```
.subckt G_FM2 1c 2c 1z 2z 1x 2x 1y 2y THETA A='1e-14'  L='1e-7'  rho='19*1e-8'
+lsf='5e-9' P='0.23'
.param g='A/(rho*L)'
.param inf=101


Gc12 1c 2c cur='g * (v(1c) - v(2c) + P * cos(v(THETA)) * v(1z) - P * cos(v(THETA)) * v
(2z) - P
+* sin(v(THETA)) * v(1x) + P * sin(v(THETA)) * v(2x))'

Gz12 1z 2z cur='g * cos(v(THETA)) * (P * lsf * sinh(L / lsf) * v(1c) - P * lsf * sinh(
L / lsf) * v(2c) + cos(v(THETA)) *
+P * P * lsf * sinh(L / lsf) * v(1z) - cos(v(THETA)) * P * P * lsf * sinh(L / lsf) * v
(2z) + cos(v(THETA)) * L * v(1z) - cos(v(THETA))
+* L * v(2z) - cos(v(THETA)) * L * P * P * v(1z) + cos(v(THETA)) * L * P * P * v(2z) -
 sin(v(THETA)) * P * P * lsf * sinh(L / lsf)
+* v(1x) + sin(v(THETA)) * P * P * lsf * sinh(L / lsf) * v(2x) - sin(v(THETA)) * L * v
(1x) + sin(v(THETA)) * L * v(2x) + sin(v(THETA)) *
+L * P * P * v(1x) - sin(v(THETA)) * L * P * P * v(2x)) / lsf / sinh(L / lsf)'


Gx12 1x 2x cur = '-g * sin(v(THETA)) * (P * lsf * sinh(L / lsf) * v(1c) - P * lsf * si
nh(L / lsf)
+* v(2c) + cos(v(THETA)) * P * P * lsf * sinh(L / lsf) * v(1z) - cos(v(THETA)) * P * P
 * lsf * sinh(L / lsf) *
+v(2z) + cos(v(THETA)) * L * v(1z) - cos(v(THETA)) * L * v(2z) - cos(v(THETA)) * L * P
 * P * v(1z) + cos(v(THETA)) * L * P * P * v(2z) - sin(v(THETA))
+* P * P * lsf * sinh(L / lsf) * v(1x) + sin(v(THETA)) * P * P * lsf * sinh(L / lsf) *
 v(2x) - sin(v(THETA)) * L * v(1x) + sin(v(THETA))
+* L * v(2x) + sin(v(THETA)) * L * P * P * v(1x) - sin(v(THETA)) * L * P * P * v(2x))
/ lsf / sinh(L / lsf)'


Gz11 1z 0 cur='-g * (-L * sinh(L / lsf / 2) * cos(v(THETA))*cos(v(THETA)) + L * sinh(L
 / lsf / 2) *
+P * P * cos(v(THETA))*cos(v(THETA)) - inf * lsf * cosh(L / lsf / 2) + cos(v(THETA))*c
os(v(THETA)) *
+inf * lsf * cosh(L / lsf / 2)) / cosh(L / lsf / 2) / lsf * v(1z) + cos(v(THETA)) * g
* sin(v(THETA)) *
+(-L * tanh(L / lsf / 2) + L * tanh(L / lsf / 2) *
+P * P + inf * lsf) / lsf * v(1x)'

Gx11 1x 0  cur='cos(v(THETA)) * g * sin(v(THETA)) * (-L * tanh(L / lsf / 2) + L * tanh
(L / lsf / 2) *
+P * P + inf * lsf) / lsf * v(1z) + g * (L * sinh(L / lsf / 2) - L * sinh(L / lsf / 2)
 *
+cos(v(THETA))*cos(v(THETA)) - L * sinh(L / lsf / 2) * P * P + L * sinh(L / lsf / 2) *
 P * P *
+cos(v(THETA))*cos(v(THETA)) + cos(v(THETA))*cos(v(THETA))
+* inf * lsf * cosh(L / lsf / 2)) /
+cosh(L / lsf / 2) / lsf * v(1x)'


Gy11 1y 0  cur='g*inf*v(1y)'


Gz22 2z 0  cur='-g * (-L * sinh(L / lsf / 2) * cos(v(THETA))*cos(v(THETA)) + L * sinh(
L / lsf / 2)
+* P * P * cos(v(THETA))*cos(v(THETA)) - inf * lsf * cosh(L / lsf / 2) + cos(v(THETA))
*cos(v(THETA))
+* inf * lsf * cosh(L / lsf / 2)) / cosh(L / lsf / 2) / lsf * v(2z) + cos(v(THETA)) *
+g * sin(v(THETA)) * (-L * tanh(L / lsf / 2) + L * tanh(L / lsf / 2)
+* P * P + inf * lsf) / lsf * v(2x)'

Gx22 2x 0  cur='cos(v(THETA)) * g * sin(v(THETA)) * (-L * tanh(L / lsf / 2) + L * tanh
(L / lsf / 2) *
+P * P + inf * lsf) / lsf * v(2z) + g * (L * sinh(L / lsf / 2) - L * sinh(L / lsf / 2)
 *
+cos(v(THETA))*cos(v(THETA)) - L * sinh(L / lsf / 2) * P * P + L * sinh(L / lsf / 2) *
 P * P * cos(v(THETA))*cos(v(THETA))
+ + cos(v(THETA))*cos(v(THETA)) * inf * lsf * cosh(L / lsf / 2)) / cosh(L / lsf / 2) /
 lsf * v(2x)'
```

```
Gy22 2y 0  cur='g*inf*v(2y)'

.tran 3m
.probe v(âœ¯) i (âœ¯)
.ends
.subckt G_FMI_NM cFM cNM zFM zNM xFM xNM yFM yNM Gc='1e-6' gs='1' Gr='1' Gi='1'

.param gain='Gi/Gr'

*** series block ***
Rc cFM cNM r='1/Gc'
Rz zFM zNM r='1/gs'

*** shunt block ***
Rx xFM xNM r='1/Gr'
Gx xFM xNM cur='gain*(v(yFM)-v(yNM))'

Ry yFM yNM r='1/Gi'
Gy yFM yNM cur='-gain*(v(xFM)-v(xNM))'

.ends




.subckt G_FM_NM cFM cNM zFM zNM xFM xNM yFM yNM  THETA PHI g='1' a='1' b='0'

* These formulas are obtained fromÂ  U(G)Uâ€™
* G = Gse or GshÂ
* U is the Rodriguez rotation matrix for (theta,phi)Â
* 4x4 Conductance Matrix for the Series ComponentÂ

E11 d11 0 vol='g'
E12 d12 0 vol='g*P*cos(v(THETA))'
E13 d13 0 vol='g*P*sin(v(THETA))*cos(v(PHI))'
E14 d14 0 vol='g*P*sin(v(THETA))*sin(v(PHI))'

E21 d21 0 vol='g*P*cos(v(THETA))'
E22 d22 0 vol='(g)*cos(v(THETA))*cos(v(THETA))'
E23 d23 0 vol='(g)*sin(v(THETA))*cos(v(THETA))*cos(v(PHI))'
E24 d24 0 vol='(g)*sin(v(THETA))*cos(v(THETA))*sin(v(PHI))'

E31 d31 0 vol='g*P*sin(v(THETA))*cos(v(PHI))'
E32 d32 0 vol='(g)*sin(v(THETA))*cos(v(THETA))*cos(v(PHI))'
E33 d33 0 vol='(g)*sin(v(THETA))*sin(v(THETA))*cos(v(PHI))*cos(v(PHI))'
E34 d34 0 vol='(g)*sin(v(THETA))*sin(v(THETA))*cos(v(PHI))*sin(v(PHI))'

E41 d41 0 vol= '(g)*P*sin(v(THETA))*sin(v(PHI))'
E42 d42 0 vol= '(g)*sin(v(THETA))*cos(v(THETA))*sin(v(PHI))'
E43 d43 0 vol= '(g)*sin(v(THETA))*sin(v(THETA))*cos(v(PHI))*sin(v(PHI))'
E44 d44 0 vol='(g)*sin(v(THETA))*sin(v(THETA))*sin(v(PHI))*sin(v(PHI))'


GC11 cFM cNM cur='v(d11)*(v(cFM)-v(cNM))'
GC12 cFM cNM cur='v(d12)*(v(zFM)-v(zNM))'
GC13 cFM cNM cur='v(d13)*(v(xFM)-v(xNM))'
GC14 cFM cNM cur='v(d14)*(v(yFM)-v(yNM))'

GZ21 zFM zNM cur='v(d21)*(v(cFM)-v(cNM))'
GZ22 zFM zNM cur='v(d22)*(v(zFM)-v(zNM))'
GZ23 zFM zNM cur='v(d23)*(v(xFM)-v(xNM))'
GZ24 zFM zNM cur='v(d24)*(v(yFM)-v(yNM))'


GX31 xFM xNM cur='v(d31)*(v(cFM)-v(cNM))'
GX32 xFM xNM cur='v(d32)*(v(zFM)-v(zNM))'
GX33 xFM xNM cur='v(d33)*(v(xFM)-v(xNM))'
```

```
GX34 xFM xNM cur='v(d34)*(v(yFM)-v(yNM))'

GY41 yFM yNM cur='v(d41)*(v(cFM)-v(cNM))'
GY42 yFM yNM cur='v(d42)*(v(zFM)-v(zNM))'
GY43 yFM yNM cur='v(d43)*(v(xFM)-v(xNM))'
GY44 yFM yNM cur='v(d44)*(v(yFM)-v(yNM))'

* 4x4 Conductance Matrix for the Shunt ComponentÂ
* First column is zero: No charge current through spin-shuntsÂ

E55 d55 0 vol= 'g*a*sin(v(THETA))*sin(v(THETA))'
E56 d56 0 vol= '-g*sin(v(THETA))*(a*cos(v(PHI))*cos(v(THETA))+b*sin(v(PHI)))'
E57 d57 0 vol= '-g*sin(v(THETA))*(a*sin(v(PHI))*cos(v(THETA))-b*cos(v(PHI)))'

E65 d65  0 vol= 'g*sin(v(THETA))*(-a*cos(v(PHI))*cos(v(THETA))+b*sin(v(PHI)))'
E66 d66  0 vol= 'g*a*( cos(v(PHI))*cos(v(PHI))*cos(v(THETA))*cos(v(THETA))+1-cos(v(PHI
))*cos(v(PHI)))'
E67 d67  0 vol= 'g*(-a*sin(v(PHI))*cos(v(PHI))+a*sin(v(PHI))*cos(v(PHI))*cos(v(THETA))
*cos(v(THETA))-b*cos(v(THETA)))'

E75 d75  0 vol='-g*sin(v(THETA))*(a*sin(v(PHI))*cos(v(THETA))+b*cos(v(PHI)))'
E76 d76  0 vol='g*(-a*sin(v(PHI))*cos(v(PHI))+a*sin(v(PHI))*cos(v(PHI))*cos(v(THETA))*
cos(v(THETA))+b*cos(v(THETA)))'
E77 d77  0 vol='-g*a*(-cos(v(PHI))*cos(v(PHI))+cos(v(PHI))*cos(v(PHI))*cos(v(THETA))*c
os(v(THETA))-cos(v(THETA))*cos(v(THETA)))'

GZ55 zNM 0 cur='v(d55)*(v(zNM))'
GZ56 zNM 0 cur='v(d56)*(v(xNM))'
GZ57 zNM 0 cur='v(d57)*(v(yNM))'


GX65 xNM 0 cur='v(d65)*(v(zNM))'
GX66 xNM 0 cur='v(d66)*(v(xNM))'
GX67 xNM 0 cur='v(d67)*(v(yNM))'

GY75 yNM 0 cur='v(d75)*(v(zNM))'
GY76 yNM 0 cur='v(d76)*(v(xNM))'
GY77 yNM 0 cur='v(d77)*(v(yNM))'

.ends




.subckt G_GSHE 1c 2c 3z 4z 3x 4x 3y 4y theta='-0.12' L='100*1e-9' W='250*1e-9'
+t='20*1e-9' rho='11.3*1e-8' lsf='40*1e-9'

.param gc='t*W/L/rho'
.param gsse= 'W*L/rho/lsf/sinh(t/lsf)'
.param gssh= 'W*L/rho/lsf*tanh(t/2/lsf)'
.param gcz= 'W*theta/rho'


Rcc 1c 2c r='1/gc'
Gc1 1c 0  cur='-gcz*(v(3z)-v(4z))'
Gc2 2c 0  cur=' gcz*(v(3z)-v(4z))'

Rse  3z 4z r='1/gsse'
Rsh1 3z  0 r='1/gssh'
Rsh2 4z  0 r='1/gssh'

Gs1 4z 0 cur='-gcz*(v(1c)-v(2c))'
Gs2 3z 0 cur='gcz*(v(1c)-v(2c))'

.ends
.subckt G_MTJ 1c 2c 1z 2z 1x 2x 1y 2y THETA sz sx sy

.param inf = 1e20

Gcc 1c 2c cur='G0*(1+P*P*cos(v(THETA)))*(v(1c)-v(2c))'
```

```
Gzz 1z 2z cur='G0*inf*(v(1z)-v(2z))'
Gxx 1x 2x cur='G0*inf*(v(1x)-v(2x))'
Gyy 1y 2y cur='G0*inf*(v(1y)-v(2y))'


Ezz sz 0 vol='conv*-i(Gzz)'
Exx sx 0 vol='conv*-i(Gxx)'
Eyy sy 0 vol='conv*-i(Gyy)'


.ends
.subckt G_NM 1c 2c 1z 2z 1x 2x 1y 2y  A=1e-18 L=1e-9 rho=1 lsf=1e-9

* Internal parameters
.param gcse='A/(rho*L)'
.param gsse='gcse*(L/lsf)/sinh(L/lsf)'
.param gssh='gcse*(L/lsf)*tanh(L/(2*lsf))'

* Series t1-t2
Rc12 1c 2c r='1/gcse'
Rx12 1x 2x r='1/gsse'
Ry12 1y 2y r='1/gsse'
Rz12 1z 2z r='1/gsse'

* Shunt for spin t1
Rx10 1x 0 r='1/gssh'
Ry10 1y 0 r='1/gssh'
Rz10 1z 0 r='1/gssh'

* Shunt for spin t2
Rx20 2x 0 r='1/gssh'
Ry20 2y 0 r='1/gssh'
Rz20 2z 0 r='1/gssh'

.ends

.subckt G_PSC t1c t2c t1z t2z A='1e-18' L='1e-9' rho='1' lsf='1e-9' gc='1e-6'

* Internal parameters
.param gcse='A/(rho*L)'
.param gsse='gcse*(L/lsf)/sinh(L/lsf)'
.param gssh='gcse*(L/lsf)*tanh(L/(2*lsf))'

* Series t1-t2
Rc12 t1c t2c r='1/Gc'
Rz12 t1z t2z r='1/gsse'

* Shunt for spin t1
Rz10 t1z 0 r='1/gssh'

* Shunt for spin t2
Rz20 t2z 0 r='1/gssh'

.ends


.subckt G_RSO V1c V2c V1z V2z V1x V2x V1y V2y

GCC1 V1c 0 cur='G0 * v(V1c) - G0 * v(V2c)'
GZZ1 V1z 0 cur='G0 * v(V1z) - G0 * cos(theta) * v(V2z) - G0 * sin(theta) * v(V2x)'
GXX1 V1x 0 cur='G0 * v(V1x) + G0 * sin(theta) * v(V2z) - G0 * cos(theta) * v(V2x)'
GYY1 V1y 0 cur='G0 * v(V1y) - G0 * v(V2y)'


GCC2 V2c 0 cur='G0 * v(V2c) - G0 * v(V1c)'
GZZ2 V2z 0 cur='G0 * v(V2z) - G0 * cos(theta) * v(V1z) + G0 * sin(theta) * v(V1x)'
GXX2 V2x 0 cur='G0 * v(V2x) - G0 * sin(theta) * v(V1z) - G0 * cos(theta) * v(V1x)'
GYY2 V2y 0 cur='G0 * v(V2y) - G0 * v(V1y)'
.ends
.subckt LLG_BLOCK Theta Phi HSX HSY HSZ

CTHETA Theta 0 c='tau'
```

```
CPHI Phi 0 c='tau'
GTHETA 0 Theta cur='-sin(v(Theta)) * hp * cos(v(Phi)) * sin(v(Phi)) - sin(v(Theta)) *
alpha * cos(v(Theta)) - sin(v(Theta)) * alpha * hp * cos(v(Phi)) ^ 2 * cos(v(Theta)) -
 hs * v(HSZ) * sin(v(Theta)) + hs * sin(v(Phi)) * v(HSY) * cos(v(Theta)) + hs * cos(v(
Phi)) * v(HSX) * cos(v(Theta)) + hs * cos(v(Phi)) * alpha * v(HSY) - hs * sin(v(Phi))
* alpha *v(HSX)'
GPHI   0 Phi   cur='alpha * hp * sin(v(Phi)) * cos(v(Phi)) - cos(v(Phi)) ^ 2 * cos(v(T
heta)) * hp - cos(v(Theta)) - hs * (v(HSX) * sin(v(Phi)) - alpha * v(HSZ) * sin(v(Thet
a)) + alpha * cos(v(Theta)) * v(HSY) * sin(v(Phi)) + cos(v(Phi)) * alpha * cos(v(Theta
)) * v(HSX) - cos(v(Phi)) * v(HSY)) / sin(v(Theta))'

EMX 6  0 vol='sin(v(Theta))*cos(v(Phi))'
EMY 7  0 vol='sin(v(Theta))*sin(v(Phi))'
EMZ 8  0 vol='cos(v(Theta))'

.ends
```