Understanding Accelerometers

Construction

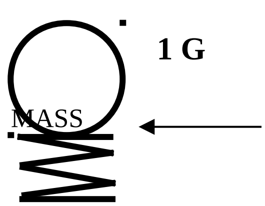
An accelerometer uses a mass and some method to measure how much the mass is resisting acceleration. One common method is to use a spring. This is shown schematically below.

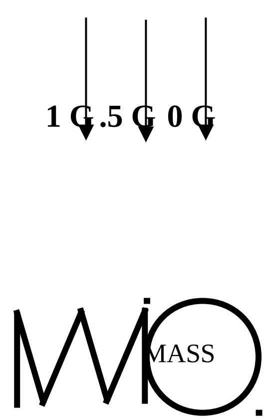
At Rest or in Uniform Motion

Under Acceleration

Calibrating an Accelerometer

One easy way to calibrate an accelerometer is to place the mass directly above the spring. The spring is then experiencing 1 G, which literally means 1 times the force of gravity. From there, a scale can be devised to measure a range of G forces.





Encoding Mass Position

As you can see, the amount of spring compression is directly proportionate to the acceleration. Somehow, we have to get this position into an electrical signal so the computer can interpret it. This can be accomplished with a potentiometer, a piezo electric crystal or an optical encoder. The specific method isn't important, as long as the signal generated is accurate.

Calculating Acceleration

Springs and encoders cannot measure acceleration directly, only force. Luckily, we have an easy way to calculate acceleration from force. It is known as Newton's second law. The formula is outlined below.

$$\textbf{Acceleration} = \frac{\textbf{Force}}{\textbf{Mass}}$$

Useful Numbers

Acceleration in and of itself is not very useful. What you really want to know is distance and speed. The formulas below help make useful predictions.

Calculating Velocity

Velocity = Acceleration X Time

This is useful because the accelerometer measures acceleration and has a built in timer, so it is able to determine how fast the car is moving at any point during the run.

Calculating Distance

Distance = ½ X Acceleration X $(\text{Time})^2$

The accelerometer again uses acceleration measurements and a timer to calculate when you've hit the 60 foot mark and the quarter mile. It is also capable of making 1/8 mile runs and extrapolating the data to predict ¼ mile times accurately. When the accelerometer figures you've crossed the ¼ mile mark, it records the time. This is used in conjunction with the acceleration recorded to calculate velocity as outlined above. Through this method, the accelerometer can determine how fast the car is moving as it crosses the ¼ mile mark.

Calculating Horsepower

Because the G-Tech knows the distance you've covered, and has timed your run, you have an elapsed time for the quarter mile. If you program in the weight, the G-Tech can calculate horsepower using the standard formula below.

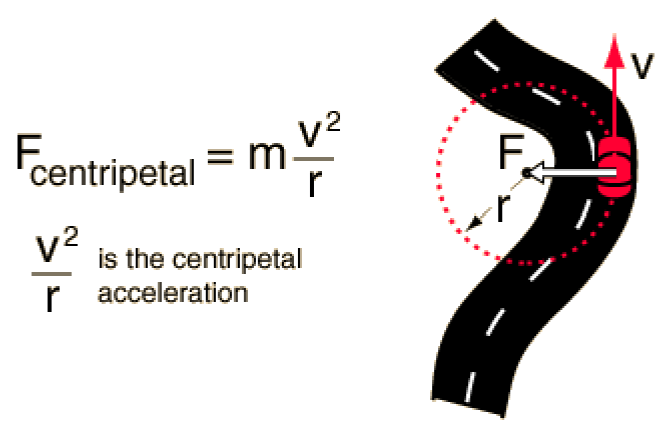
$$\text{HP} = \frac{\text{Weight}}{(\text{ET}/5.825)^3}$$

Lateral Acceleration

$$A_{\text{centripetal}} = \frac{V^2}{\text{Radius}}$$

The accelerometer measures lateral acceleration directly, though it could be calculated with only a speedometer and a skid pad of a known size. The formula is given above. Note that angular velocity is given in radians per second.

The more useful calculation on the skid pad is the centripetal force. The word centripetal literally means "center seeking". As you will recall, the car has mass, and as a result, inertia. This inertia makes the car want to keep going in a straight line at a constant speed. To make the car take a circular path, a force must be provided to pull the car toward the center of the skid pad. Recall that



acceleration is any change in velocity. Velocity includes speed and direction, so to change the direction of the car, you must accelerate. According to Newton's laws, we must have a force to create the acceleration. This force is provided by the pavement pushing on the tires, which is of course, the equal and opposite reaction to the tires pushing on the pavement. The tire-pavement pair are a friction couple. When the inertia that makes the car want to continue in a straight line exceeds the friction of the tires attempting to pull the car towards the center of the circle, the car "drifts" out. Centripetal force can be calculated with the following formula.

$$F_{centripetal} = \frac{\text{Mass X } V^2}{\text{Radius}}$$

Notice that radius is on the bottom of the fraction, indicating that as the radius of the circle gets smaller, the centripetal load on the tires gets higher. Experience tells us that this is correct. As the circle we attempt to drive gets smaller, it is harder to maintain the same speed without sliding out.

Let us consider a practical example. A C-5 Corvette has a weight of 3500 lbs on earth. This works out to a mass of 1590 Kg. Suppose it's driving around a skid pad with a radius of 20 meters. How fast would the car have to go to pull 1 G? Well, by definition, when $F_{centripetal}$ equals the weight of the car, it is pulling 1 G. So, the weight of the car in SI units is 15,590 Newtons. We can plug these numbers into the formula getting:

$$\text{15,590 Newtons} = \frac{\text{1590 Kg X } V^2}{\text{20 meters}}$$

Now we use algebra to get V^2 by itself, resulting in:

$$\text{20 meters X 15,590 Newtons} = \text{1590 Kg X } V^2$$

Turning the crank…

$$\frac{\text{20 meters X 15,590 Newtons}}{\text{1590 Kg}} = V^2$$

A few dazzling algebraic contortions…

$$\text{200 m/s} = V^2$$

Taking the square root…

$$14.14 \text{ m/s} = V$$

Converting to M.P.H…

$$14.14 \text{ m/s} \times 2.24 = 32 \text{ m.ph.}$$

So, to pull 1 G on a skid pad with a radius of 20 meters, you must drive at 32 m.p.h.

Problems

Directions: Use the formulas below to predict the performance of the car.

1. A car is being run on a skid pad with a radius of 20 meters. A number of different tires are available with different coefficients of friction. For each scenario, calculate how fast the car could be moving around the circle. Recall that a tire's coefficient of friction corresponds directly to the number of G's it can pull on the skid pad.

$$\sqrt{(R \times A \times 9.8)} \times 2.24 = V$$

Where:
R is the radius of the skid pad in meters
A is the centripetal acceleration in G's
9.8 is a conversion factor from G's to m/s^2
2.24 is a conversion factor from m/s to m.p.h.
V is the velocity in m.p.h.

$$\text{Elapsed Time in Seconds} = \frac{\text{Velocity in M.P.H.}}{141}$$

Traction Rating	Coefficient of Friction	Forward Speed	Elapsed Time
C	.6		
B	.7		
A	.8		
AA	.9		