An Equivalent Electrical Model for a Geophone

From *Encyclopedia of Petroleum Science & Engineering V3*
Geophone equivalent circuit values:

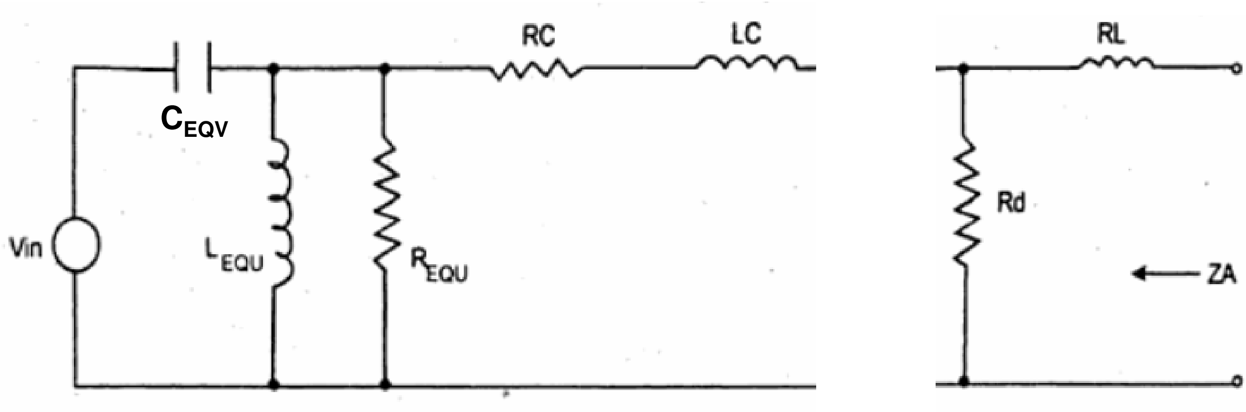
$$Reqv = \frac{1}{B}\left(\frac{G}{2.54}\right)^2 \times 10^7 \text{Ohms}$$

$$Leqv = \frac{1}{K}\left(\frac{G}{2.54}\right)^2 \times 10^7 \text{Henries}$$

$$Ceqv = M.\left(\frac{1}{(G/2.54)^2}\right) \times 10^{-7} \text{Farads}$$

where B is in dynes/cm/sec
K is in dynes/c/m **[dynes /cm]**
M is in grams
G is volts/inch/sec [**Note: If in V/cm/sec, above factors of 2.54 disappear.**]

Vin is 1V / cm/sec



Geophone **Load**

Using CGS units, if:
B is the geophone open-circuit physical damping in dynes/cm/sec = dyne-sec/cm
K is the geophone spring constant in dynes/cm
* M is the geophone mass in grams
* G is the geophone sensitivity in V/cm/sec = V-sec/cm
* F_0 is the geophone natural frequency in Hz
* D is the geophone open-circuit damping ratio vs critical damping, dimensionless
* Rc is the geophone coil resistance in Ohms
Lc is the geophone coil inductance in Henrys [measured]

(* normally provided by the manufacturer)

Since K and B are usually not provided on geophone spec. sheets we must calculate them from other parameters which are available.

We recall that $2 \pi F_0 = \text{sqrt}(K/M)$ [natural frequency of a spring-mass]

so $K = M / (4 \pi^2 F_0^2)$

and $B = 2M\omega_0 * D = 4\pi F_0 * M * D$ [relation between physical damping B and damping ratio D]

So:

$R_{EQV} = G^2 / B * 1E7$ Ohms

$\mathbf{= G^2 / (4\pi F_0 * M * D) * 1E7}$ **Ohms**

$L_{EQV} = G^2 / K * 1E7$ Henries

$\mathbf{= G^2 / (4 \pi^2 F_0^2 * M) * 1E7}$ **Henries**

$C_{EQV} = M / G^2 * 1E\text{-}7$ Farads

$\mathbf{= M / G^2 * 0.1\ \mu F}$

For PS-4.5B geophone:

Given Rc = 375 Ohms

Lc = 32 mHy (measured)

M = 11.3 g

G = 0.288 V/cm/sec

F_0 = 4.5 Hz

D = 0.6

We calculate:

R_{EQV} = 2163.4 Ohms

L_{EQV} = 91.817 Hy

C_{EQV} = 13.624 µF

I prefer the SI system, with:

M in kg

G in V/m/sec

in which units

$R_{EQV} = G^2 / (4\pi F_0 * M * D)$ Ohms

$L_{EQV} = G^2 / (4 \pi^2 F_0^2 * M)$ Henries

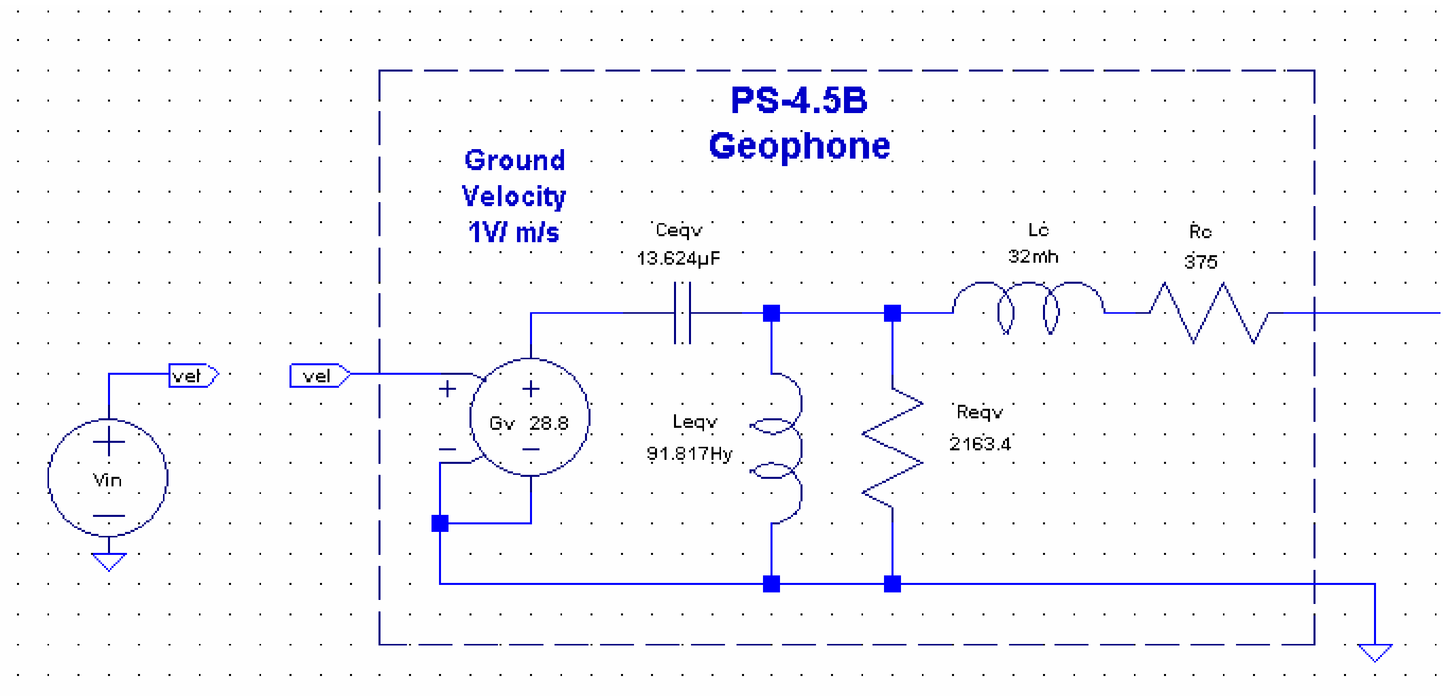
$C_{EQV} = M / G^2$ Farads or $= M / G^2 * 1E6$ uF

In the circuit model:

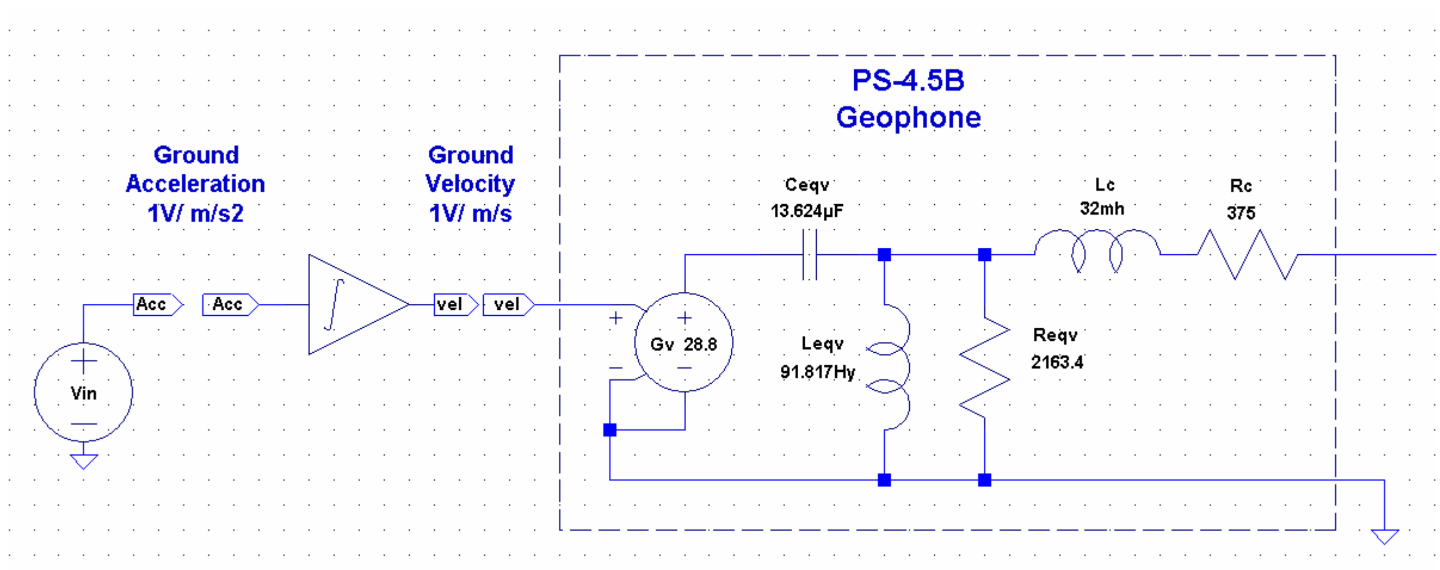
The input velocity-analog voltage, Vin, Volts/velocity, will be in the same units as the model assumes for G. So, Vin = 1V/m/s means that 1Volt at the circuit input represents a ground velocity of 1 meter/second. A variety of input voltage sources may be specified to represent ground motion, including swept sine and a pulse train, or Vin will become the reference point when modeling input-referred noise.

Some geophone models include a stray coil capacitance to ground, which should be small enough to be ignored.

The model uses one of two commonly encountered systems for creating the electrical analog of a mechanical system. In this system velocity is represented by a voltage.



This is how the geophone analog appears when used in a Spice model.



Here the geophone is shown with an acceleration input.

Dimensions for Electrical Units

Farads

$$\mathbb{F} = \frac{A \cdot s}{V} = \frac{J}{V^2} = \frac{W \cdot s}{V^2} = \frac{C}{V} = \frac{C^2}{J} = \frac{C^2}{N \cdot m} = \frac{s^2 \cdot C^2}{m^2 \cdot kg} = \frac{s^4 \cdot A^2}{m^2 \cdot kg} = \frac{s}{\Omega}$$

Henries

$$\mathbb{H} = \frac{m^2 \cdot kg}{C^2} = \frac{m^2 \cdot kg}{s^2 \cdot A^2} = \frac{J}{A^2} = \frac{Wb}{A} = \frac{V \cdot s}{A} = \frac{s^2}{F} = \Omega \cdot s$$

where F = farad, A=ampere, V=volt, C=coulomb, J=joule, m=meter, N=newton, s=second, W=watt, kg=kilogram, Ω=ohm, Wb = weber.