TRIPOLI Vegas 6

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Gyro Rockets

by Steve Ainsworth and Brian Riordan

On March 9, 1996 at Eldorado dry lake (Springfest 96) I conducted the third flight of my gyroscope controlled guidance system. The flight was documented on video by Ky Michaelson and is included in the Rocketman Springfest 96 video (one of, if not the best launch video yet!).

This guidance system is designed to keep the vehicle on a vertical flight path to obtain the highest possible altitude with the least travel downrange. The ultimate goal being to use the system on the next Las Vegas Tripoli Altitude attempt. The forward fin size and position were selected to keep the CP well ahead of the CG for the rocket to maintain a stable flight even in the event of gyro failure.

The system was developed by testing the effectiveness of the commercially available model helicopter gyro for roll control. I selected controlling the roll axis first since a failure would not be as catastrophic as a yaw or pitch control failure.

I contacted FUTABA and discussed the project with one of their service tech's who provided some valuable information on their gyro:

1) The gyro needed a 1.5ms pulse sent every 20ms. The gyro would normally get this pulse from the helicopter receiver. FUTABA suggested a G154 gyro.
2) Futaba provided a prototype schematic for a circuit to generate the needed pulses.
3) The gyro, which is driven by a small electric motor can run on up to 6 volts, which also increases its rpm and thus its sensitivity. The gyros work very well to control model helicopter yaw when powered at 5 volts.
4) There is a separate power circuit to the gyro motor separate from the 5 volt power supply for the electronics.
5) They recommended using the FUTABA S9101 servo since it is one of their fastest and has a .17 second travel time to move 60. The total throw for this application is about 5.

FUTABA was not certain how their gyro would react under boost acceleration, and they were not sure the gyro's response would be fast enough.

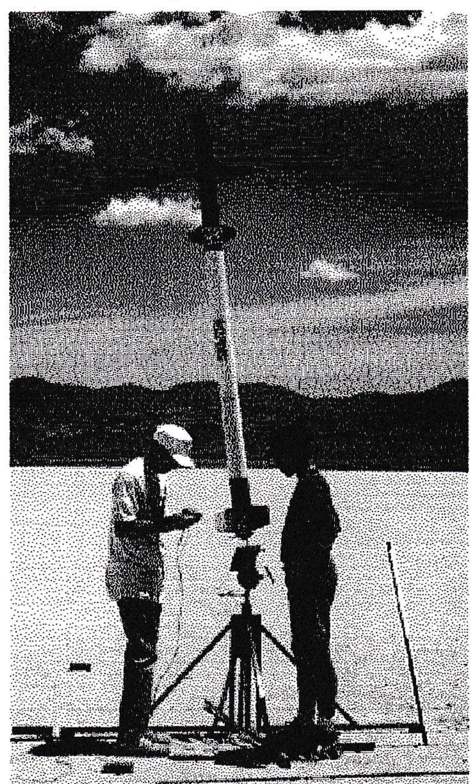
Brian Riordan TRA#3551 is a member of the LV Tripoli and is also an electronics engineer. Brian agreed to construct and test the pulse generator. During that process he corrected several errors in the FUTABA prototype circuit. The resulting circuit is simple and all parts are available from Radio Shack. Brian constructed two pulse generators on one circuit board, each with its own adjustable pot to permit electronic zeroing of the control surfaces prior to each flight.

The first test flight was conducted at Eldorado dry lake on Jan. 20, 1996 and a single gyro was used to control roll. The single servo was connected to two counter pivoting flaps to provide roll control only. I then added sections of "trailing edge" material to one side of each of the three fins on the EZI boost vehicle, to create a forced roll for the test. The overall vehicle weight was 7 pounds all lifted aloft with an Aerotech H180W. The chute deployment did not function but the rocket fell sideways and only the phenolic guidance bodytube was damaged. The rebuilt guidance section now is 4" LOC cardboard tube. The entire flight was videotaped (from the ground) and no roll was visible during the flight. The rocket was painted dark blue with a 2" wide white longitudinal stripe to aid in visual observation of roll.

A second test was conducted by installing the gyro in a radio-controlled Estes Astro Blaster boost glider controlling pitch, which is the trickiest axis to control, especially during boost. Two flights were made and both were videotaped. Some porpoising was evident, but the gyro functioned at an acceptable level for the boost glider. I was also able to crash test the gyro one more time – they are rugged!

The second rocket test occurred on Feb. 17, 1996, this time using my modified EZI booster (with 4 fins) powered by an Aerotech hybrid J210H donated by Gary Rosenfield (my first J motor flight). This was the first flight with gyros providing control of pitch and yaw. The guidance section control surfaces are situated in front of the rocket CG due to construction restrictions and a desire to reduce the length of any control rods between the servos and the control surfaces. The control surfaces are F-16 style trapezoidal surfaces that are 100% movable. The control surface axles are placed just ahead of the control surface center of pressure to provide a zeroing force on them, and hopefully reduce flutter. I have not been able to find any data that I could use to predict the force exerted on the rocket based on the surface, size, and deflection for various velocities, so I decided to start small and work up. The gyros are located as close as practical to the CG, with the control surfaces about 18" ahead of the CG. The overall rocket length is 70", with the booster's fins 38" behind the CG with far greater surface area. The rocket would be stable, even with the control surfaces deflected to their maximum. The overall weight was 14 pounds including motor. The total weight of the guidance system in a 4" airframe is 3 pounds.

Observers from the LV Tripoli witnessed the guidance system jink the rocket as it was deflected by the wind when it left the



ɿunch rail, and again as it approached ɿpogee. Overall a very successful flight.

The third flight occurred as men-ːioned above at Springfest and is on ‹y's video. Again, corrections to the ·light path are noticeable.

The fourth flight was made at the .V Tripoli Delamar Experimental .aunch on May 18 and used a J90 with ɿ 7 second burn time. The launch was ɿnade in the wind and again course ːorrections were noticeable.

Future tests will include a pulse gen-ɜrator for three servos so roll control ːan be provided together with pitch ɿnd yaw control. With this system, a ɿlow constant roll rate can be built-in ·or altitude rockets to smooth out any ɜffect of off-axis forces. I also plan to ɿse larger control fins with mechanical ɿtops to prevent an unstable flight in ːhe event of a guidance failure.

The cost of a single gyro system is ɿround $120 for the gyro, $90 for the ɿervo and about $20 worth of elec-ːronic parts. The same $20 electronics ːan be used to control the second axis ɿo one axis control costs $230 and two ɿxis control costs $440 total. All con-ɿtruction uses standard radio-control ɔarts and accessories.

Gyro Control Circuit by Brian ɿiordan- Steve asked me to construct a ːircuit suggested by Futaba to control ɿ/C helicopter gyro's he was planning ɔn using in a guided rocket.

The control circuit generates pulses ːhat tell the R/C helicopter gyro's to ɿteer the rocket in a straight path (this ·equires a pulse 1.5ms wide approxi-ɿnately every 20ms).

The schematic supplied by Futaba ɿsed one 555 timer that oscillated with ɿ period of 20ms. This timer in turn ·ires a second 555 operating as a 1.5ms one-shot timer. This causes a 1.5ms pulse to be generated every 20ms. The schematic had a few minor ɔroblems, mostly with component val-ɿes for timing. I planned to use a dif-·erent one-shot timer for each servo, to ɿllow minor trim adjustments to be ɿnade.

I built the circuit on a Radio Shack ːxperimenter Board. I tested the oscil-ator and the one-shot timers separate-y and everything worked great. When connected the timers together the ɔutput looked like an oscillator with a 20ms period, instead of a 1.5ms pulse ɜvery 20ms. After reading the data ɔook on the 555 timer for some time, I ·ound that a much narrower pulse was ɿeeded to correctly trigger the one-shot. The schematic from Futaba hadn't mentioned anything about this. Since I'd already soldered everything, I needed a quick fix that would allow me to salvage as much of my work as possible. Jim Opalinski (an engineer I work with) suggested adding an RC network to shorten the pulse (R4/C7) (D1 was added, because it is possible for the voltage at the trigger pin of the one-shots to briefly exceed the supply voltage with this pulse "shortener"; it's not essential, but it's a good idea). The values chosen for R4/C7 were picked because they "sounded" about right, and may not work with all manufacturer's 555 timers (they worked fine with the Texas Instrument ones I used). C7 may need to be as high as 0.01uf or so and R4 could probably be increased to around 10k.

Hints and Suggestions – Use multi-turn pots for the timer adjustment potentiometers; it's a lot easier to trim the servos using a 15 turn pot than a single turn one.

Each 555 timer should have a bypass capacitor of around 0.01uf connected as close as possible to power and ground connections. It may work without doing this, but you'll save yourself a lot of potential problems using these capacitors. I'd also suggest a bypass capacitor around 10uf as close as possible to where power enters the board.

You could save some board space by using 556 timers (two 555 timers in one package), instead of 555 timers.

If you have any questions or suggestions about the controller circuit you can reach me via email at 150@westside.com.

R/C Servo Operation – Most "standard" Servos designed for R/C use have three connections. The first one is for power, this would typically go to the positive battery terminal. The second is for ground, this would typically go the negative battery terminal. The third is used to control the servo.

R/C Servos are controlled by a technique called Pulse Width Modulation (PWM). A pulse 1.5ms (0.0015 seconds) wide tells the servo to position, and a 1.0ms pulse tells the servo to travel to the full left position. These pulses are usually sent about every 10-20ms.

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Launch Dates

June 22	El Dorado Dry Lake Bed
July 20	El Dorado Dry Lake Bed
August 17	El Dorado Dry Lake Bed
September 21	El Dorado Dry Lake Bed
October 19	El Dorado Dry Lake Bed
November 23-24	El Dorado Dry Lake Bed

Meeting Dates

Every Thursday prior to a launch date