Girandola Design Considerations

Figure 1: A 12" and 24" girandola.

Figure 2: A 24" girandola that launches four quad tourbillions during flight.

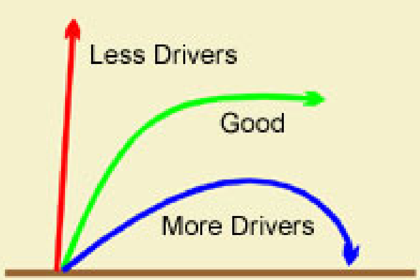

Figure 3: Stick test flight path indicators.

Introduction:

Girandolas are perhaps one of the most complex types of fireworks commonly made by the hobbyist. These spin stabilized flying set pieces involve almost all aspects of other firework devices! They combine the functionality of rockets, wheels, gerbs, lances, shells and anything else that the designer can lift into the air with them.

The amount of lift a girandola is capable of is much higher than what a typical rocket can provide, which allows this device to carry a much larger payload of effects. The ability to lift such large payloads in a slow and controlled manner is what makes girandolas such an open ended platform for creativity.

Designing the proper amount of lift, arranging the components in a stable fashion and fusing it all together in a reliable manner is what makes girandolas such a challenge. This article touches on the basics behind designing reliable girandolas and some of the different effects possible.

Thrust Calculations:

One of the first things you will need to determine when designing a girandola is the number of drivers required. Many people simply figure this out by trial and error, or even worse, just take an educated guess and send their piece into competition with no testing at all!

While the trial and error method will work, it is very time consuming to build a complete girandola several times just to find out the optimal number of drivers. It is indeed possible to calculate the exact number of drivers you need in order to get your girandola to fly to a desired height.

Stick Test Method:

The most common method of testing girandola drivers is the stick test. For this test to work, you have to know the weight of all girandola components minus the weight of the drivers. This includes the weight of the frame, the headers, horizontal drivers etc. Once this weight is known, it is divided by the number of drivers you think will be required. A wooden rocket stick is then fabricated that equals this weight, and one driver is produced and fired as a rocket using the weighted stick.

The speed and height of the weighted rocket will give you a good indicator as to how the resulting girandola will perform. If the stick rises too slowly and the rocket arcs back to the ground, then more drivers will be required. If the stick rockets up in a straight line like a normal rocket, then less drivers will be required than you had anticipated. The ideal flight should be a rather slow moving rocket that still arcs quite a bit but never heads back down to the ground (see Figure 3).

While this method still requires trial and error, you only have to build a single driver each time instead of fabricating an entire girandola. Only a single girandola is built for the final test, and if the stick test was carried out correctly then the fully completed girandola should work as anticipated.

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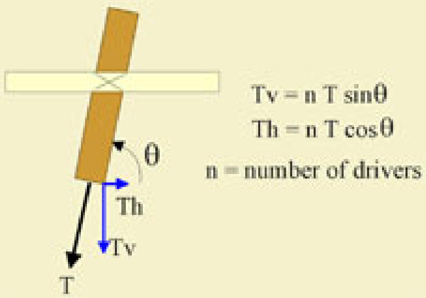

Angled Driver Thrust Calculator:

Driver Thrust = [ ] g

Angle = [ ] deg

Driver Count = [ ]

Vertical Thrust = [?] g

Horizontal Thrust = [?] g

Calculate

Thrust to Weight Ratio Method:

One flaw with the stick test method is that it is not accurate for girandola designs in which the lift drivers will be mounted at an angle, which is quite common for maintaining horizontal rotation during flight. When mounted at an angle, the drivers total thrust will be divided into a horizontal and vertical thrust vector, as illustrated in the calculator to the left. Thus, the usable vertical thrust will be less than the thrust of the driver itself.

In this case it becomes necessary to measure the actual thrust of the driver. While many contraptions have been devised for measuring driver thrust, one crude yet workable method is to build a fixture that allows you to measure the thrust using a digital scale. A piece of plywood that overhangs the edges of the scale to protect it from fallout is fitted with a hole equal to the O.D. of your driver. The driver is tightly inserted into this hole with the nozzle end pointed upward, and the board is placed on the scale. It is recommended that you use an inexpensive scale for this purpose in the event your driver detonates.

A method must be devised for reading the scale when the driver is fired. This can be done with binoculars from a distance, or possibly using a video camera on a tripod. If your readout is large enough, you may even be able to wear a face shield and read it visually from a distance. Make the assumption that the driver will detonate, then devise a remote viewing plan based around that hazard.

There will be an initial impulse from the driver when it first takes fire that is greater than its sustained thrust. Since the weight of the driver is also decreasing as it burns, the thrust readout will appear to decrease as it burns. However, the decrease in weight is not likely to exceed 8% of the thrust value so it can be ignored. You are just trying to get a rough estimate of the average thrust, so you need to pay attention to the range of numbers that will appear on the scale.

Once you have a good thrust reading, it becomes quite easy to determine the number of drivers you need without any further testing. While the thrust values can be used with elementary physics equations based on Newton's laws of motion, I have found that a much simpler method is to maintain a desired thrust to weight ratio for your girandola. Through experimentation, I have found that if the total thrust for a given design is about two and a half times greater than the total weight for the completed girandola, then you will get a very pleasing rate of ascension that reaches a height of around 250 feet if the burn time is at least seven seconds.

If your drivers burn for a longer period, say 10 seconds, then you will want to lower the thrust to weight ratio to around 2.0, unless a very high flying girandola is what you desire. Keep in mind that girandola headers are typically not much larger than 2" shells at the most, so sending a girandola up 500 feet will diminish the perceived size of the header bursts for your audience.

One nice advantage to using the thrust to weight ratio method of design is that you can modify your girandola and still be able to accurately determine the correct number of additional drivers you may need. If you decide you want bigger headers half way into your project, you can just determine the total weight with the new headers and then solve for: thrust = 2.5 x weight. Keep in mind that lower thrust to weight ratios will result in slower ascension speeds, and higher ratios result in higher ascension speeds. Thus, your thrust to weight ratio needs to be dialed into your driver burn time and your personal preference for rate of ascension and final height achieved. The 2.5 value gives you a good place to start with your own designs.

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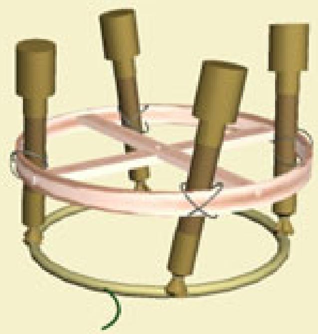

Figure 4: Design with no horizontal drivers (not recommended).

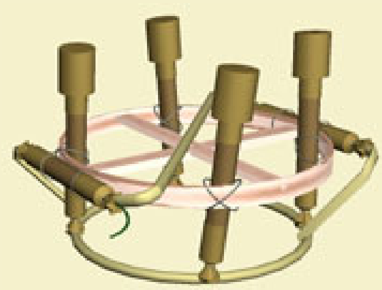

Figure 5: Classic girandola design.

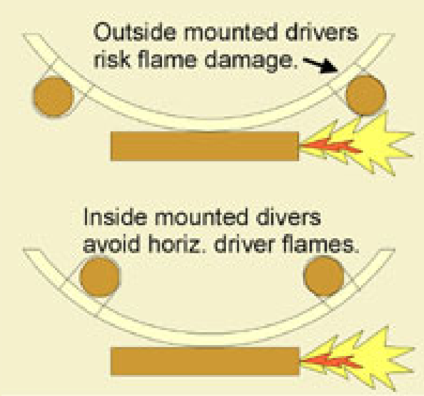

Figure 6: Advantage of placing vertical drivers inside the frame.

Vertical Driver Angle:
Although it isn't necessary to angle your vertical drivers, doing so helps maintain the horizontal spin that serves to stabilize the girandola during flight. Some designs utilize horizontal drivers that burn during the entire flight of the girandola, which eliminates the need to angle the vertical drivers. This allows the full thrust of the vertical drivers to be utilized for lift.

Other designs utilize a rather large angle on the vertical drivers as a replacement for the horizontal drivers completely, as seen in Figure 4. While this type of design can be made to work, it is more prone to failure when all the drivers do not ignite at the exact same time. Since there is no gyroscopic stabilization set in motion at the time of lift off, uneven ignition of the vertical drivers can easily cause the girandola to flip over and become a disappointing display of ground fountains.

The most common design uses horizontal drivers that spin the wheel up to speed and then ignite the vertical drivers at the end of their burn. The vertical drivers will have a slight angle to them to keep the spin going as it rises into the air. This angle really doesn't need to be much more than 15 degrees from the vertical plane (note that this translates to 75 degrees when using the calculator on page 2).

Driver Design:
Most girandola drivers are end burning black powder rockets, which is to say they have no cavity inside the powder charge. This is necessary in order to maximize the burn time from the driver. Girandolas are not devices meant to rapidly fire into the air in the way that rockets do. The characteristic that sets them apart from any other kind of effect is the long duration and slow speed of their ascent.

All drivers have a design tradeoff between thrust and duration. All other variables remaining constant, higher thrust from faster burning composition results in shorter burn times. While it may be tempting to save work by using fewer drivers that produce more thrust, this approach significantly increases the risks of driver failure during operation. Building drivers that operate right on the edge of detonation in order to reduce the number of drivers required will result in ruptured casings and blown out end plugs at the worst possible times (i.e.- during competition).

It is always a better idea to produce a lower thrust driver that performs well within the tolerance of the tubes and plugs you are using and just use more of them to get the lift you want. It is less stress to make a few extra drivers than to have your girandola blow drivers and fail to get off the pad due to uncontrollable variances in your process, materials, relative humidity or whatever keeps the same thing from working the same way twice.

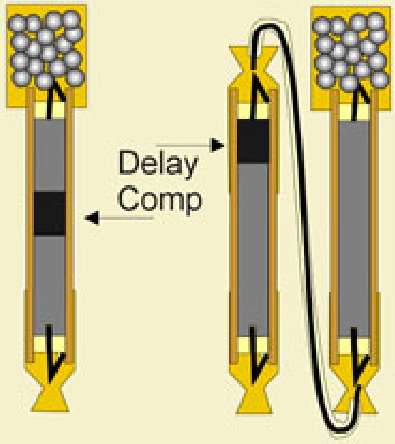

Figure 7: Two methods of producing "bouncing" girandolas.

Figure 7 shows two methods of producing a "bouncing" girandola, which is an effect where the girandola pauses mid flight, sometimes even dropping back towards the ground before a second stage boosts the girandola upwards again. The simplest method is to utilize a delay composition at the center of all the drivers, which is a slower burning comp with less thrust. The normal driver comp is then rammed on top of the delay so that the girandola will resume normal thrust levels after the delay has executed.

A more complex bouncing girandola scheme uses two separate sets of drivers. While this method produces a longer lasting performance, the extra weight that the first set of drivers are required to lift can make this design difficult to implement. This method will require considerably more drivers to achieve virtually the same visual effect.

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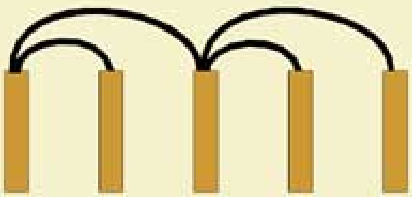

Figure 8: Skip fusing method.

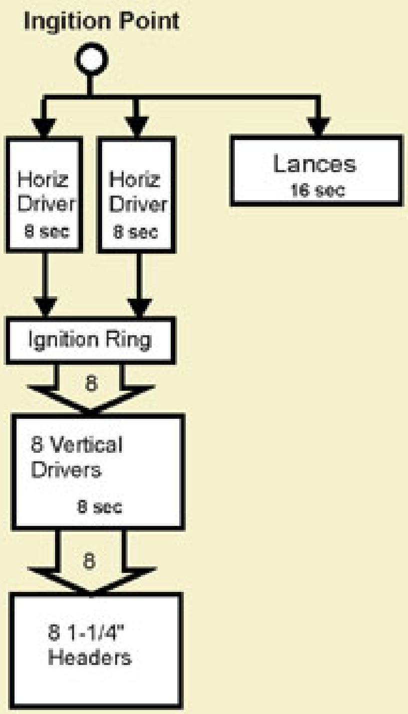

Figure 9: Ignition diagram of an angled driver girandola with lance work.

Fusing It All Together:
Large girandolas containing many effects can contain upwards of 40 ignition points or even more. Reliable fire transfer to each of these junctions is critical to proper performance. This is especially true in the case of the vertical drivers, since they must all ignite at the same time.

One problem that often occurs with the use of quickmatch on complex set pieces is when pieces of match recoil from the rapid movement of gas through the pipes during fire transmission. If the black match that passes fire into the driver choke is physically connected to the piped match leading to it, the match stick can easily be yanked from the choke hole and result in ignition failure. For this reason, it is best not to couple the passfire that enters the driver with the match that ties into the nosing. Fusing the choke with a small piece of match that is fastened to the case with either hot glue or prime slurry is a good way to avoid this problem (see this page for an illustration of this method).

There are a few different methods for fusing all the drivers together in order to obtain rapid fire transfer to all of them at once. One trick used by the Maltese involves a pattern of matching the drivers which is illustrated in Figure 8. The idea is to create multiple channels for the fire to travel so that the fire does not progress in a single-file fashion. The match simultaneously ignites the next driver and also the one after it at nearly the same time. This skipping pattern cuts the propagation time in half.

A second method of fusing the drivers involves creating one large hoop of match I call the "ignition ring." This is a continuous piece of match with no obstructions that allows the fire to shoot around in a ring. Regardless of where the fire first enters the ring, flame propagation heads down the ring in both directions very rapidly. Holes are punched in the sides of the ring to accept pieces of black match from the drivers and anything else it is to ignite.

Anytime a piece of piped match is tied into the nosing of a junction of any kind, bending the piece of exposed black match into a hook is a precautionary step that helps insure that the black match will not accidentally get pulled out of the junction during assembly or even from the recoil during ignition.

When designing the sequence of events that is to take place on your girandola, or any other set piece for that matter, it helps to make a flow chart as shown in Figures 9 and 10. These charts lay out the ignition paths as well as define the timing of events.

The example chart in Figure 9 shows a girandola in which two horizontal drivers ignite first along with a pattern of lance work. Note the redundant ignition path coming from the horizontal drivers to the ignition ring. Should

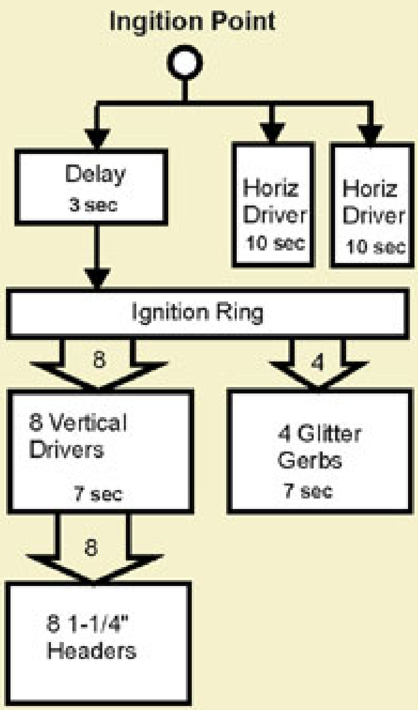

Figure 10: Ignition diagram of a girandola with continuous horizontal drivers.

either path fail, there is a backup to ensure that the ignition ring takes fire.

The example in Figure 10 shows the design for a girandola where the horizontal drivers continue to burn for the entire flight of the girandola. The design could be improved by adding a second delay circuit leading to the ignition ring, once again adding the desired redundancy for insuring ignition of the main event.

Not only do these type of diagrams serve as a good visual aid when designing your girandolas, they make useful blueprints when you reference your notes at a later date in hopes of repeating your efforts. Too many people produce one hit wonders that can not be duplicated months later when they realize they took poor notes on the project.

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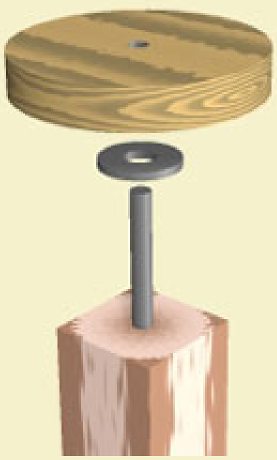

Figure 11: A launch stick with stabalizing platform.

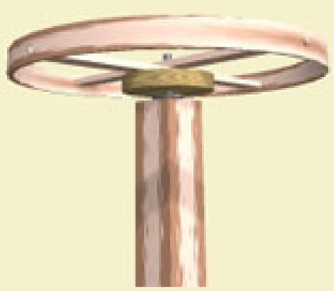

Figure 12: Launch stick with wheel in place.

Launch Sticks:

The best girandola in the world will get nowhere without a well designed launch stick. Neglecting this seemingly trivial component can lead to disappointment. Perhaps the biggest mistake I've seen with launch sticks is overly long center pins. The pin that allows the girandola to spin before taking off should be made as short as possible. As soon as the girandola has enough lift to fly, you want it to clear the pin as fast as possible so that it doesn't have to fight friction and lose valuable air time. However, you don't want the pin to be so short that the girandola could flip off the stand in the event of uneven driver ignition. I prefer to use a 1" pin for single frame girandolas and 2" for double frame types.

For small girandolas that only contain a single flat frame, some builders will fasten a cardboard tube into the center hole that slides over the pin on a launch stick. This adds unnecessary weight and can be eliminated by using a different launch stick design as shown in Figure 11. A wooden disk of about 3 inches in diameter is used as a stabilizing platform for the wheel to rest on during launch. This platform must freely spin so that it will spin with the girandola if it needs to. The little bit of time spent making this extra component of the launching stick is well worth the work saved of not having to attach tubes to the center of every girandola wheel you make. This stabalizer disk also helps to eliminate wobble in larger double frame girandolas as well.

Lastly, the stick itself should be firmly grounded. If it can still wobble after being buried in the ground, then the post can be staked down with lengths of twine.