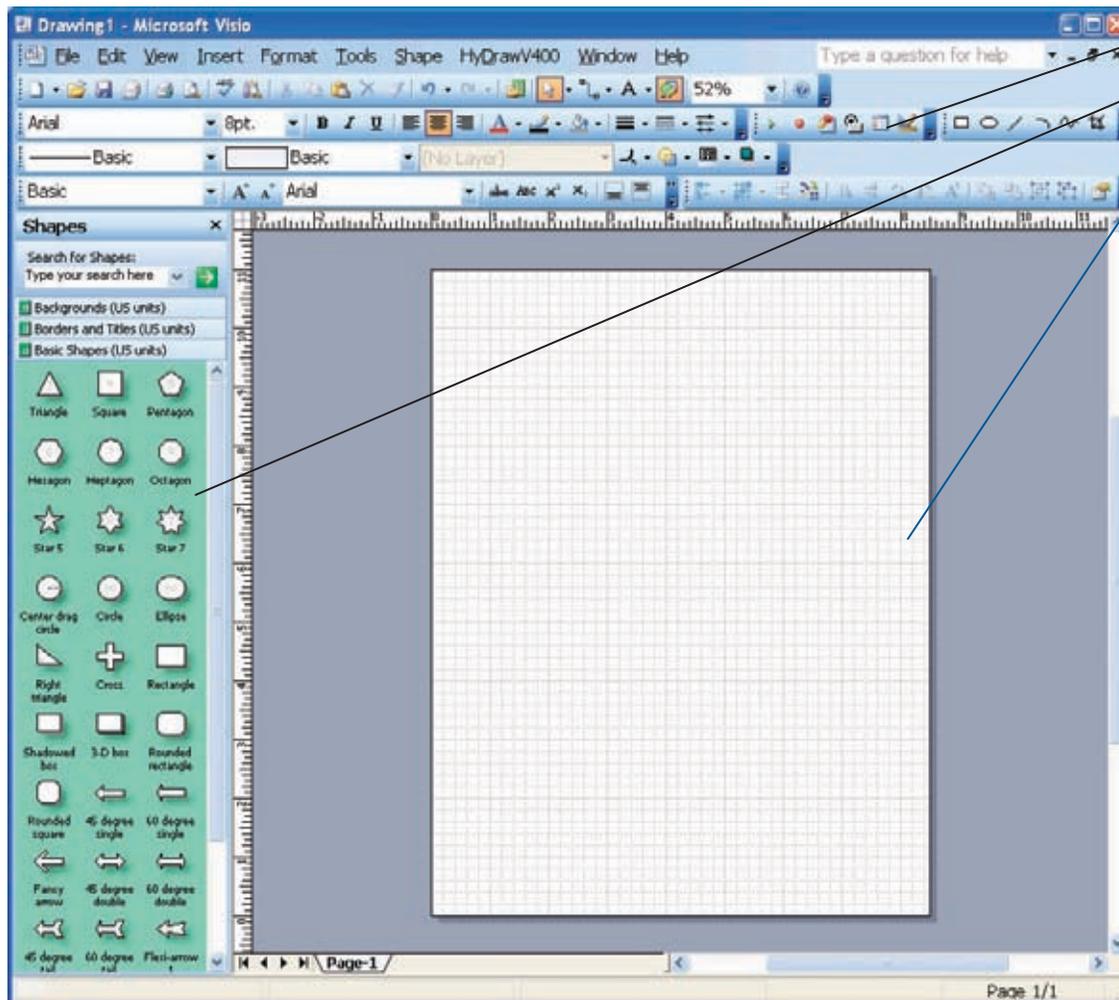
For instance, if you want to make a square... you could enter an equation like $Height=Width$ for the shapes to obey the rules of a square.

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 based on the “Basic Diagram (US Units) _____





The drawing tools

The stencil

Hey, it is even green like we remember.

The drawing page

Drag our friend the Square on to the page.

Drag out another one.

Or control click and drag the first one to make a copy.

Select File/Shapes/Visio Extras/Connector (US Units).
 This will add another stencil to the palette on the left.

Add a dynamic connector to the page.

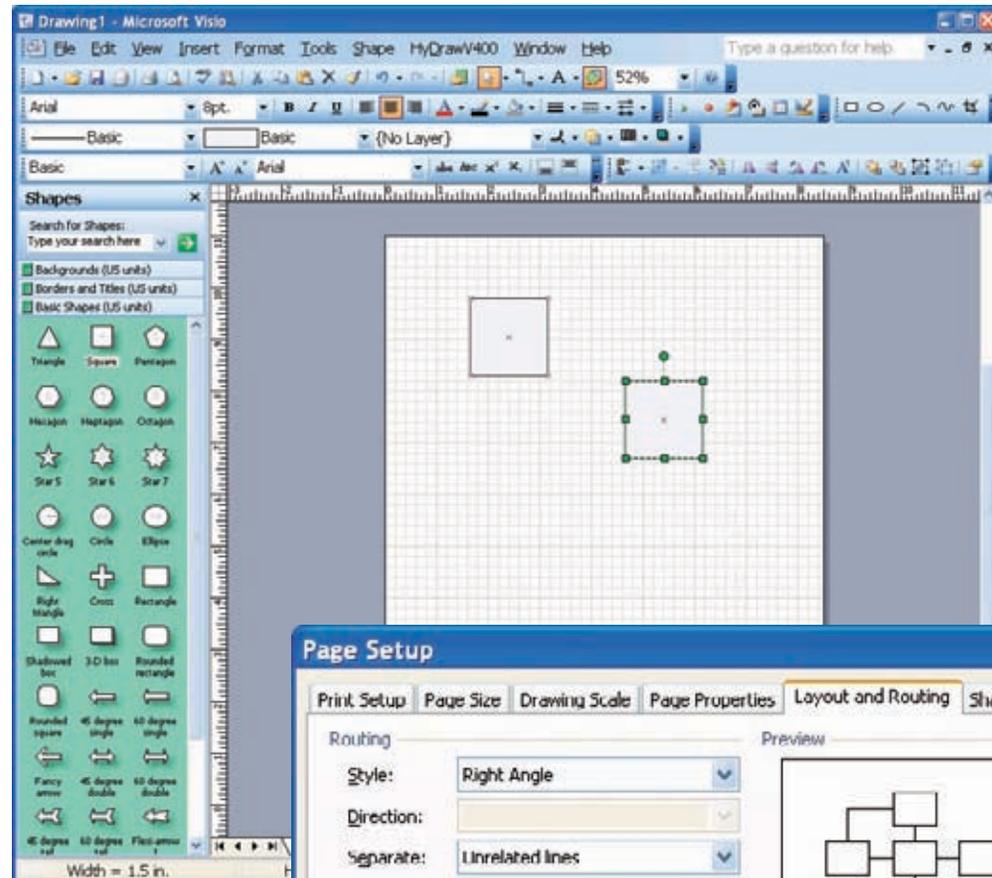
Pull the ends to the little blue 'x' on the squares.

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.

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.

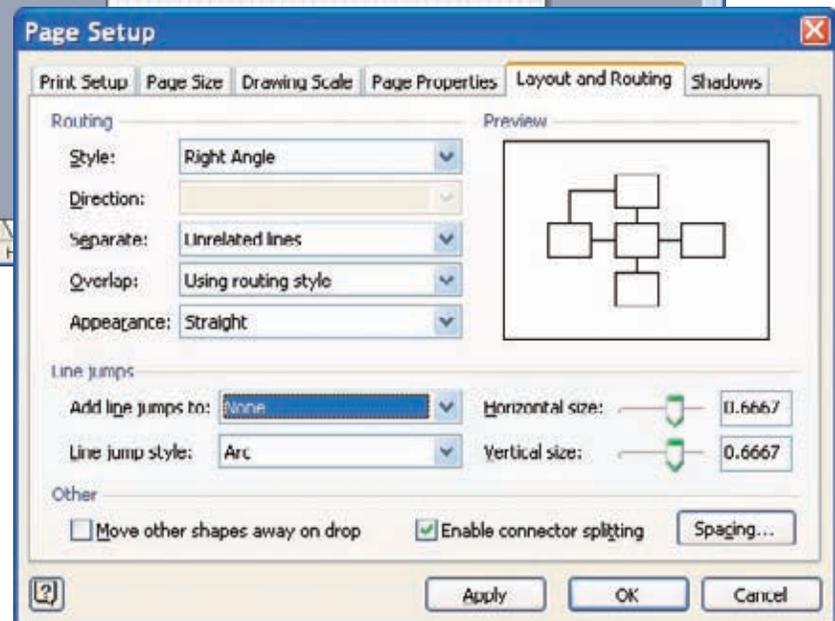
However, there is about a 2% chance that you would have discovered the connection point tool and made the wire actually connected to the square rather than just drawn to end at the edge of the box.

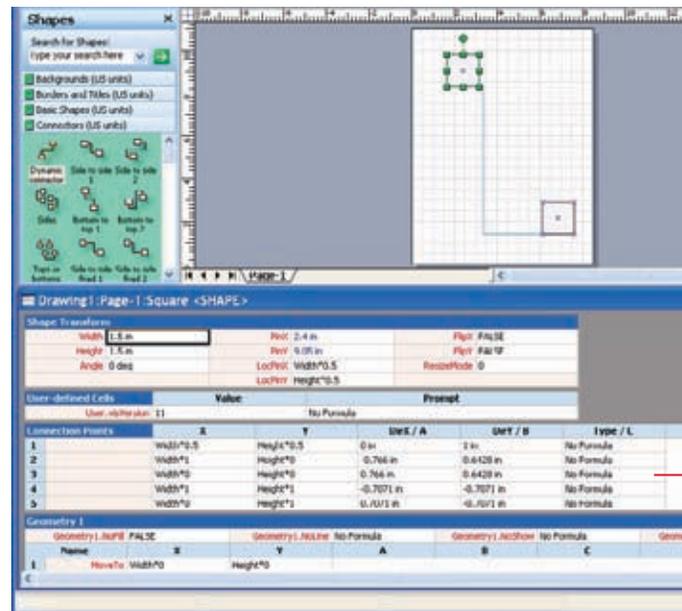
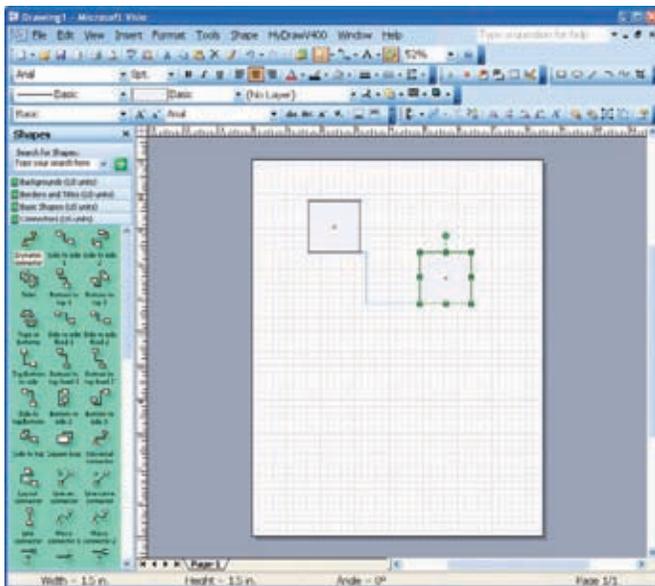
The probability is even lower that you would have made the line somehow reroute itself.

NOTE: Never make a drawing like this where lines and boxes are just drawn in proximity to one another.
 You will be cursed along with your offspring for generations.

Having Visio route wires for you can be a frustrating endeavor.

TIP: Go to File/Page Setup/Layout and Routing.
 Set the "Add Line Jumps to:" setting to "None".
 That usually helps reduce blood pressure considerably (but, alas, not completely).





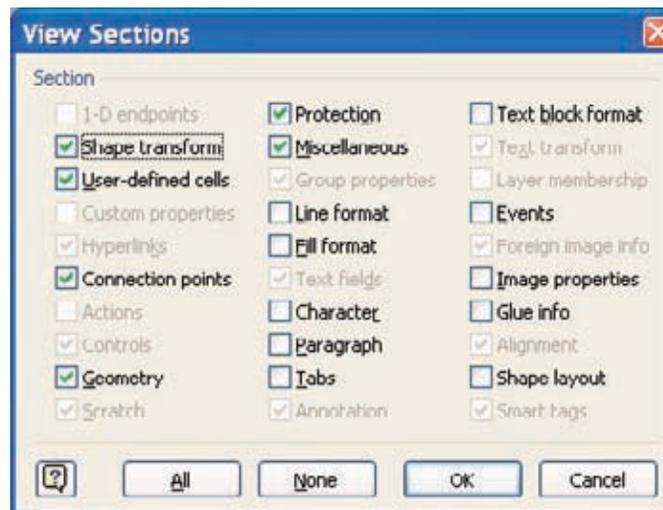
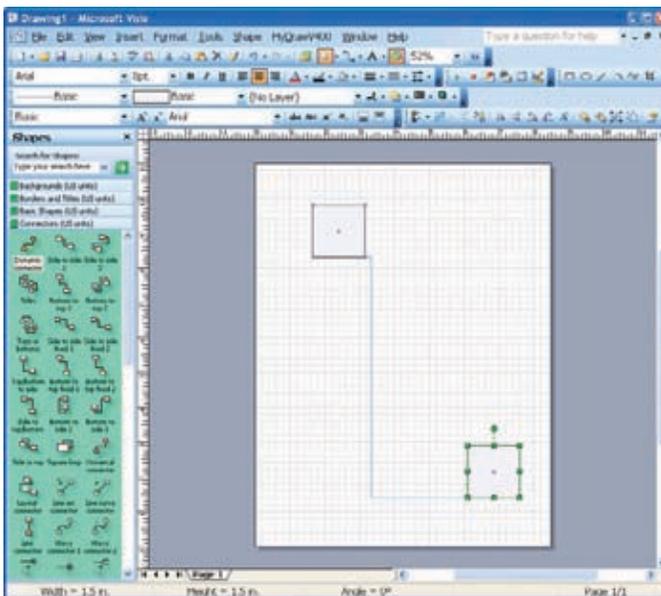
Believe it or not, you are now as skilled as 94% of all Visio users. Plop boxes (or any of the 100's of shapes on the stencils), connect them together, and boom you have a Space Shuttle drawing or a map to your kid's school. If you can't master these elements, please use PowerPoint instead, enjoy management, and don't bother me, I have some work to do.

The Shapesheet

Time for some Jedi training...
Click on one of those squares.

Go to Window/Show Shapesheet.
Hold your breath. Son of a gun. That kind of 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.

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 shapesheet.

Jedi Visio for Padawans

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

1. Popping and Connecting Shapes in Visio (OK, that was easy)
2. Adding connection points to a shape via the shap sheet
3. Creating Line ends that represent connectors
4. And, for Jedi Masters, how to add custom properties to a shape

Adding connection points to shapes via the shap sheet.

Visio tries to make connections too easy with a "Connect Shapes" tool that will automatically create connection points for you.

Seductive yes, powerful, not so much.

Unfortunately, these connection points disappear when disconnected.

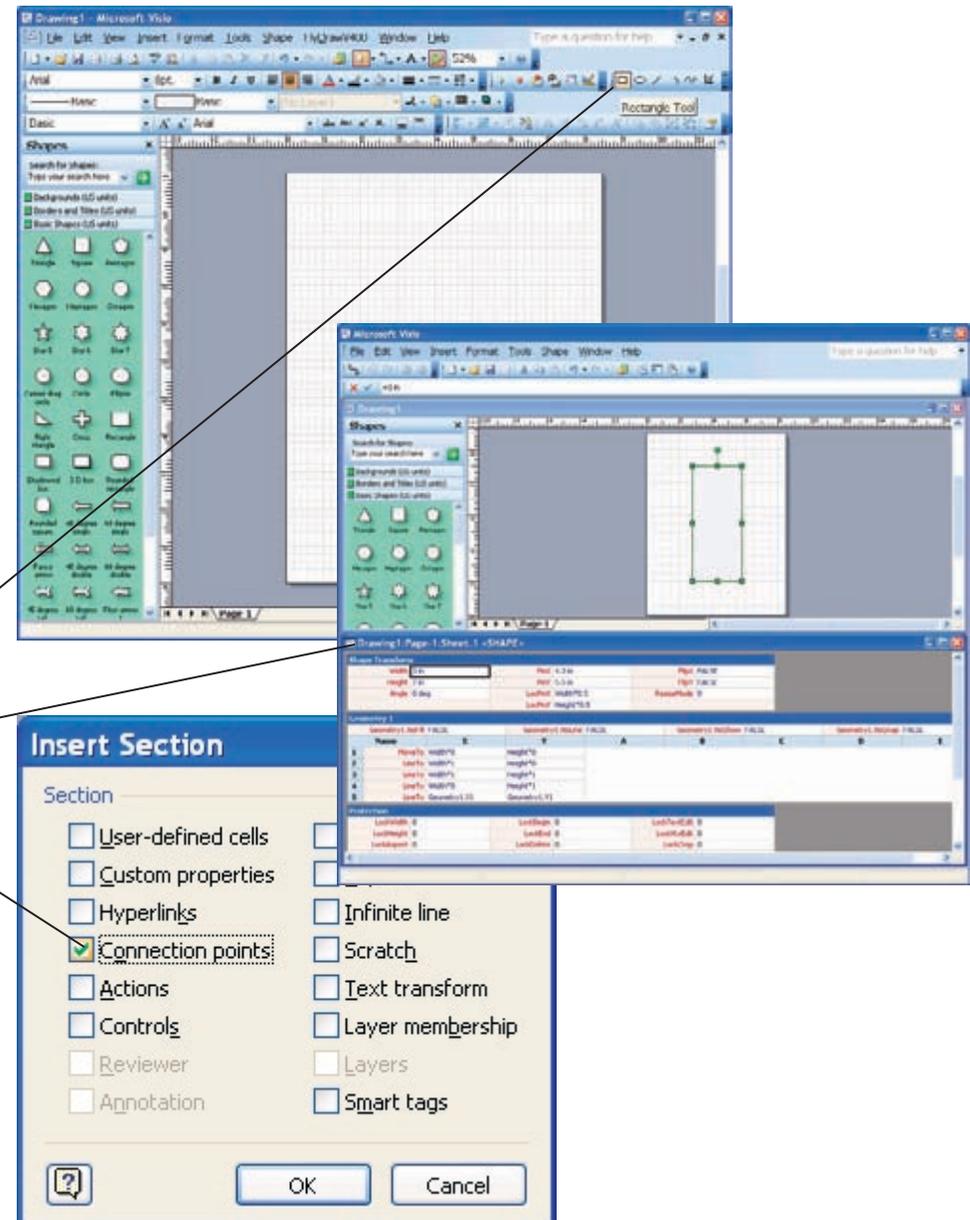
That's weird. The AC socket in my wall doesn't vanish when I unplug the Christmas tree, but apparently in Seattle (home of Visio), they do. So, time to pull a trick.

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

Get a shape or create one. For now just create a rectangle.

Open the shap sheet for the newly created shape.

Right click and Insert Section: Select Connection Points. Hit 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".

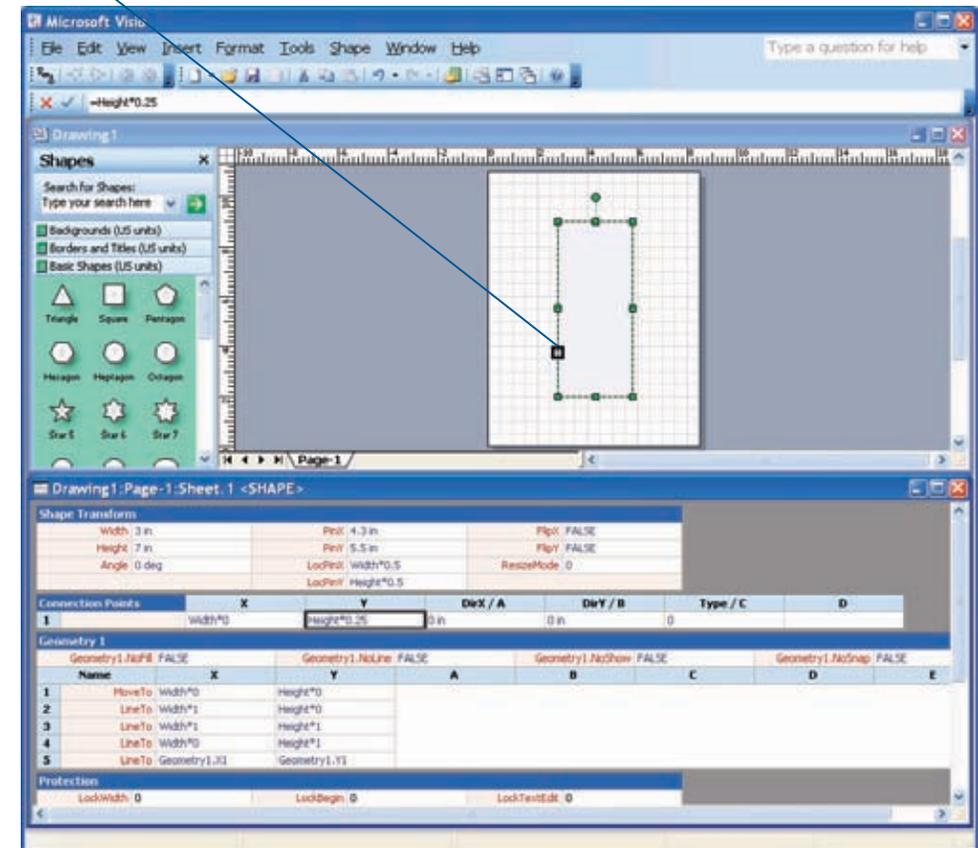
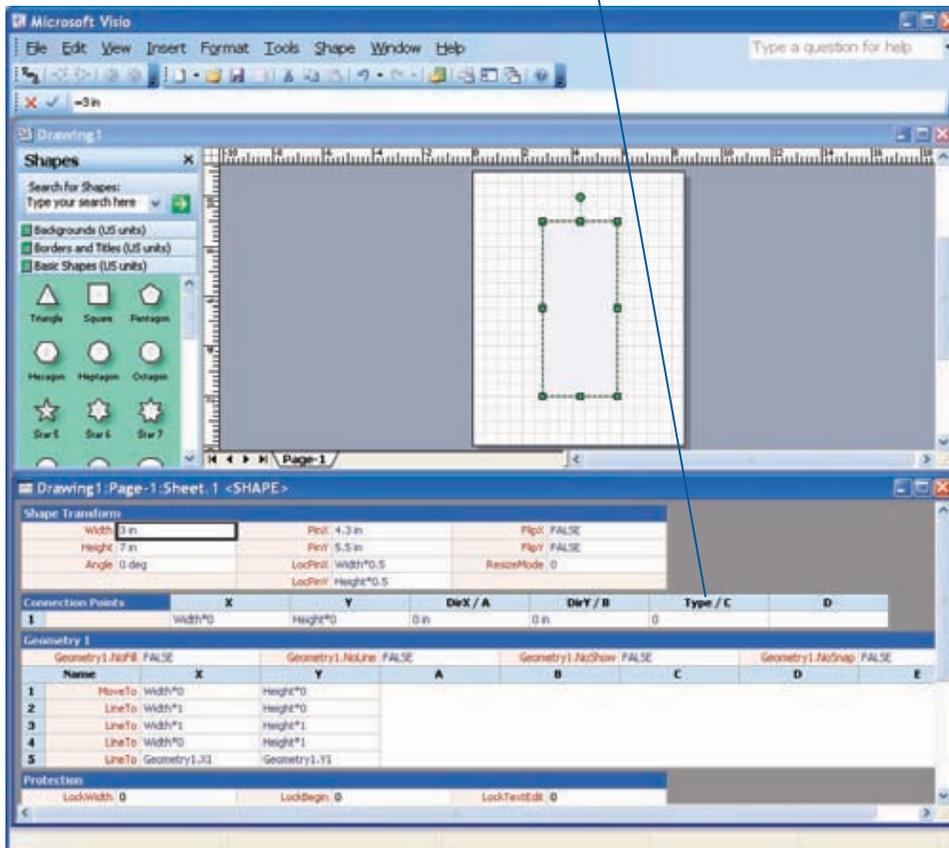
Enter $\text{Width} * 1$ in the X column and Connections. Y1 in the Y column.

Don't worry about the other columns for now.

However, if you are interested, select a cell in any column of the shapesheet 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.

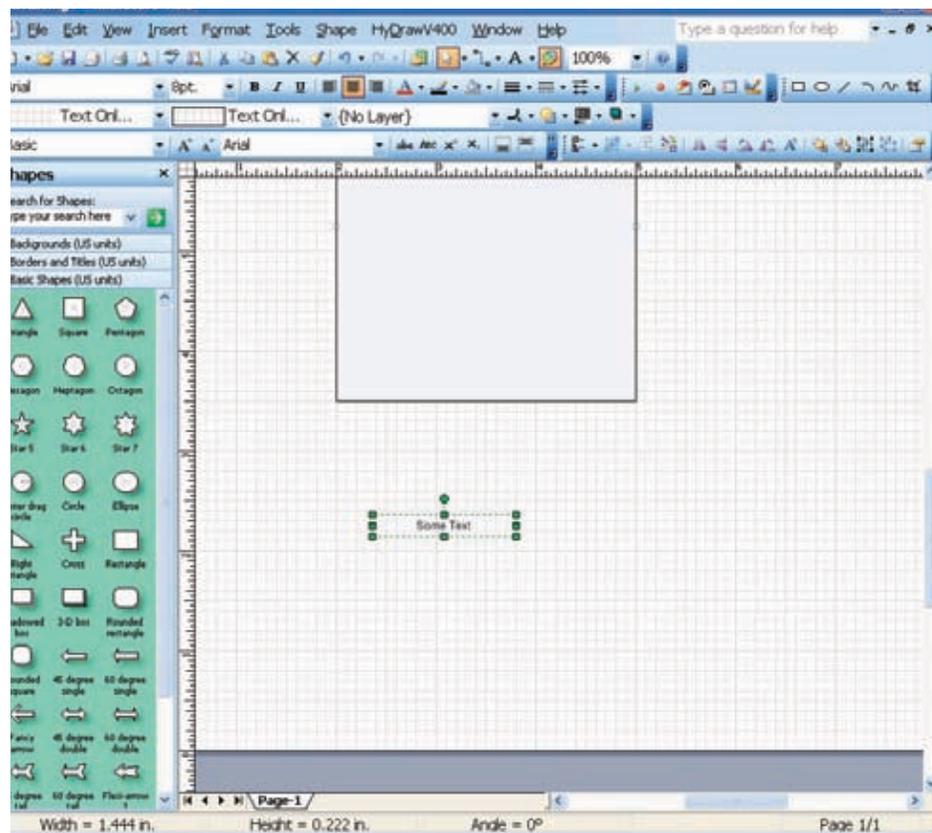
Are you kidding me? I need to manually enter all those points?

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.

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

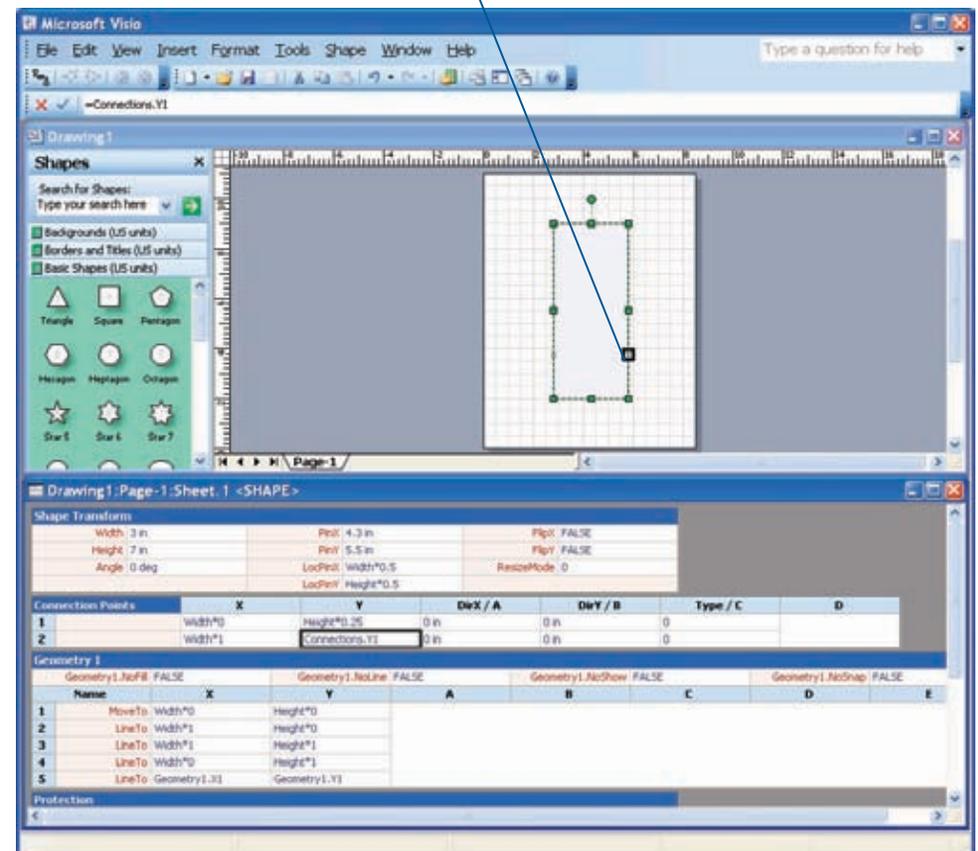


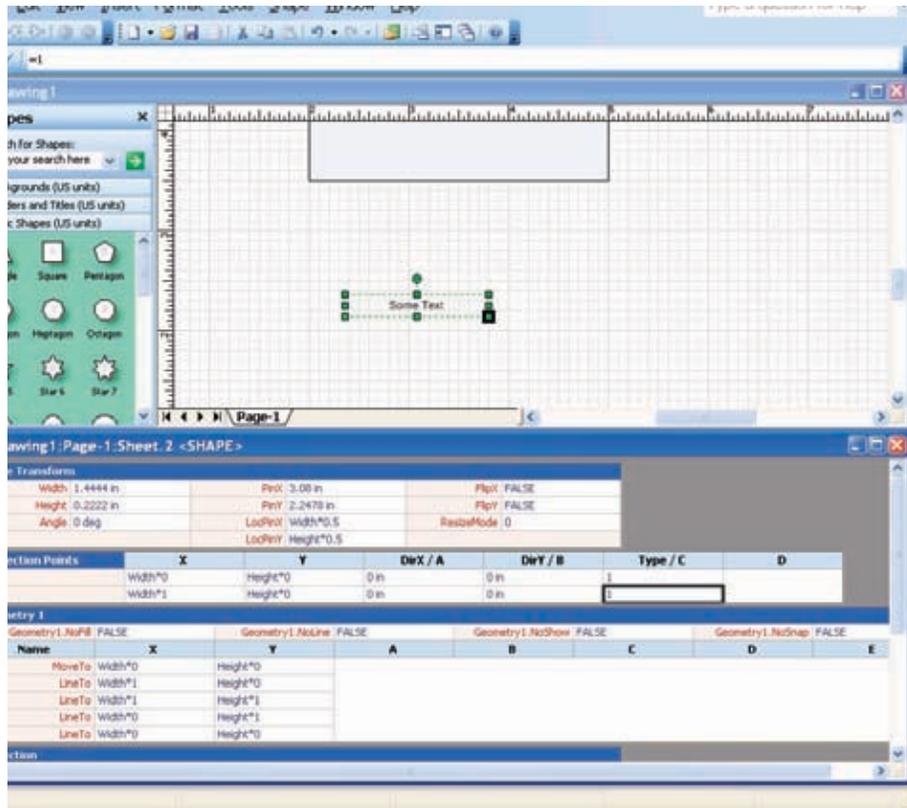
Open the shapessheet.

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).

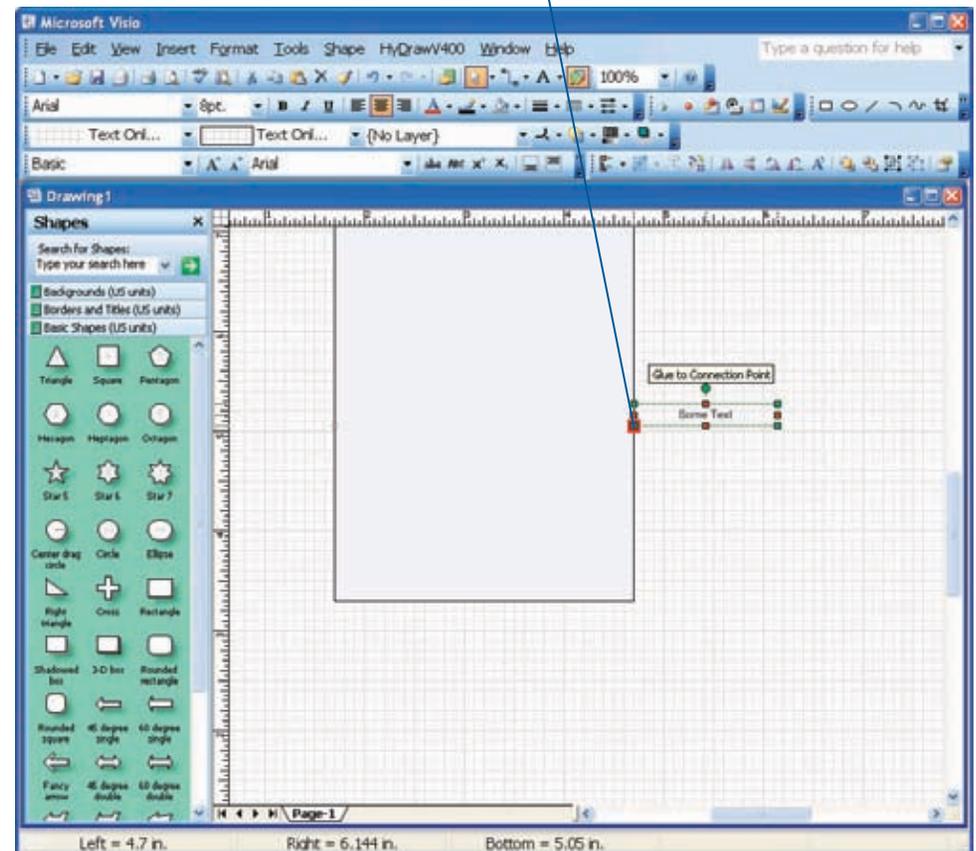
Another connection point



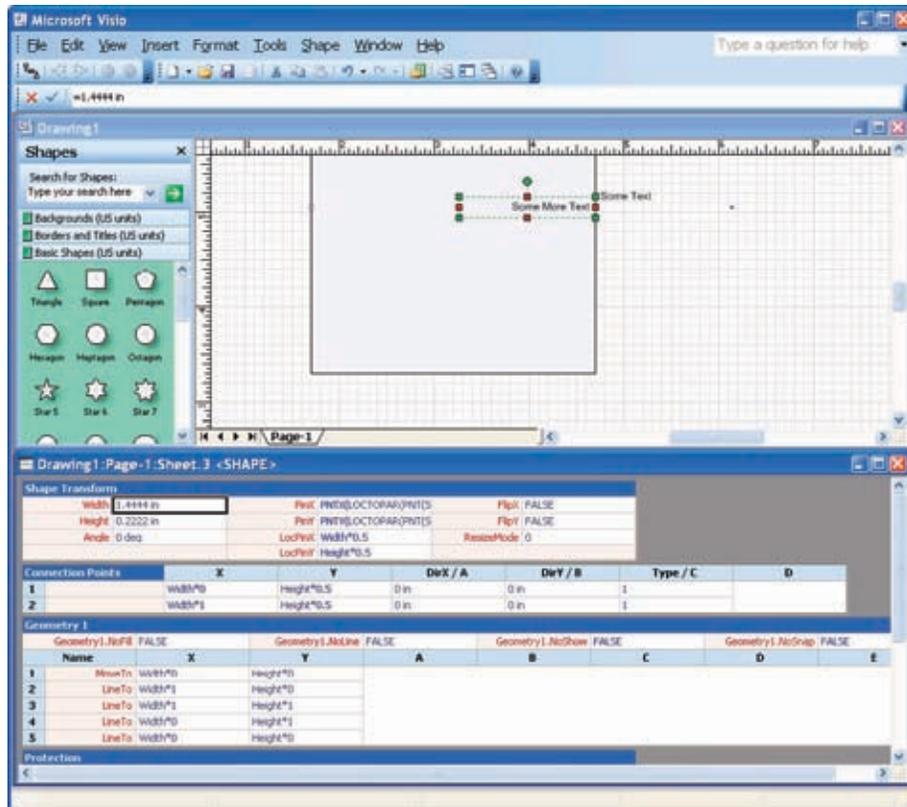


Now move the shape over to one of your connection points, and if you grabbed it by an end near the connector, you should see the magic red glue indication.

Red means it is glued.

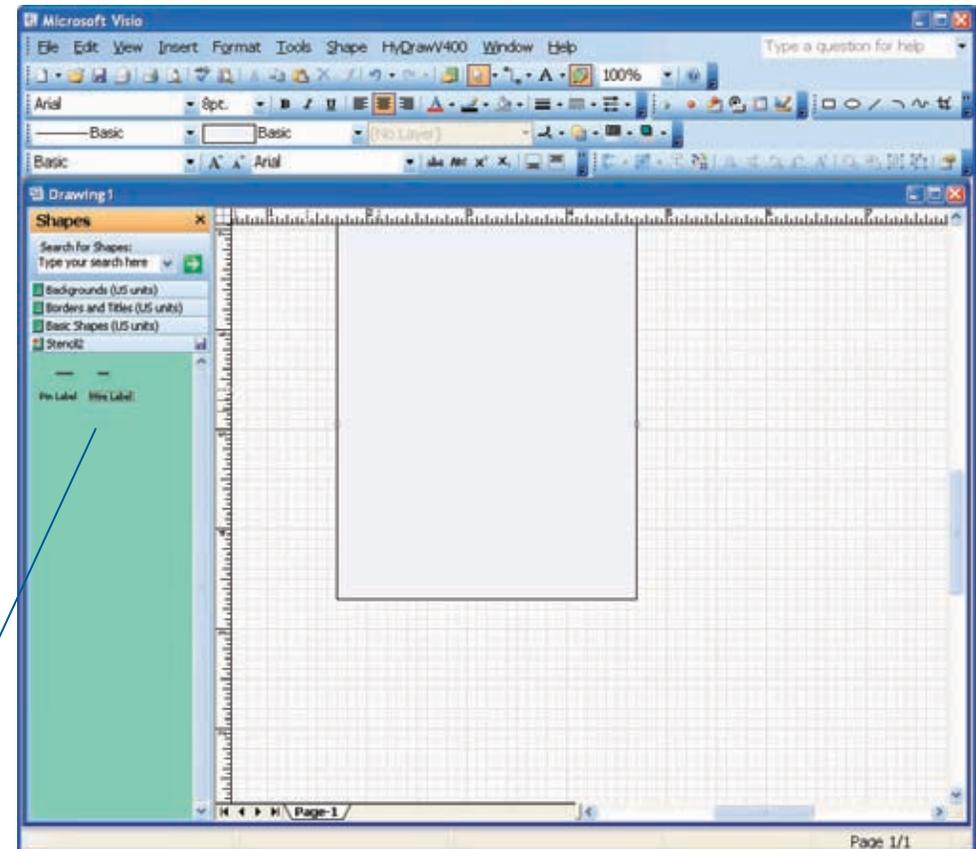


Let's build one more.
Create a text label and add the connectors,
but this time put the connection points 50% vertically.



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.

Jedi Trick: 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.



Our very own stencil

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

Two more shapes to create that will make our lives simpler

1. Create a 1/4 inch square box with connection point on either side at 50% altitude. This will represent a connector pin.

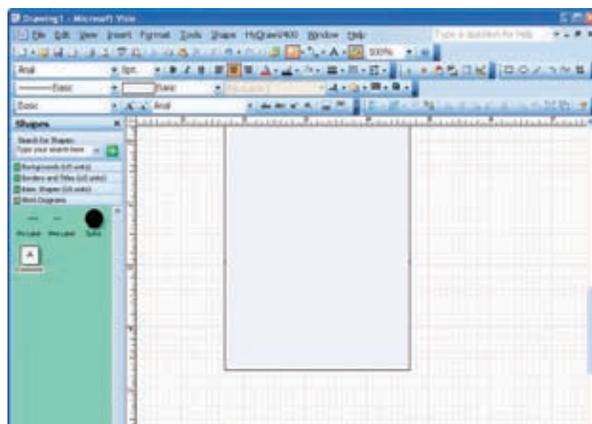
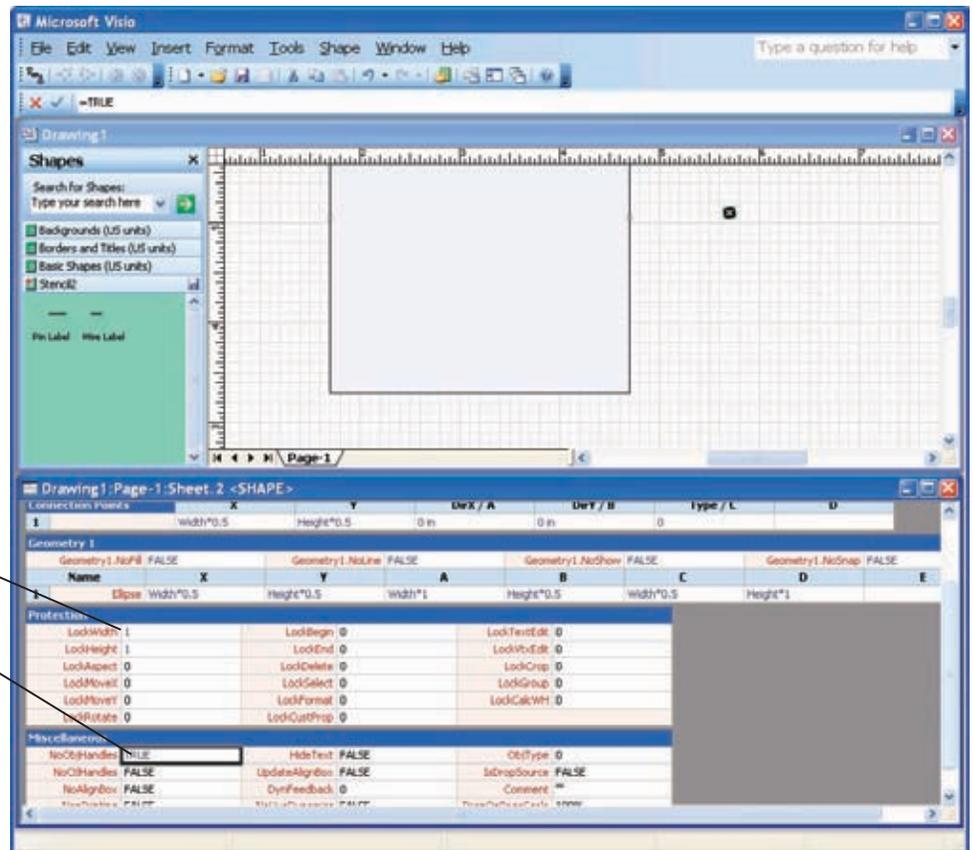
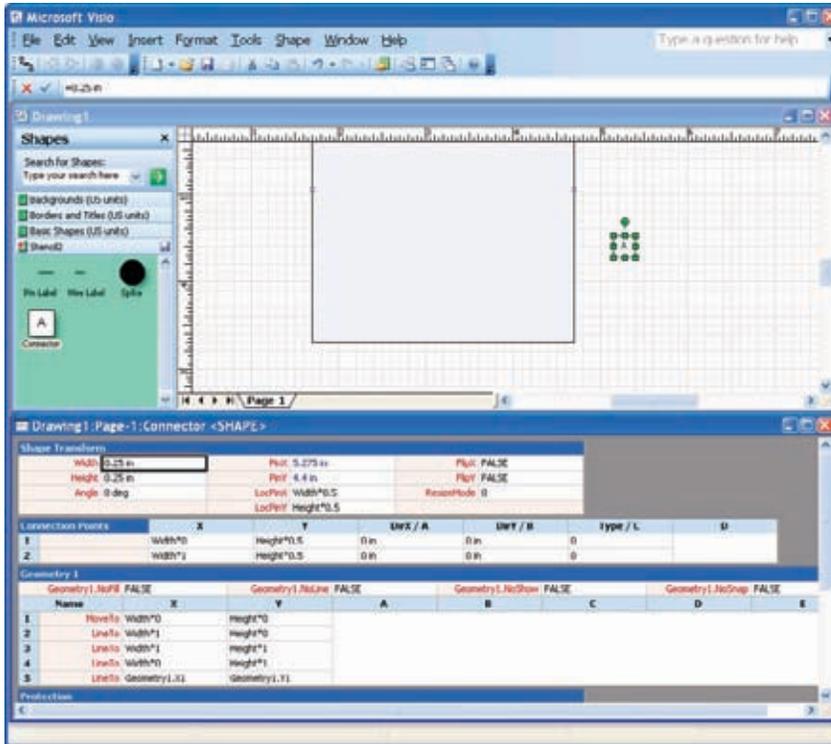
2. Create a black filled 1/8 inch diameter circle with a single connection point in the center.

This will be a splice.

Jedi Trick: 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 menu.



Lock this circle

And lose the green boxes

Congratulations — you are now armed and dangerous to make block diagrams. Let's do that next...

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 of the universe, 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.

Screw up this drawing and the curse of a thousand controls nerds will be cast upon your house.

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.

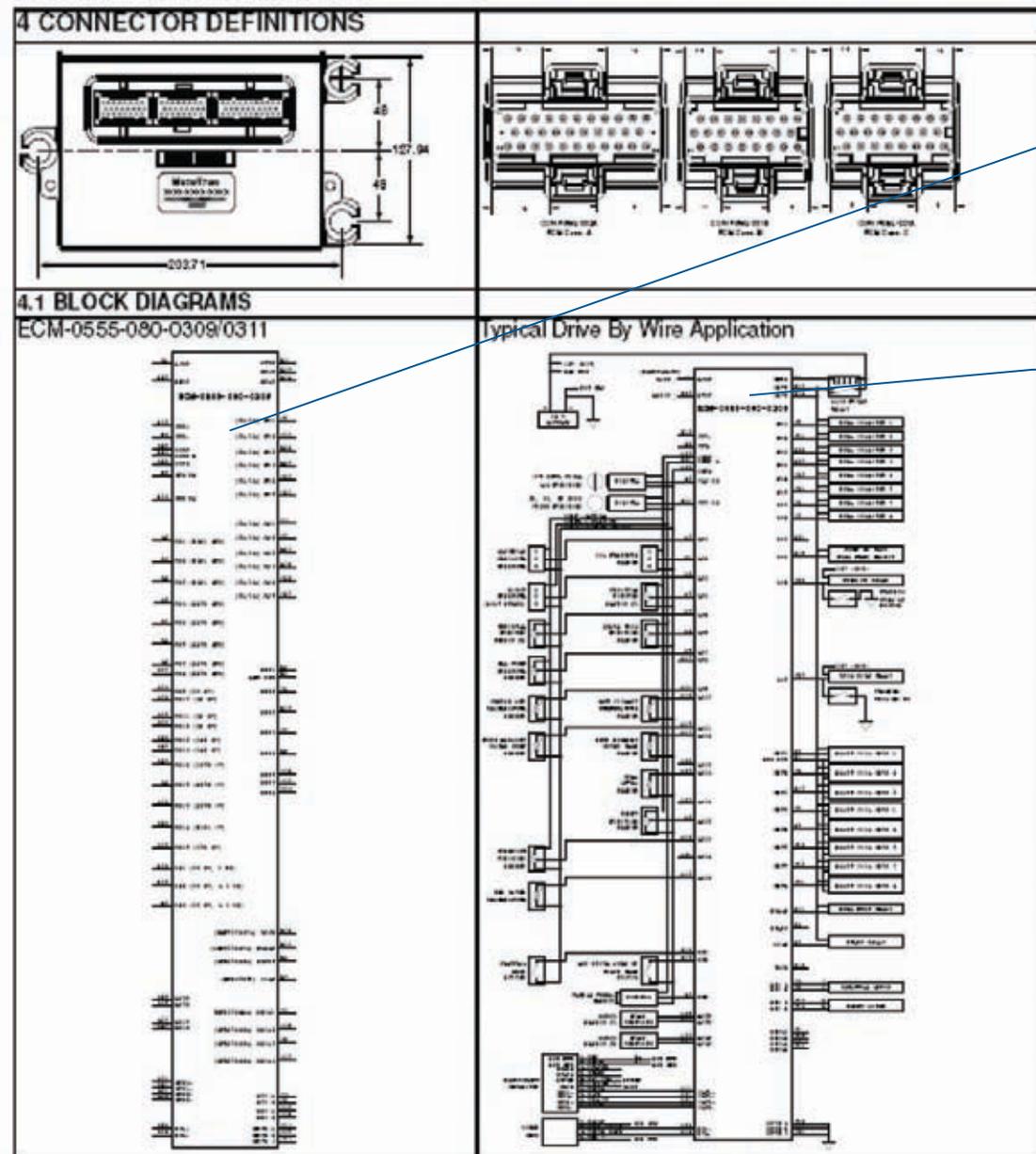
The key to a good block diagram is to show as much information that you possible can. Connectors, wire numbers, colors, etc.

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

A 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 the steps to making this easy in Visio:

Get an image of you connector.

Remember, we downloaded those from www.powerandsignal.com.

Let's put that picture in Visio and try to use it.

Select Insert/Picture/From File.

Grab the line drawing from your data directory for the Metripack connector (LD12162825.gif).

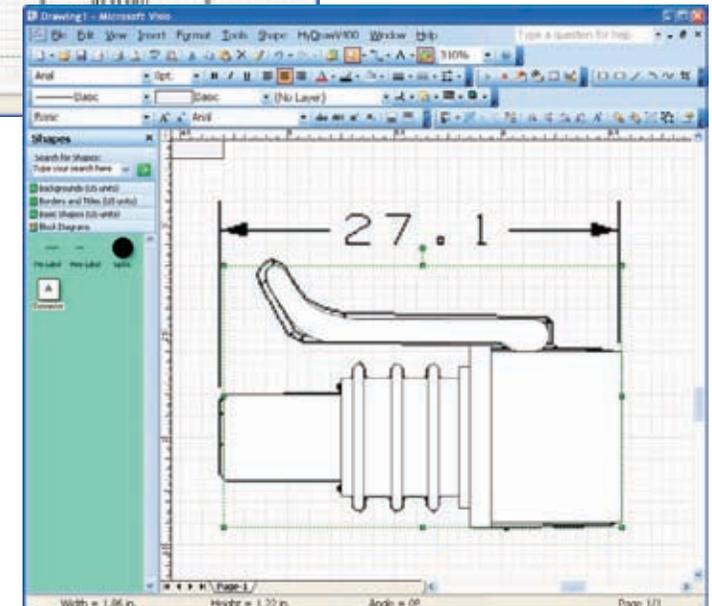
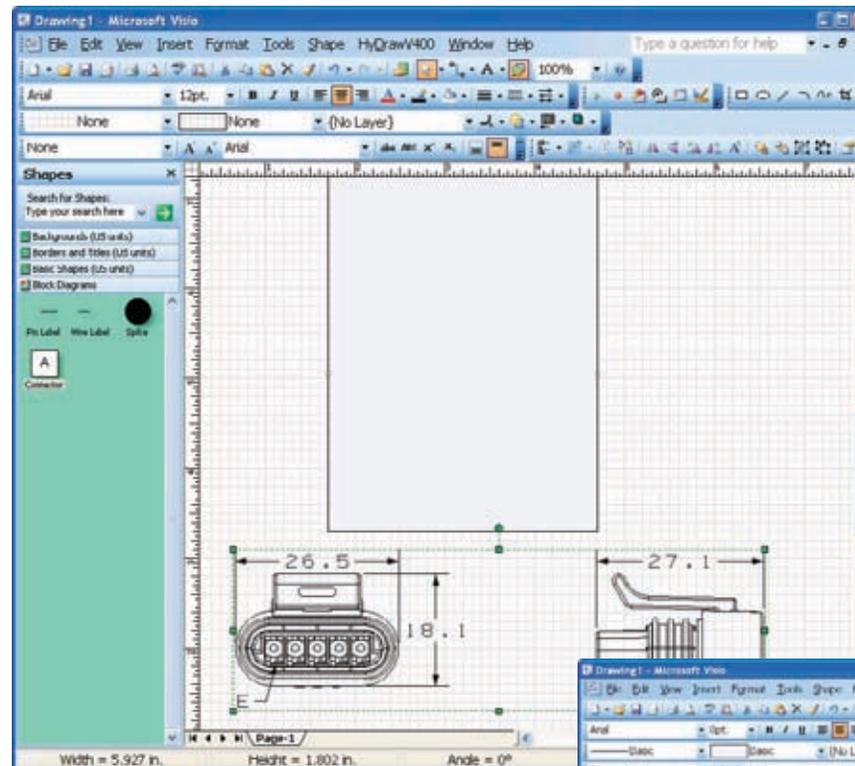
Unfortunately, Visio will not let you use images for line ends. And, Visio won't trace an image for you so you are stuck tracing it yourself.

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.

Crack open the shapessheet.

We need to get the dimension accurate. Since they only gave us the overall length, we'll need some shapessheet magic to keep the aspect ratio correct.

Look at the width and height cells and not the current values.



We need to make the height equation maintain the aspect ratio as a function of the length. So enter:

$$= \text{guard}(1.22/1.86 * \text{width})$$

Then we can enter the proper dimension shown in their drawing for the width.

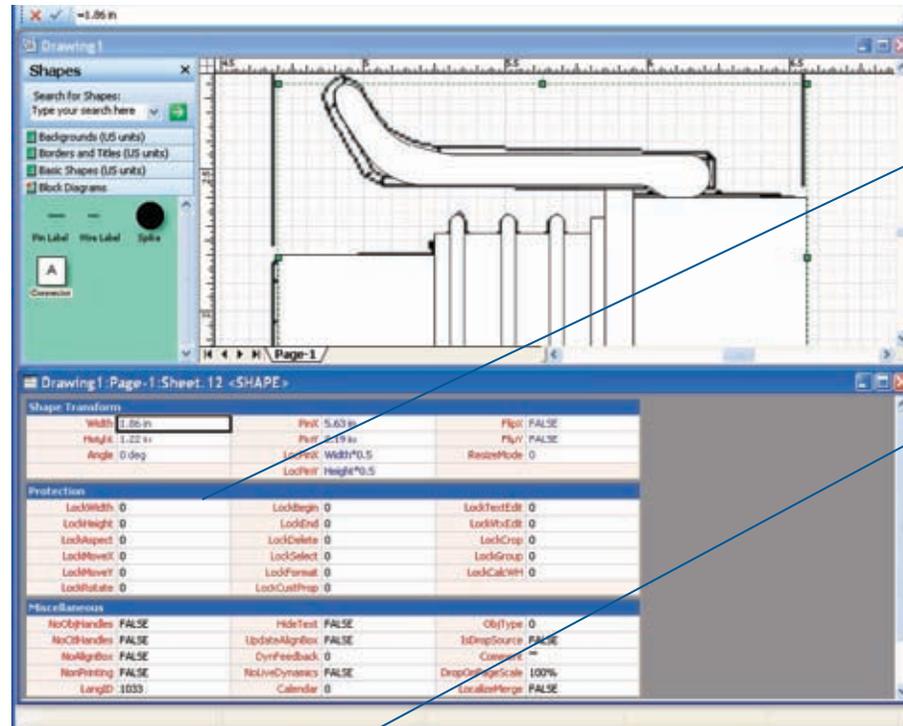
Note you can use a units suffix and let Visio do the conversion for you.

Unfortunately, Visio line ends need to be drawn with the end on the right rather than on the left. We can't just flip the connector because Visio just ignores that setting for line ends. (I don't know why, probably the same reason that their AC sockets disappear). So another trick...

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.

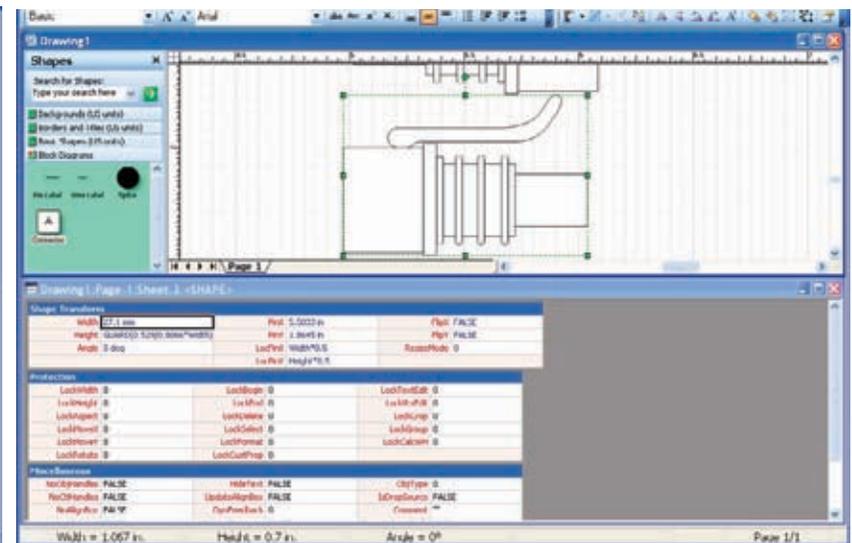
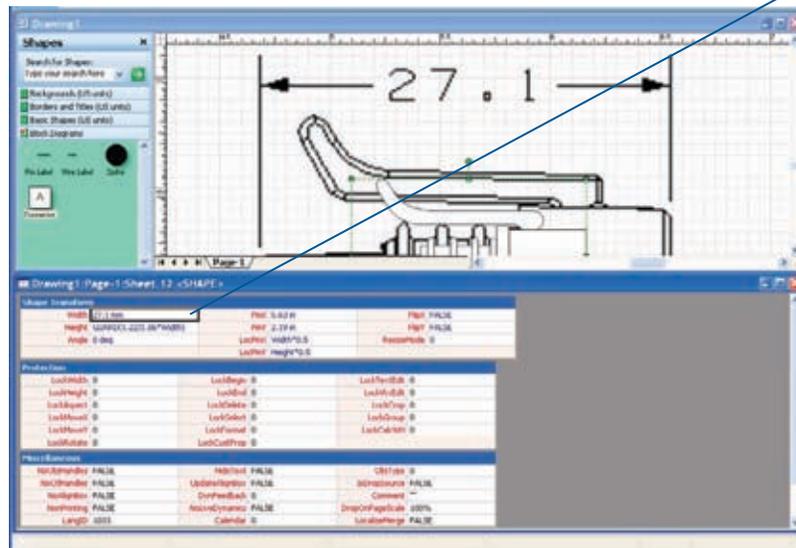
Now regroup the shape with Shape/Grouping/Group.

Now we have to do our width and length trick again to get the size back correct.



Note these values.
Your mileage may vary.

27.1 mm



Now its time to make a line end.

Select View/Drawing Explorer Window.

Right click on the Line Ends folder.

Choose New Pattern.

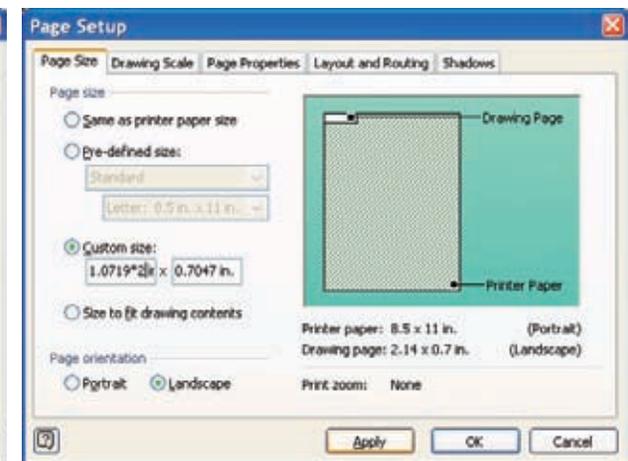
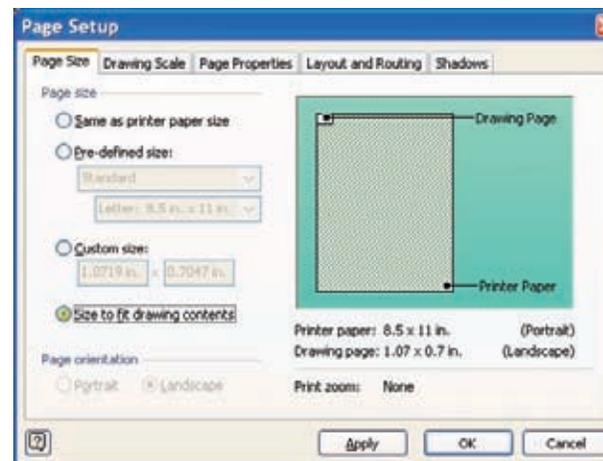
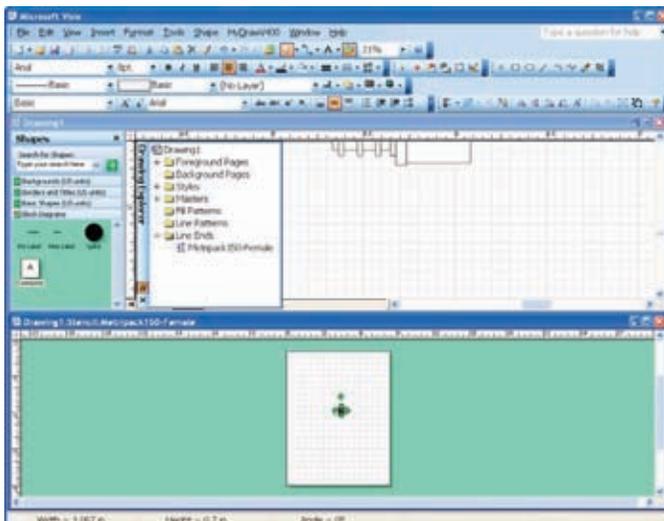
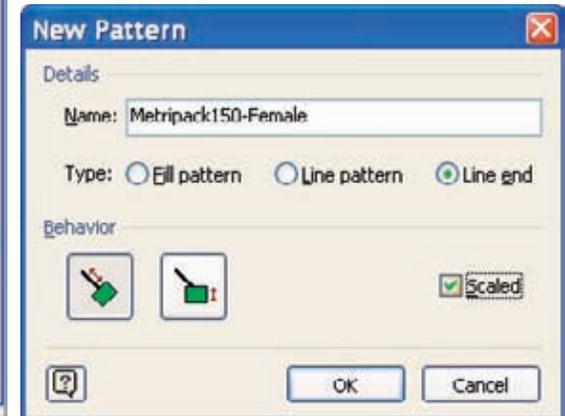
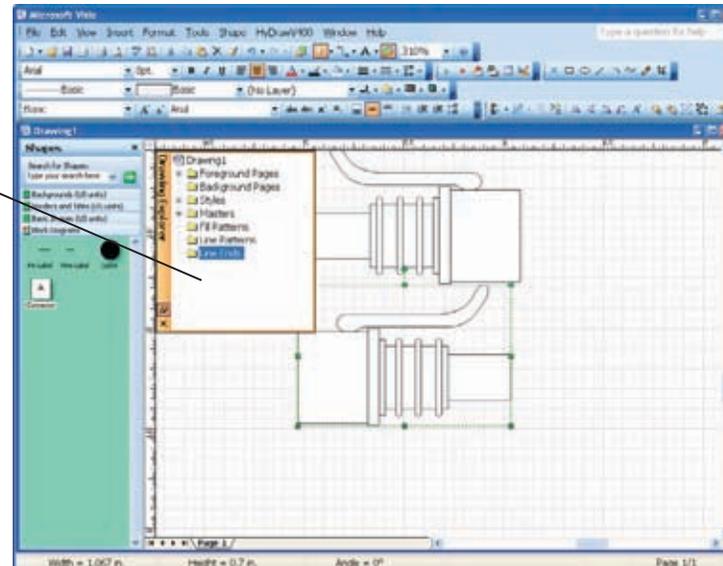
Give the line end a useful name, choose the behavior box on the left, and select the scaled checkbox.

Right click on the new pattern Edit Patten Shape.

Pull your right hand facing connector onto that new page.

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.

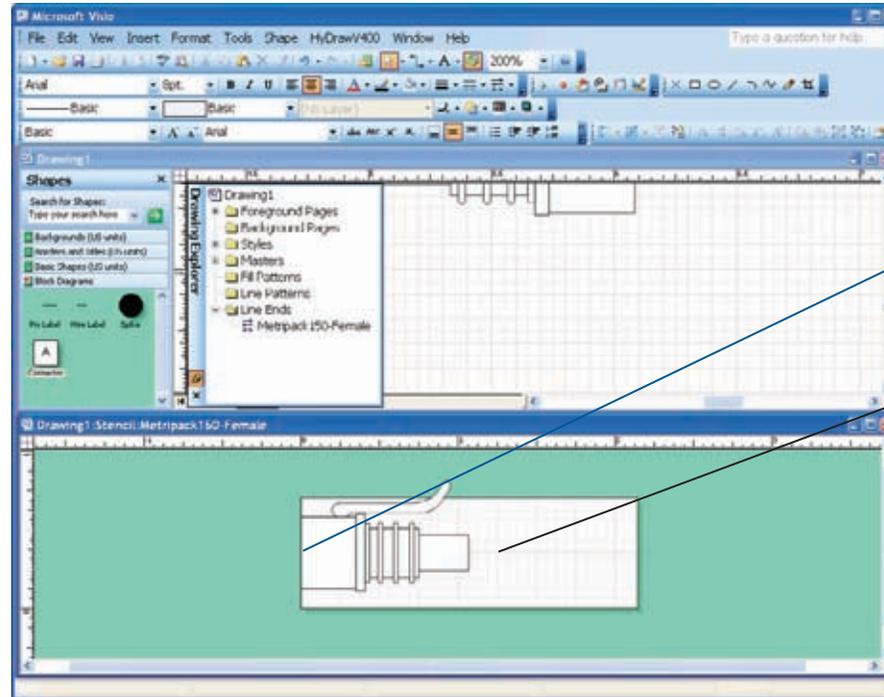
Close the line end by clicking the Red X.

Now, create a line on your page and see if we can get the line end on it.

Select the line tool, draw a line, and then Format/Line.

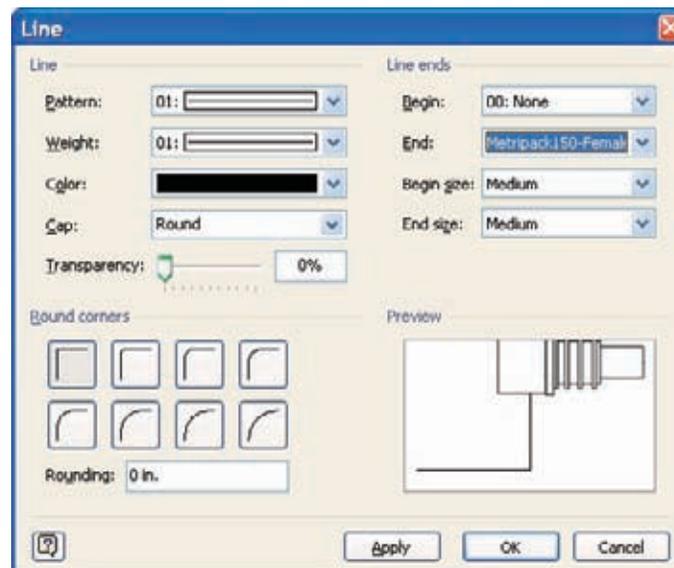
Select the end style of either end to be the line end that you just created.

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.



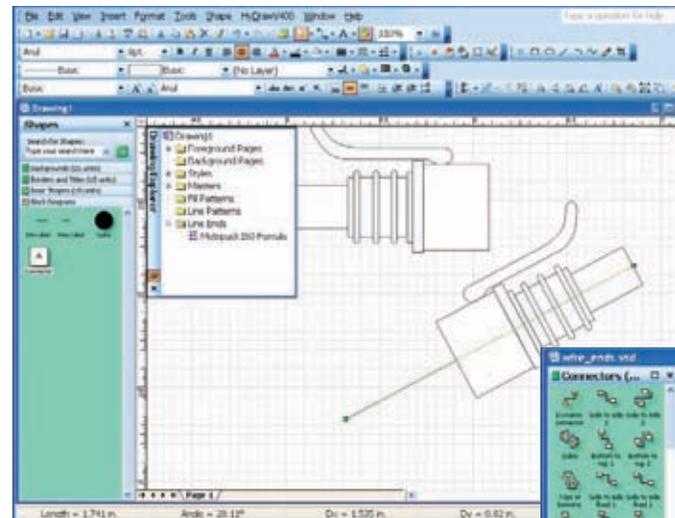
Center of graphic located at center of page.

Guide



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.

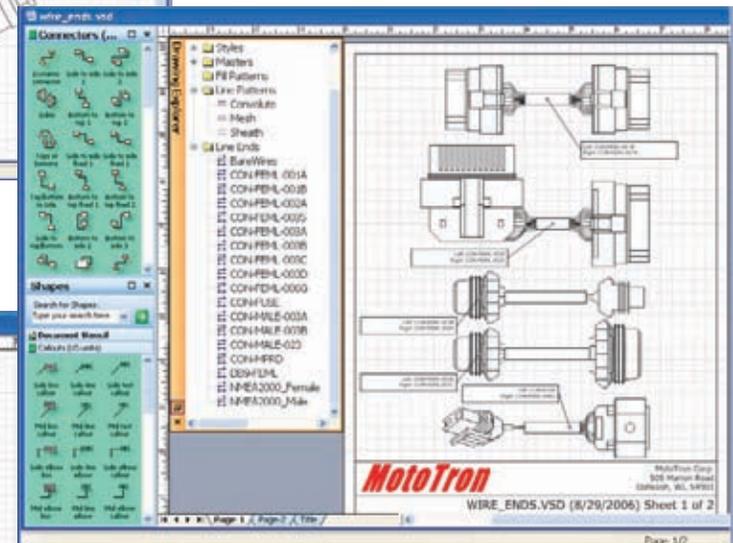
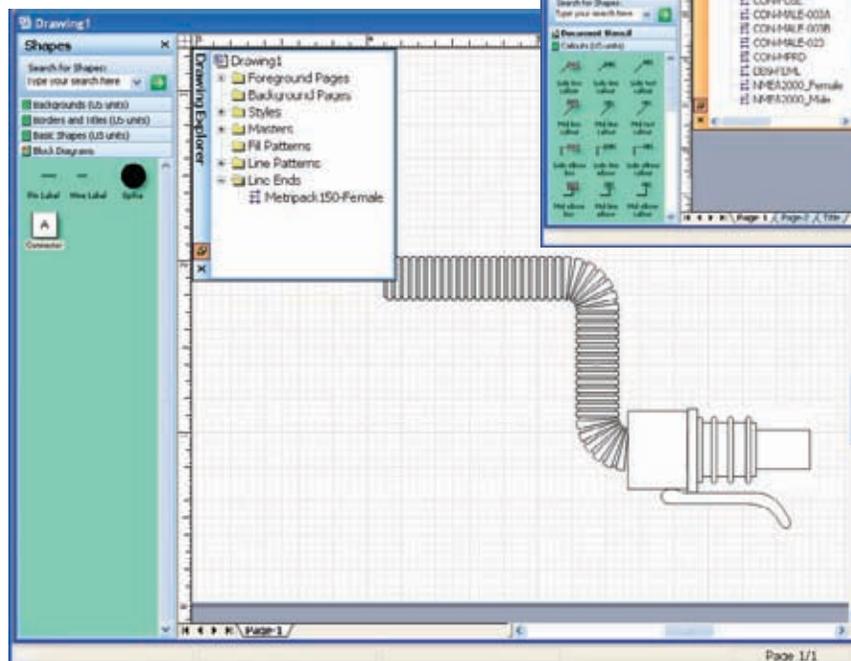


Visio doesn't make it easy to put line ends and line patterns into a stencil. However, if you pull a wire with the correct ends from another drawing, Visio will automatically add those new ends and patterns to your new drawing.

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.



Back to 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.

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 the 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 and BOM for your drawing.

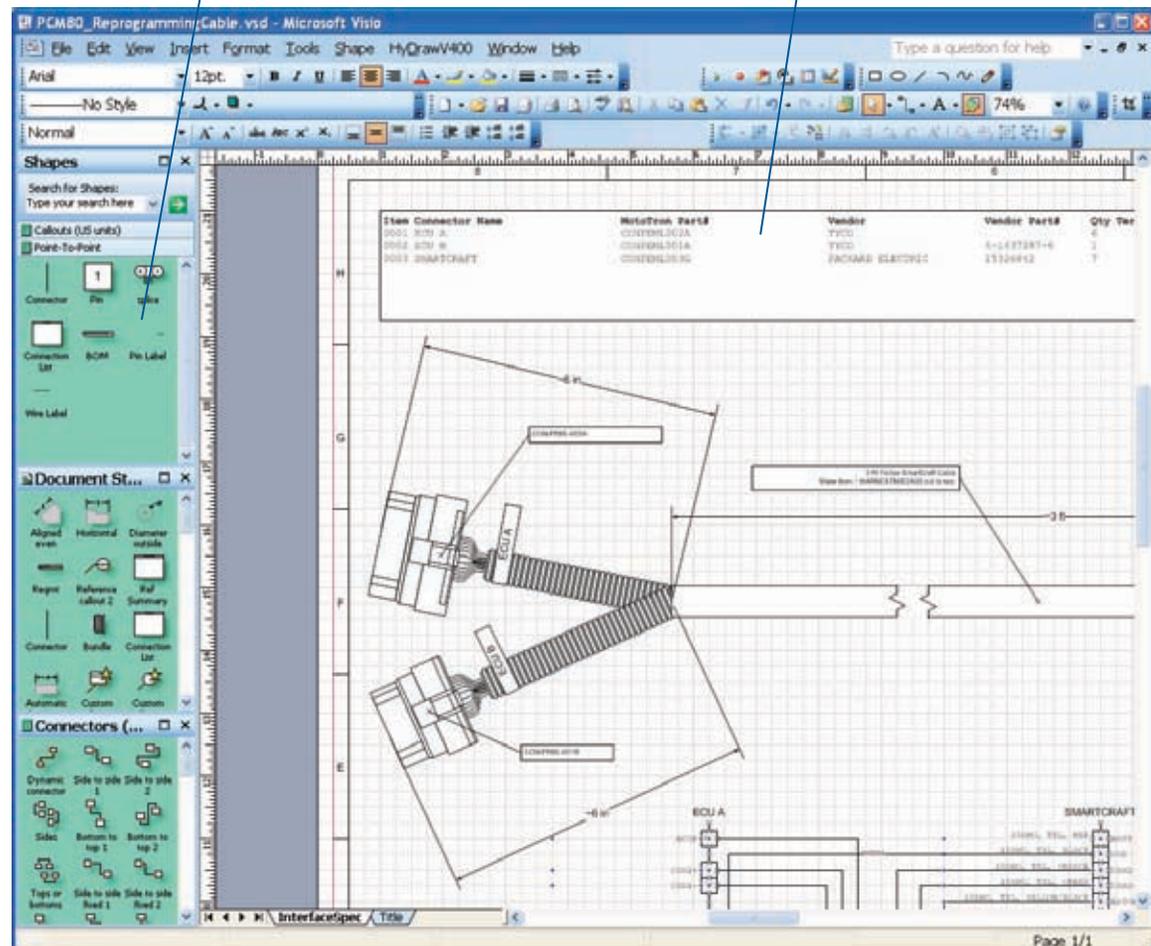
Lets take a look...

Stencil: Point-To-Point.vss

This has the "proper" shapes that you will need.

Bill of Materials

Double Click to refresh.



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!!

Connector
Double Click
to record the
BOM details.

Custom Properties

Connector Name: SMARTCRAFT

MotoTron Part Number: CONFEM009G

Vendor: PACKARD ELECTRIC

Vendor Part Number: 15326942

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

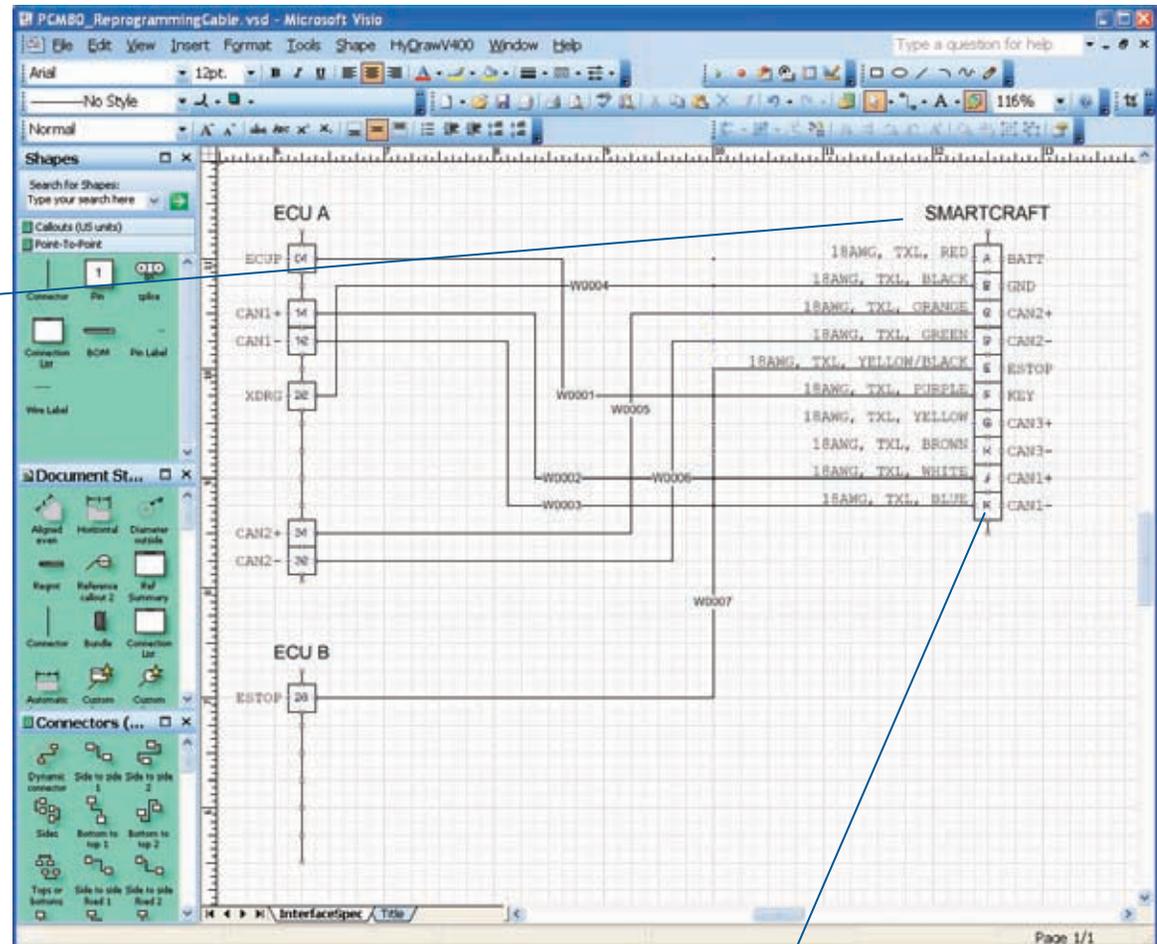
Cover Part Number:

Strain Relief Quantity: 0

Strain Relief Part Number:

Prompt
Connector Name

Define... OK Cancel



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.

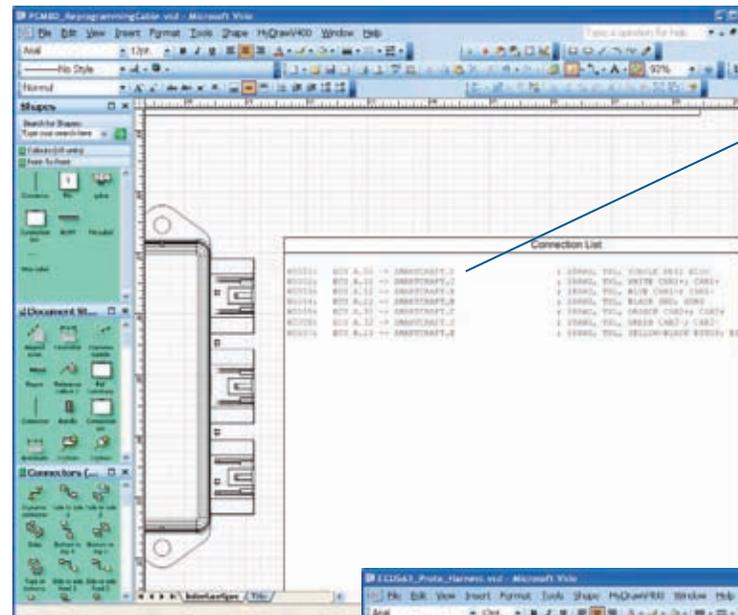
Typically, you would think of the A side meaning the left side of the splice and the B side as the right.

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!



Harness Connection List
Double Click to update.

Note how the J1939 connector and the Smartcraft connector share one side of the splice with the other side heading toward the ECU

