"I am proud of the fact that I never invented weapons to kill"
- Thomas Edison

Fifteen percent of all Americans spend an average of ten minutes each day searching for their television remote controls.
- Eli the Mule, CEM

GilderAppNote

Application Hints from Gilderfluke & Co.

GilderHeadquarters ▪ 205 South Flower Street ▪ Burbank, California 91502-2102 ▪ 818/840-9484 ▪ 800/776-5972 ▪ FAX: 818/840-9485

Build a Motion Base

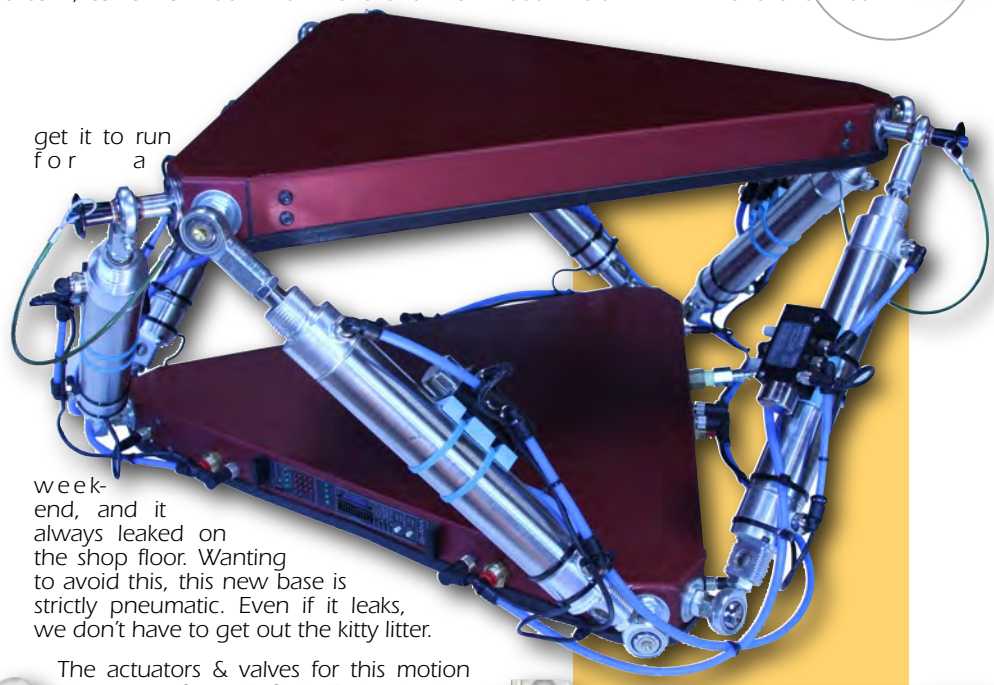
For 2011's IAAPA we built a small motion base for demonstrating the programming abilities of our Pc▪MACs software, and the simplicity of a Gilderfluke & Co. control system when applied to a motion base attraction.

Motion bases come in many flavors. In motion base lingo, this is usually described in terms of the number of 'Directions of Freedom' or axis of movement, commonly shortened to the simple abbreviation 'DOF's. Most small motion bases are three, or less commonly, two or four 'DOF'. These have two, three or four actuators moving the motion base.

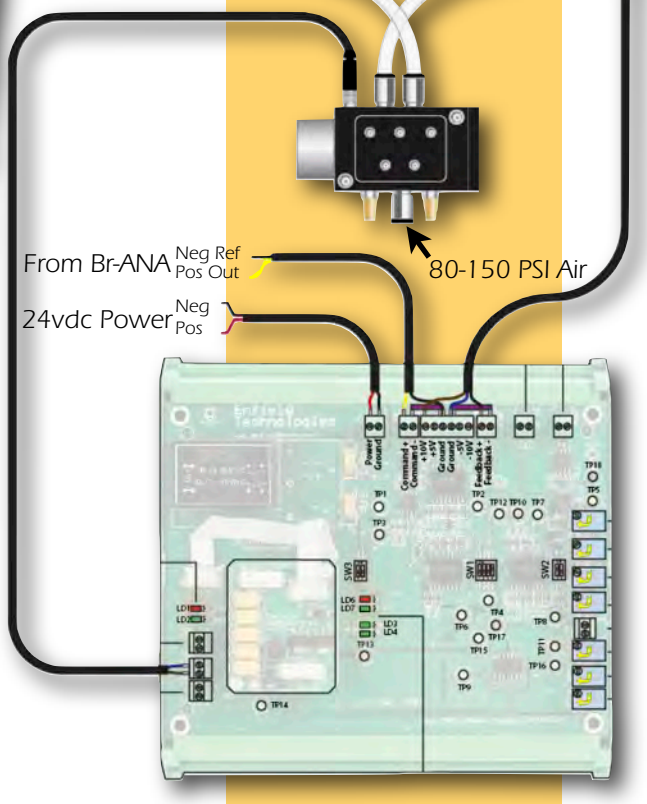
The 'Cadillac' of motion bases is a 'Six-DOF'. It has six cylinders arranged in three pairs of triangles. The motion platform can move in any of six possible directions. These are also sometimes referred to as a 'Stewart Platform', 'Gough/Stewart Platform', or simply 'Hexapod' for the six legs. This is what we will be building for our demo unit.

The actuators on any motion base can be hydraulic, pneumatic, electric, or a combination of these. In almost all cases, the actuators are controlled as closed loop proportional analogs. The control system continually monitors a position sensor on each actuator, compares the position of the actuator with the position that the control system (that's our part of the system) is asking for, and moves the actuator to match.

Our older demo motion base was an electrically actuated hydraulic system. It was our 'British Sports Car' of demo gear. When it ran, it was really fun, but we had to tinker with it for weeks to get it to run for a weekend, and it always leaked on the shop floor. Wanting to avoid this, this new base is strictly pneumatic. Even if it leaks, we don't have to get out the kitty litter.



The actuators & valves for this motion base are from Enfield Technologies. The actuators are 1-½ inch bore and six inch



Today's Shopping List

1) Br-ANA Analog Output Show Controller (Gilderfluke & Co.)
1) Br-CC08 Card Cage (Gilderfluke & Co.)
1) Ps-24vdc5a Power Supply (Gilderfluke & Co.)
6) LSV05C ServoValves (Enfield Technologies)
6) LSC41 EFB Cards (Enfield Technologies)
6) Act1b150s0600 6" stroke, 1-½" bore (Enfield Technologies)
6) Ball Joint, 7/16"-20 Female (McMaster-Carr 60745K851)
6) Ball Joint, 7/16"-20 Male (McMaster-Carr 60745K651)
12) Nylon-insert Locknut 7/16"-20 (McMaster-Carr 97135A245)
6) Steel Thin Hex Nut, 7/16"-20 (McMaster-Carr 94846A520)
12) Washer, 7/16" x 1-1/4" Od (McMaster-Carr 90108A032)
12) Washer, 7/16" x 59/64" Od (McMaster-Carr 90126A032)
10') Self Gripping Vinyl Edge Trim (McMaster-Carr 24175K131)
2) Tube Stem Elbow 3/8" x 1/4" (McMaster-Carr 5779K686)
7) Tube Stem Tee 3/8" x 3/8" (McMaster-Carr 5779K695)
1) Bulkhead 3/8" Od Tube x 3/8" npt (McMaster-Carr 5111K206)
4) Bulkhead 3/8" Od Tube (McMaster-Carr 5779K679)
4) 3/8" Od to ¼" Tube Reducer (McMaster-Carr 5779K718)
12) Elbow ¼" Od Tube x ¼" Npt (McMaster-Carr 5779K152)
18) Elbow ¼" Od Tube x 10-32 (McMaster-Carr 5779K286)
12) Exhaust Muffler 10-32 (McMaster-Carr 4450K31)
50') Blue Nylon Tube ¼" Od (McMaster-Carr 51185K113)
10') Blue Nylon Tube 3/8" Od (McMaster-Carr 51185K222)
6) .2" Nano Connector, 90° FM Plug (McMaster-Carr 7138K21)
6) .2" Nano Connector, Male Plug (McMaster-Carr 7138K11)
1) 2.1mm snap-in power Connector (Mouser 163-1060-EX)
2) RJ-12 Chassis Connector (DigiKey TM2RG-L66-5S-150M)
1) XLR-5 Male Chassis Connector (Mouser NC5MD-L-1-B)
1) XLR-5 Female Chassis Connector (Mouser NC5FD-L-B-1)
12) Snap In Strain Relief (McMaster-Carr 74125K11)
1 set) Motion Base Sheet Metal (Base and Platform)
misc) wires, screws, nuts and other small parts

Now

Programing Your Motion Base:

Once you have built your mini Motion Base, here's how you make it move. You will need:

- The Latest Pc▪MACs
- A PC of some sort
- Rs-422 port & cable
- USB-MbJoystick
- Motion Base Video

If you don't have a motion base video, go ride in a roller coaster while holding your iPhone over your head to video the ride. Views from the back seats work the best.

In Pc▪MACs, create a 'new' show & site file. Select 'Audio/Video' for sync and point Pc▪MACs at your video file. This will bring up your video while you are programming so you can match your movements to it. Add a Br-ANA to the channels list (12 bit resolution). Select your serial port and enable 'RealTime Updates' and select 'Soft Console' as your programming console. These are set under the preferences menu.

Plug in the serial cable to the base. Configure the Br-ANA for twelve bit resolutions and adjust the gain & endpoints for your base.

Open the Soft Console, assign your first six sliders to the first six analogs. Hit the 'find Joystick' button. Turn on 'manual' mode. You can now move your motion base by moving your USB-MbJoystick.

Now you are ready to hit 'Record' and 'fly' your base! You can then use the OffLine window to edit your show until it is 'perfect'. When done, save all your shows to the Br-ANA's Sd flash card. ~ G

stroke, and have built-in feedback sensors (potentiometers). These cylinders are also available with non-contact types of position sensors, which will potentially last much longer. Moving from the 6" stroke cylinders to 12" stroke cylinders or to a slightly larger bore cylinder would result in a larger base, for only a small amount more cost for the longer cylinders.

With 100 PSI, these six cylinders will lift about 175 pounds each. With six of them working together, this base should be able to lift about 1000 pounds, but because of the angles of the cylinders and uneven loading, the actual limit is around 500 pounds. This should be plenty of umpf if you want to bolt a chair to the top and take a ride.

Because this base is pneumatic and air is a compressible medium, this base will be more 'spongy' than a base that uses electric or hydraulic actuators. Using a higher supply air pressure will make it less so, but may cause problems with hoses popping off.

We wanted the ball ends to be located on the same center lines as the cylinders. We ordered the cylinders with 'universal' mount tails. We temporarily removed the tails from the cylinders and using just a drill press, we drilled and tapped them 7/16"-16 so we could screw the tail rod ends into the ends of the cylinders.

Jamb nuts were used on each of the rod ends, so that they won't come unscrewed too easily. If you are making a 'real' motion base that will be carrying people, you should use aircraft safety wires to keep the rod ends from unscrewing.

The ball end studs are attached to the top/bottom plates using the 7/16" x 1-¼" and 7/16" x 59/64" washers sandwidged on each side of the sheet metal (to spread the load) and held in place by the nylock hex nuts. These too should be safety wired if you will be carrying people.

A solenoid valve is either open or closed. The valves used for most motion bases are analog. They can open a little or a lot, as needed. The Enfield LSV05C valves we chose use a 'voice coil' to move the spools of the valves, and as a result draw more than out EFB-Quad to PID-Quad Electronic FeedBack (EFB) cards can source. We used the Enfield LSC41 feedback cards to take the 0-10 volt position commands from our Br-ANA, and close the feedback loop with the valves and cylinders. They are wired/plumbed as shown above. The '24 vdc power' should be wired directly to the base's 24 vdc power supply connection, and not to the Br-ANA.

Enfield has a new 'S2' feedback card that you may choose to use in place of the LSC41. It adds a new control algorithm with an inside differential pressure loop. The result is better performance, less space, and lower cost. They also have a 'S2' new valve with integrated electronics and differential pressure sensor. It has a much higher maximum flow rate, which can control much larger cylinders.

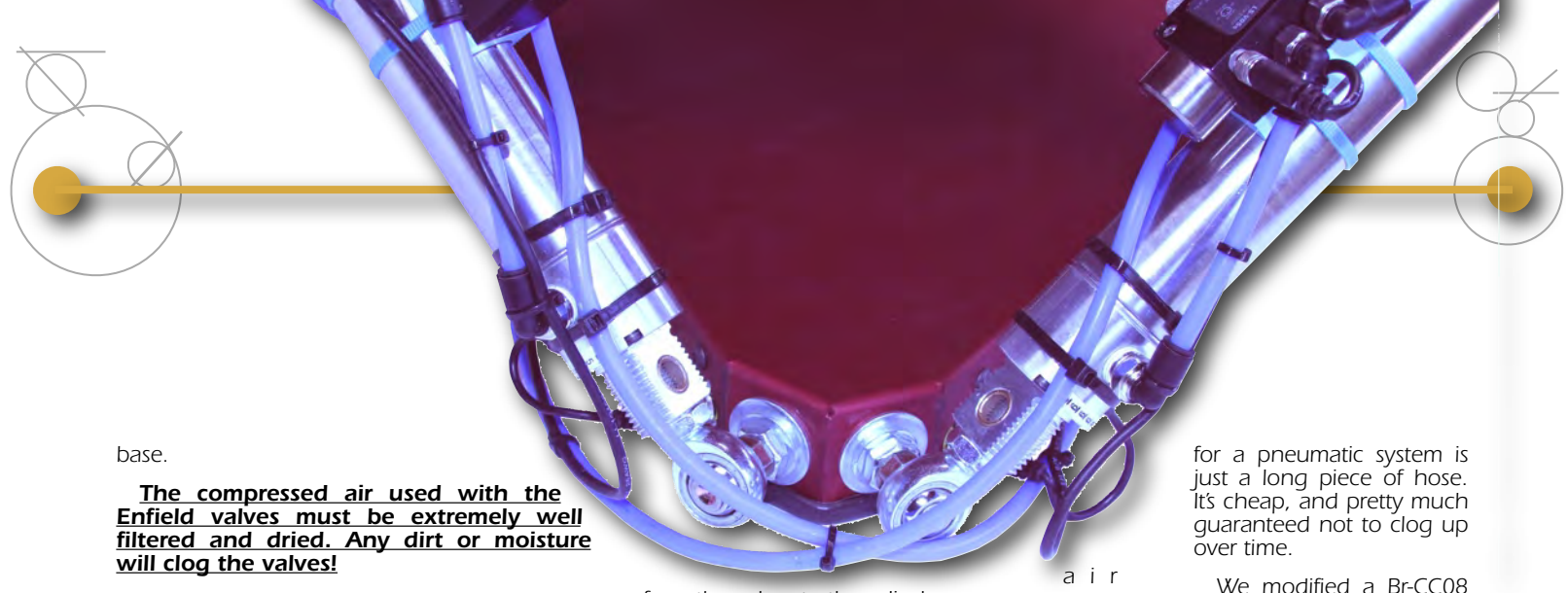
The geometry of a typical six DOF platform is a hexagonal base and a hexagonal platform. The actuators attach to three of the corners on the base, and three of the corners on the top. Since only three corners are used on the top or bottom plates, the unused corners are usually truncated. This makes the base and platform look more like a pair of triangles, with the platform rotated 60° from the base. If you project the corners where the actuators attach, you can see that the shapes were originally hexagons.

The size of the base is determined by the retracted length of the actuators. Viewed from the side, typical 6-DOF entertainment bases have the actuators sitting at about a 45° angle when retracted. If you calculate a right angle triangle, with the long side equal to the length of your actuator, and at a 45° angle, this will give you the lengths of each side of the hexagon base and platform. Just a tad more needs to be added to the calculated side length so there is room to attach the actuators to the base and platform. You want each pair of cylinder attachments to be as close as is physically possible to each other. In this case, we added 1.6" to the calculated length for the actuator attachments.

The base and platform of our model are both made from (almost) identical pieces of .1" thick sheet aluminum. This was water-cut and fabricated by our sheet metal supplier. The corners are welded, but after one particularly large person tested its load capacity, some of these welds opened up. We have since added some straps on the insides of the corners to prevent this in the future. Even with these straps, this base is not intended to be a 'working' motion platform. If you want to build a base that will carry heavy loads on a day in, day out basis, you will need to make it sturdier than this 'demo' model.

The difference between the top and bottom pieces is that the top has just the six mounting holes for the six cylinders. The bottom also has holes for the Br-ANA card, wires and air lines.

The compressed air enters the motion base through the ⅜" NPT fitting on the side of the



base.

The compressed air used with the Enfield valves must be extremely well filtered and dried. Any dirt or moisture will clog the valves!

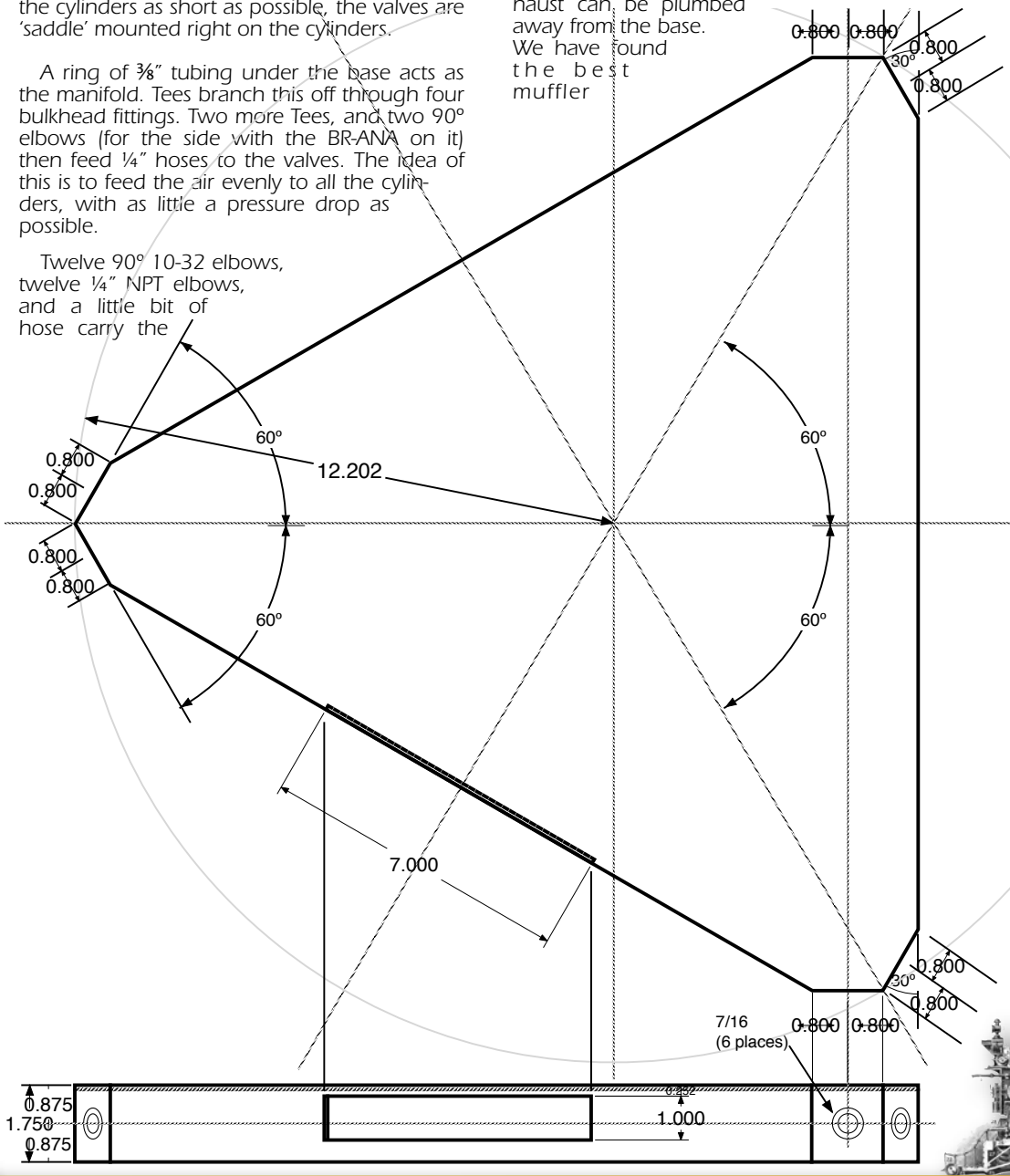
If you possibly can, build a 'last chance' filter right into your motion base to protect if from anything that gets past the main filters.

To keep the hoses between the valves and the cylinders as short as possible, the valves are 'saddle' mounted right on the cylinders.

A ring of ⅜" tubing under the base acts as the manifold. Tees branch this off through four bulkhead fittings. Two more Tees, and two 90° elbows (for the side with the BR-ANA on it) then feed ¼" hoses to the valves. The idea of this is to feed the air evenly to all the cylinders, with as little a pressure drop as possible.

Twelve 90° 10-32 elbows, twelve ¼" NPT elbows, and a little bit of hose carry the air from the valves to the cylinders.

Small exhaust mufflers screw right into the valves. If you want your motion base to run even more quietly, this exhaust can be plumbed away from the base. We have found the best muffler for a pneumatic system is just a long piece of hose. It's cheap, and pretty much guaranteed not to clog up over time.



We modified a Br-CC08 card cage to hold the Br-ANA. You may want to leave it intact or just use a sixty pin ribbon cable edge connector to make your own cage. The first six analogs are wired to the Enfield control boards. Power, DMX-512 and the Rs-422 serial port are wired to jacks on the outside edge of the base to make them easier to get to.

In our prototype, we used bulkhead connectors at the points where the wires to the valves or wires from the feedback pots went through the base. To simplify construction, we are recommending using standard snap-in strain reliefs instead. The holes for these smaller wires and plumbing are now shown on the drawing for the motion base top/bottom plates. Just drill them as needed. You can see these in the photo of the motion base on the first page of this app. note.

Another mod we made to our motion base was to make it easier to transport. Three of the top rod ends are connected using 'push-to-release' quick connect pins. This allows the base to be quickly flattened down for ease of transport.

You can see videos of this motion base in action and the process of programming it using our Pc▪MACs software at the GilderWebsite and YouTube. ~ G