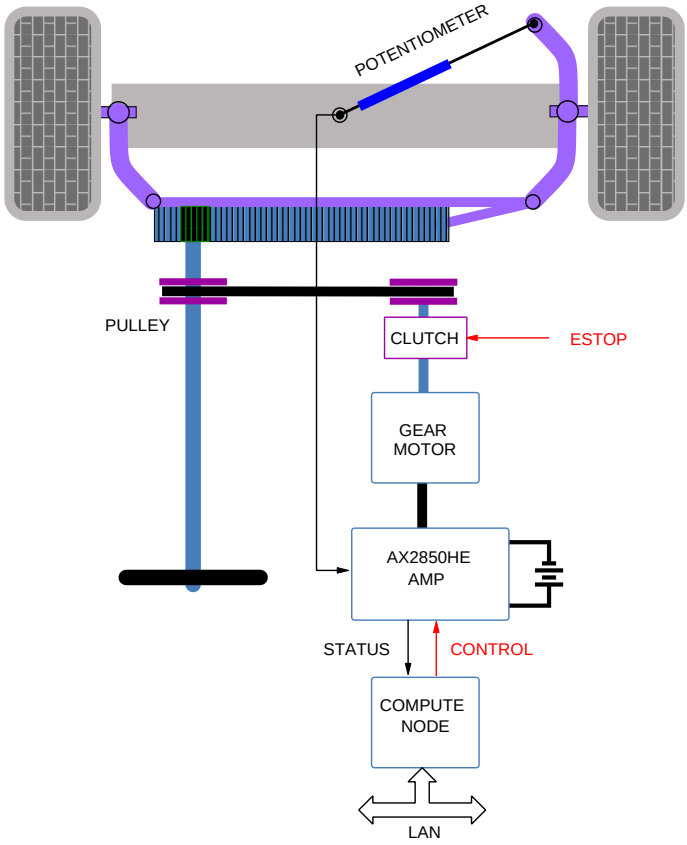
Steering

The ERTS steering subsystem is designed to translate commands of the form $1/r$ into a mechanical motion that executes a turn with radius r. The *turning radius*, rather than turning radius is used because it is intuitive at higher levels of control. The value is *inverted* to avoid discontinuities as r approaches zero, driving straight ahead.

The drawing below shows electromechanical steering linkage. Since quickly imposing human over computer control is a requirement, the steering system must be left mechanically intact, so that a person can assume steering control at any moment.



Under computer control, the *steering actuator* is a gear motor linked through a clutch by a pulley belt to the steering column—the shaft that the steering wheel turns. The Dual Channel 120 Amp amplifer turning the actuator is governed by control software. A pinion gear on the steering column moves a gear rack back and forth. The rack moves mechanical levers that pivot the front wheels to execute a turn.

The steering sensor is a linear potentiometer that changes voltage as it is

lengthened or shortened. Thus, it measures the front wheels' pivot angle. The digitized value of the potentiometer voltage is used to feed positional information back to the controller

Steering Radius and Angle

In the diagram in Figure **??** the *wheel base*, b (the distance between the front and rear axles) is a constant. Suppose the the vehicle is turning at an angle, ϕ. Define the *turning circle*, to be the circle traced by the midpoint of the rear axel, and define the *turning radius* to be the radius, r, of the turning circle.

Right triangle $\triangle CRF$ is formed by the turning circle's center and the axels' mid-points. CF is perpendicular to FT which is tangent to circle traced by point F. Hence, $\alpha' = \alpha - 90°$, and thus $\angle RCF = \alpha$. Therefore, the relationship between α and r is given by

$$\tan\alpha = \frac{b}{r}$$

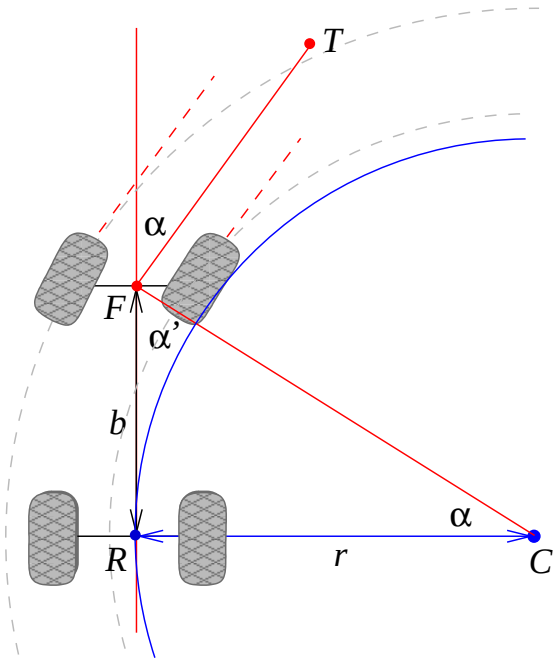
Solving for α,

$$\alpha = \arctan(\frac{b}{r})$$

$$\tan\phi = \frac{B}{r}, \text{ hence, } r = \frac{B}{\tan\phi}$$

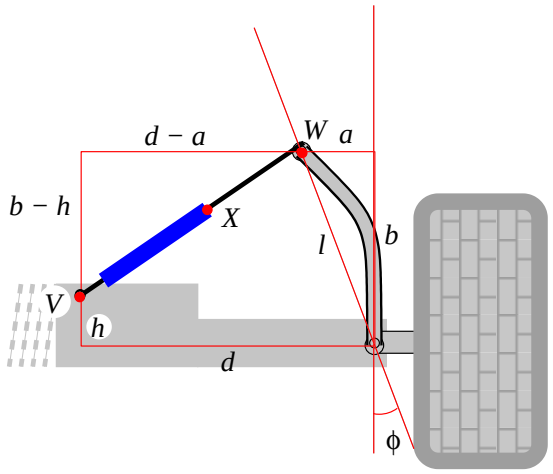
and conversely,

$$\phi = \arctan\frac{B}{r} = \phi \quad \Leftrightarrow$$



COMMENT. As Figure **??** suggests, the inner and outer wheels of the vehicle are not positioned at the same angle because they turn circles of different radii. This correction achieved using an *Ackerman* steering mechanism. It is reasonable to assume that the turning angle at Point F is tangent to a circle that lies between the paths followed by the front wheels.

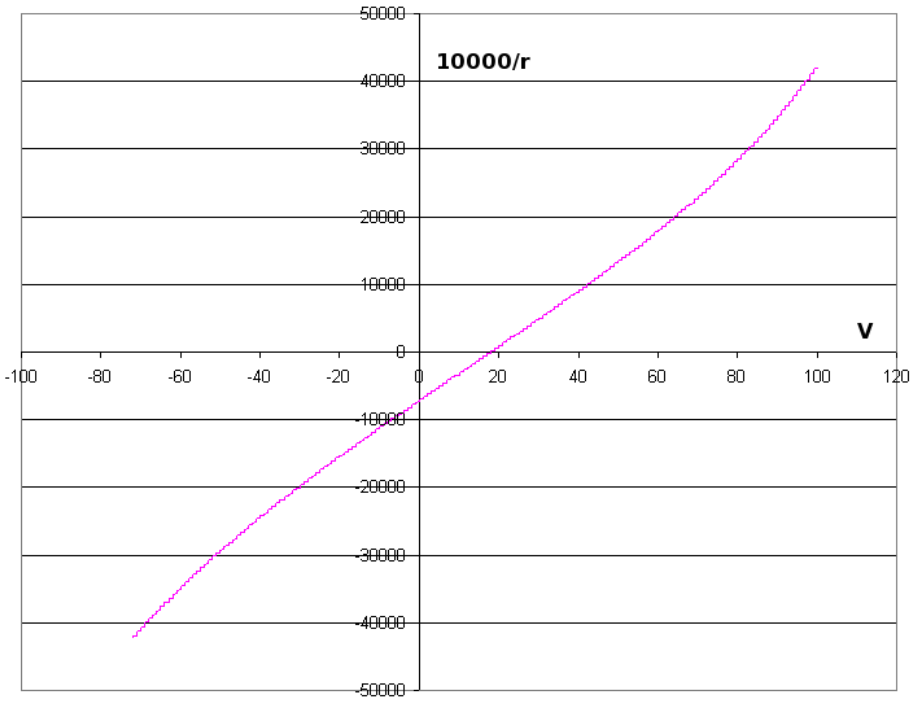
Steering Conversion



$$
\begin{aligned}
|VW| &= \sqrt{(b-h)^2 + (d-a)^2} \\
\sin\phi &= \frac{a}{\ell} \\
a &= \sin\phi \cdot \ell \\
\cos\phi &= \frac{b}{\ell} \\
x &= f(\phi) \triangleq \sqrt{\ell(\cos\phi - h)^2 + (d - \ell\sin\phi)^2}
\end{aligned}
$$

A graph of this formula looks like this. It reflects non-linear characteristics of

the potentiometer.



The graph is converted to a look-up table used in controlling steering amplifier.

```
steering_offset = -1930
steering_table =
  [(-72, -42181),(-72, -42025),(-71, -41869),(-71, -41713),(-71, -41557),
   (-71, -41402),(-70, -41248),(-70, -41094),(-70, -40940),(-70, -40786),
   (-69, -40633),(-69, -40480),(-69, -40328),(-69, -40176),(-69, -40024),
   (-68, -39873),(-68, -39722),(-68, -39571),(-68, -39421),(-67, -39271),
   (-67, -39121),(-67, -38972),(-67, -38823),(-66, -38674),(-66, -38526),
   (-66, -38378),(-66, -38230),(-65, -38083),(-65, -37936),(-65, -37789),
   (-65, -37643),(-64, -37497),(-64, -37351),(-64, -37206),(-64, -37060),

                                . . .

   ( -1,  -7397),(  0,  -7290),(  0,  -7183),(  0,  -7077),(  1,  -6970),
   (  1,  -6864),(  1,  -6757),(  1,  -6651),(  2,  -6544),(  2,  -6438),
   (  2,  -6332),(  2,  -6225),(  3,  -6119),(  3,  -6013),(  3,  -5907),
   (  3,  -5801),(  4,  -5694),(  4,  -5588),(  4,  -5482),(  5,  -5376),
   (  5,  -5270),(  5,  -5164),(  5,  -5059),(  6,  -4953),(  6,  -4847),
```

. . .

```
   ( 97,  39873),( 97,  40024),( 98,  40176),( 98,  40328),( 98,  40480),
   ( 98,  40633),( 98,  40786),( 98,  40940),( 99,  41094),( 99,  41248),
   ( 99,  41402),( 99,  41557),( 99,  41713),(100,  41869),(100,  42025),
   (100,  42181)]

steering_table_length = len(steering_table)
```

The controlling program takes the desired turning angle and changes the output of the amplifier until the measured angle voltage maches the table entry.