Design Considerations for the Characterization of Capacitors

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Outline

Aim of Work

Background

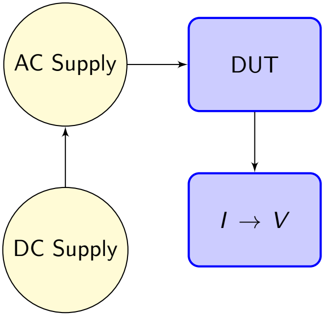
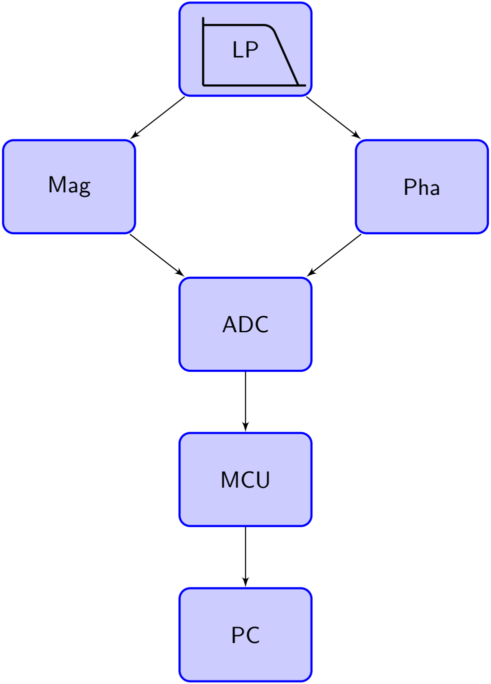
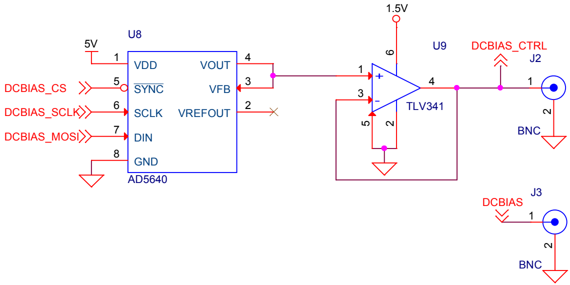
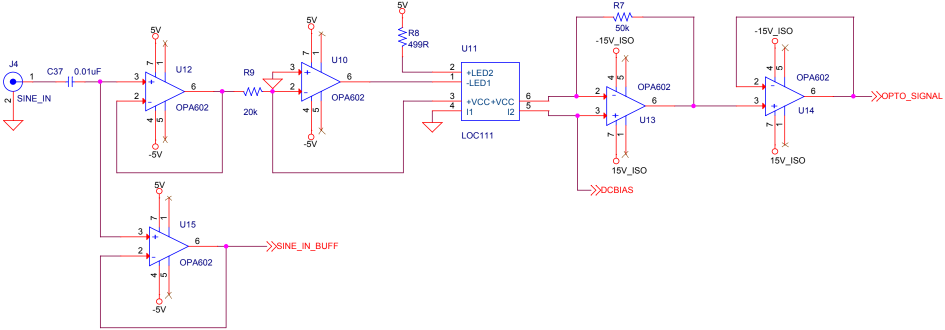


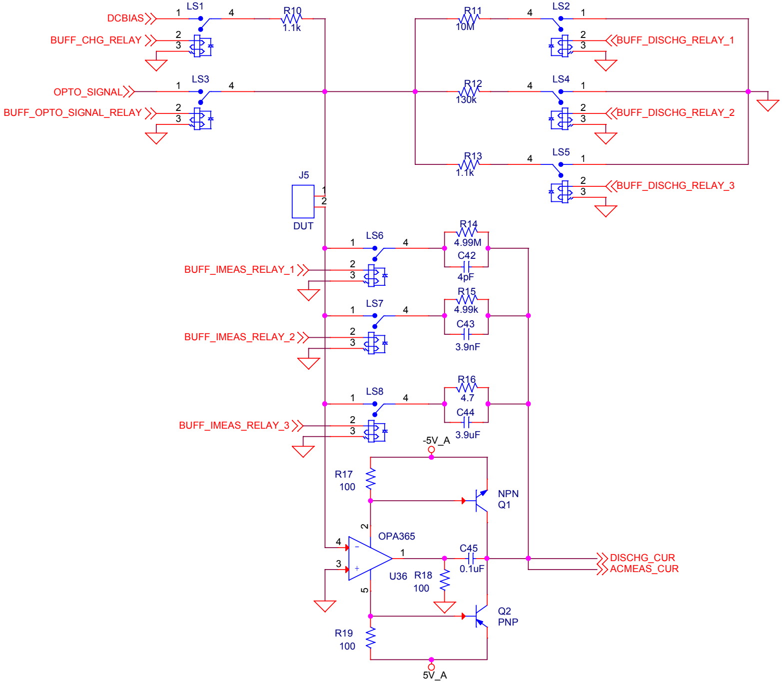
Figure: Circuit Flow Chart

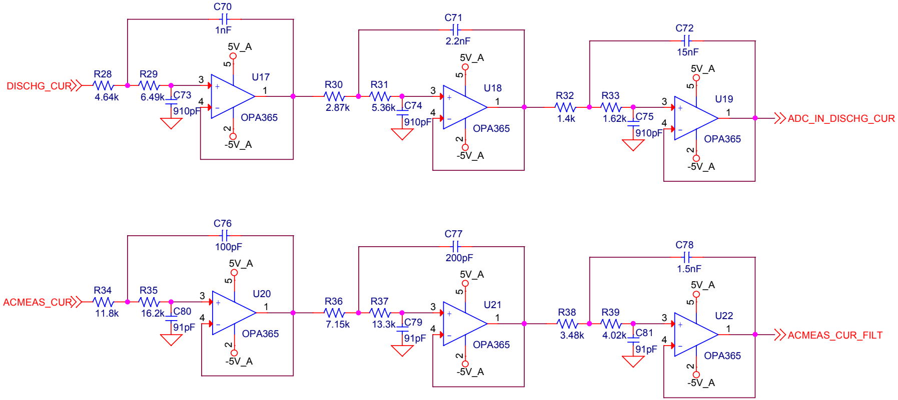

LP
Mag
Pha
ADC
MCU
PC



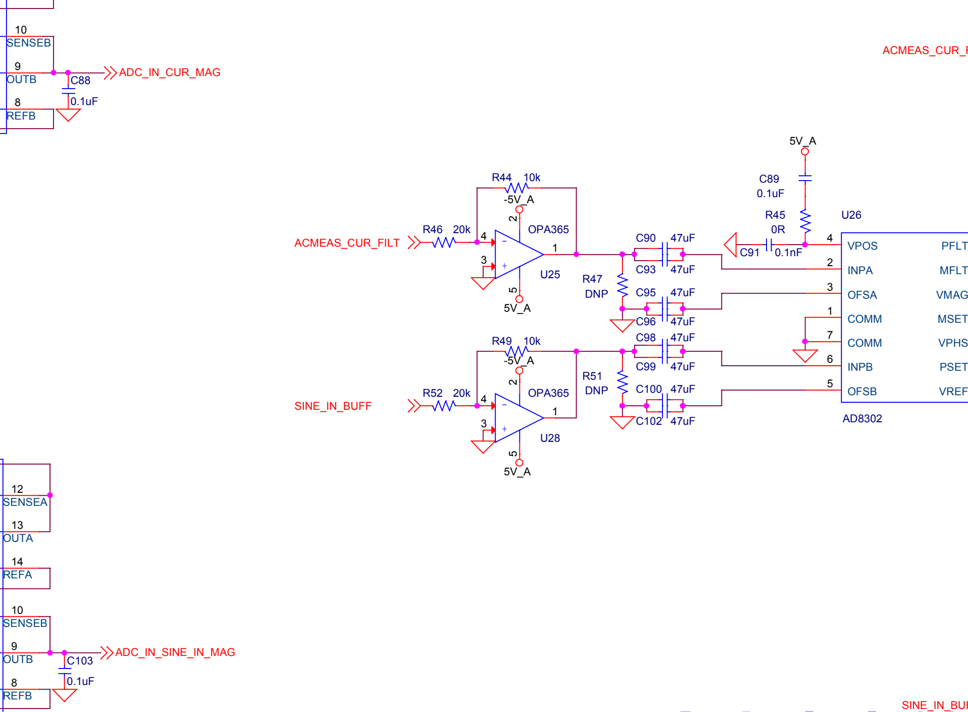
U8
5V
1
VDD
VOUT
4
DCBIAS_CS
5
SYNC
VFB
3
DCBIAS_SCLK
6
SCLK
VREFOUT
2
DCBIAS_MOSI
7
DIN
8
GND
AD5640
1.5V
6
U9
1
3
5
2
4
TLV341
DCBIAS_CTRL
J2
1
2
BNC
J3
DCBIAS
1
2
BNC


J4
1
2
SINE_IN
C37
0.01uF
5V
U12
3
2
6
7
1
4
5
OPA602
-5V
R9
20k
5V
U10
OPA602
-5V
5V
R8
499R
U11
+LED2
-LED1
+VCC+VCC
I1
I2
LOC111
R7
50k
-15V_ISO
OPA602
U13
15V_ISO
DCBIAS
-15V_ISO
OPA602
U14
15V_ISO
OPTO_SIGNAL
5V
U15
OPA602
-5V
SINE_IN_BUFF


DCBIAS
BUFF_CHG_RELAY
LS1
R10
1.1k
R11
10M
LS2
BUFF_DISCHG_RELAY_1
OPTO_SIGNAL
BUFF_OPTO_SIGNAL_RELAY
LS3
R12
130k
LS4
BUFF_DISCHG_RELAY_2
R13
1.1k
LS5
BUFF_DISCHG_RELAY_3
J5
DUT
LS6
R14
4.99M
C42
4pF
BUFF_IMEAS_RELAY_1
LS7
R15
4.99k
C43
3.9nF
BUFF_IMEAS_RELAY_2
LS8
R16
4.7
C44
3.9uF
BUFF_IMEAS_RELAY_3
-5V_A
R17
100
NPN
Q1
OPA365
U36
C45
0.1uF
R18
100
DISCHG_CUR
ACMEAS_CUR
Q2
PNP
R19
100
5V_A



DISCHG_CUR
R28
4.64k
R29
6.49k
C73
910pF
C70
1nF
5V_A
-5V_A
U17
OPA365
R30
2.87k
R31
5.36k
C74
910pF
C71
2.2nF
U18
OPA365
R32
1.4k
R33
1.62k
C75
910pF
C72
15nF
U19
OPA365
ADC_IN_DISCHG_CUR
ACMEAS_CUR
R34
11.8k
R35
16.2k
C80
91pF
C76
100pF
U20
OPA365
R36
7.15k
R37
13.3k
C79
91pF
C77
200pF
U21
OPA365
R38
3.48k
R39
4.02k
C81
91pF
C78
1.5nF
U22
OPA365
ACMEAS_CUR_FILT



10
SENSEB
9
OUTB
8
REFB
C88
0.1uF
ADC_IN_CUR_MAG
ACMEAS_CUR_F
5V_A
C89
0.1uF
R45
0R
U26
R44 10k
-5V_A
OPA365
U25
R46 20k
ACMEAS_CUR_FILT
5V_A
C90 47uF
C93 47uF
R47
DNP
C95 47uF
C96 47uF
C91 0.1nF
VPOS
INPA
OFSA
COMM
COMM
INPB
OFSB
PFLT
MFLT
VMAG
MSET
VPHS
PSET
VREF
AD8302
R49 10k
-5V_A
OPA365
U28
R52 20k
SINE_IN_BUFF
5V_A
C98 47uF
C99 47uF
R51
DNP
C100 47uF
C102 47uF
12
SENSEA
13
OUTA
14
REFA
10
SENSEB
9
OUTB
8
REFB
C103
0.1uF
ADC_IN_SINE_IN_MAG
SINE_IN_BUF

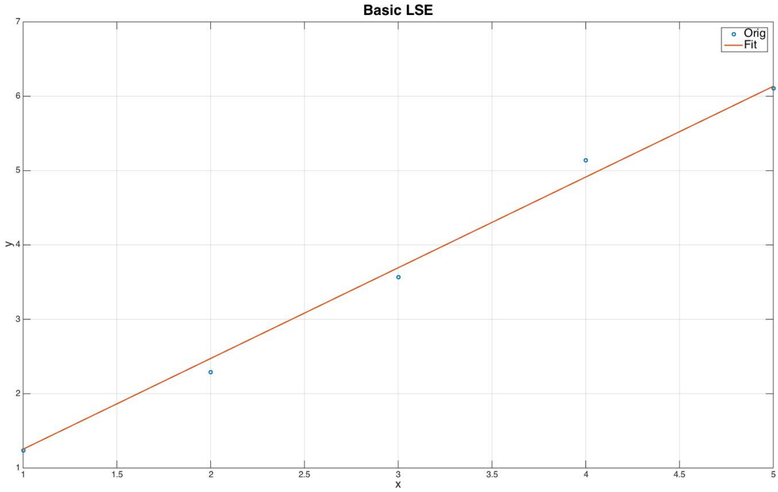


Figure: Basic LSE

Basic Regression

$$y = a_0 + a_1 x \tag{1}$$

$$E^2 = \sum_{i=1}^{n} (y_i - y)^2 \tag{2}$$

$$E^2 = \sum_{i=1}^{n} (y_i - (a_0 + a_1 x_i))^2 \tag{3}$$

$$\frac{\partial E^2}{\partial a_0} = 0 = \sum_{i=1}^{n} (-2y_i + 2a_0 + 2a_1 x_i) \tag{4}$$

$$\frac{\partial E^2}{\partial a_1} = 0 = \sum_{i=1}^{n} (-2y_i x_i + 2a_0 x_i + 2a_1 x_i^2) \tag{5}$$

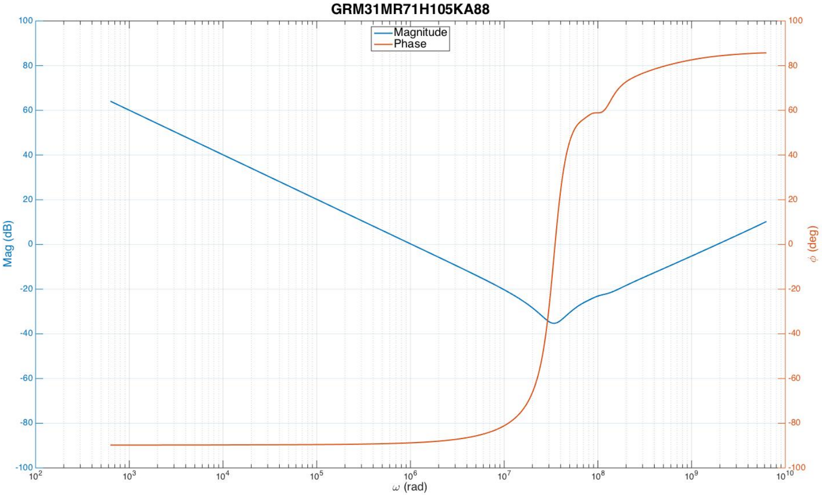


Figure: GRM31MR71H105KA88 Capacitor Data [3]

$$G(s) = \frac{A_0 + A_1 s + A_2 s^2 + ... + A_n s^n}{B_0 + B_1 s + B_2 s^2 + ... + B_m s^m} \; [1][Eq.\ 3] \tag{6}$$

$$\lambda_h = \sum_{k=0}^{m} \omega_k^h \; [1][Eq.\ 15] \tag{7}$$

$$S_h = \sum_{k=0}^{m} \omega_k^h R_k \; [1][Eq.\ 16] \tag{8}$$

$$T_h = \sum_{k=0}^{m} \omega_k^h I_k \; [1][Eq.\ 17] \tag{9}$$

$$U_h = \sum_{k=0}^{m} \omega_k^h (R_k^2 + I_k^2) \; [1][Eq.\ 18] \tag{10}$$

$$M = \begin{bmatrix} \lambda_0 & 0 & -\lambda_2 & 0 & T_1 & S_2 \\ 0 & \lambda_2 & 0 & -\lambda_4 & -S_2 & T_3 \\ \lambda_2 & 0 & -\lambda_4 & 0 & T_3 & S_4 \\ 0 & \lambda_4 & 0 & -\lambda_6 & -S_4 & T_5 \\ T_1 & -S_2 & -T_3 & S_4 & U_2 & 0 \\ S_2 & T_3 & -S_4 & -T_5 & 0 & U_4 \end{bmatrix} \tag{11}$$

$$N = \begin{bmatrix} A_0 \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ B_1 \\ B_2 \\ B_3 \\ \vdots \end{bmatrix} \text{ [1][}Eq.\ 21b\text{]} \quad (12) \qquad C = \begin{bmatrix} S_0 \\ T_1 \\ S_2 \\ T_3 \\ \vdots \\ 0 \\ U_2 \\ 0 \\ \vdots \end{bmatrix} \text{ [1][}Eq.\ 21c\text{]} \quad (13)$$

$$MN = C \text{ [1][}Eq.\ 20\text{]} \qquad (14)$$

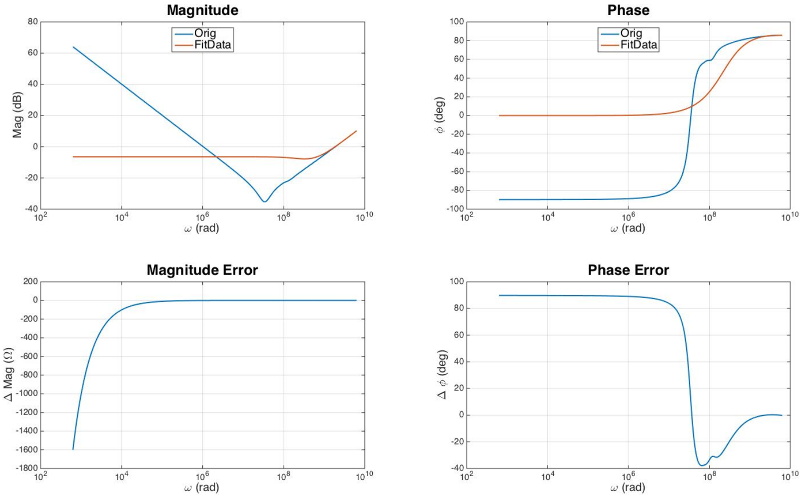


Figure: Levy's Technique

$$W_{kL} = \frac{1}{|Q(jw_k)_{L-1}|^2} \ [2] \tag{15}$$

$$E = \sum_{k=1}^{n} |\epsilon_k^{'}|^2 W_{kL} \ [2][Eq.\ 7] \tag{16}$$

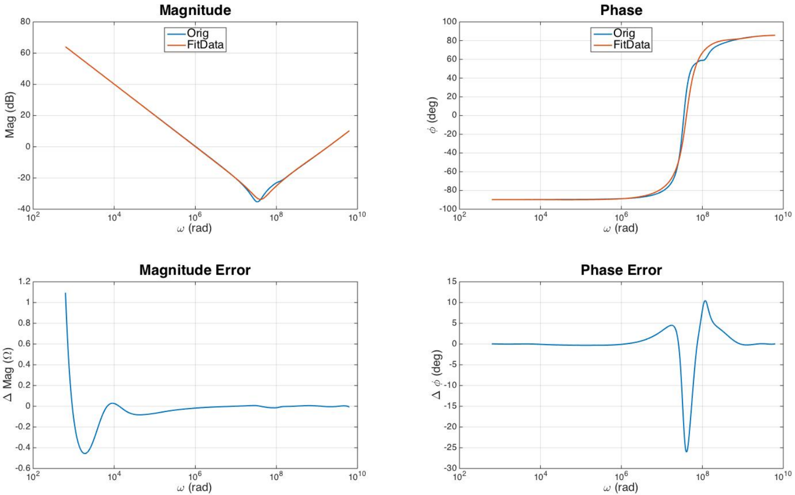


Figure: LSE + Iteration

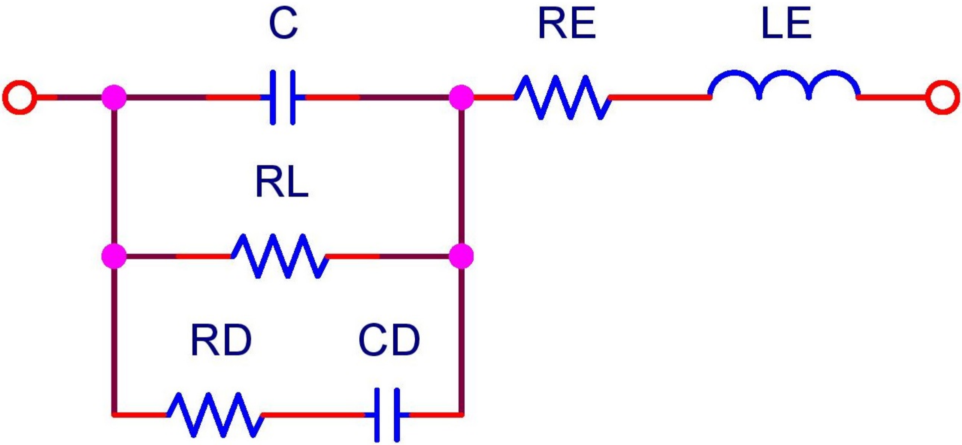


Figure: 6 Term Model

$$\bar{Z}(s) = \frac{(R_E + R_L) + (L_E + C_D R_D R_E + C_D R_D R_L + C R_E R_L + C_D R_E R_L)s}{1 + (C_D R_D + C R_L + C_D R_L)s + C C_D R_D R_L s^2} + \frac{(C_D L_E R_D + C L_E R_L + C_D L_E R_L + C C_D R_D R_E R_L)s^2 + C C_D L_E R_D R_L s^3}{1 + (C_D R_D + C R_L + C_D R_L)s + C C_D R_D R_L s^2} \tag{17}$$

$$\bar{Z}(s) = \frac{a_0 + a_1 s + a_2 s^2 + a_3 s^3}{b_0 + b_1 s + b_2 s^2} \tag{18}$$

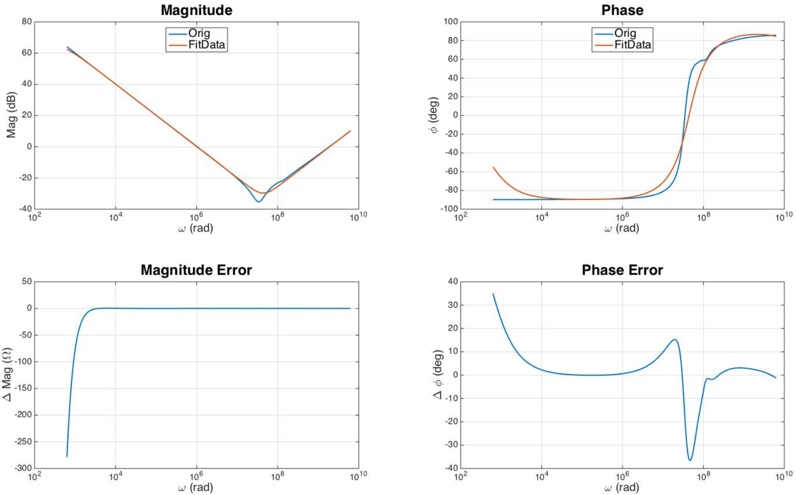


Figure: 6 Term Model: Bad Initilization

$$
\begin{aligned}
a_0 &= 5.9991E^{+03} \\
a_1 &= 1.7934E^{-04} \\
a_2 &= 3.3158E^{-12} \\
a_3 &= 6.8295E^{-22} \\
b_0 &= 1.0000 \\
b_1 &= 5.9057E^{-03} \\
b_2 &= 1.4067E^{-12}
\end{aligned}
\tag{19}
$$

$$
\begin{aligned}
C &= -8.2563E^{-10} \\
R_E &= 3.1886E^{-01} \\
L_E &= 4.8551E^{-10} \\
R_L &= 4.8551E^{-10} \\
C_D &= 9.8536E^{-07} \\
R_D &= -2.8824E^{-01}
\end{aligned}
\tag{20}
$$

$$
\begin{aligned}
a_0 &= 1 \\
a_1 &= 1 \\
a_2 &= 1 \\
a_3 &= 1 \\
b_0 &= 1 \\
b_1 &= 0 \\
b_2 &= 0
\end{aligned}
\tag{21}
$$

$$
\begin{aligned}
C &= INF \\
R_E &= INF \\
L_E &= INF \\
R_L &= IND \\
C_D &= IND \\
R_D &= IND
\end{aligned}
\tag{22}
$$

$$\begin{aligned} a_0 &= 2 \\ a_1 &= 5 \\ a_2 &= 4 \\ a_3 &= 1 \\ b_0 &= 1 \\ b_1 &= 3 \\ b_2 &= 1 \end{aligned} \tag{23}$$

$$\begin{aligned} C &= 1 \\ R_E &= 1 \\ L_E &= 1 \\ R_L &= 1 \\ C_D &= 1 \\ R_D &= 1 \end{aligned} \tag{24}$$

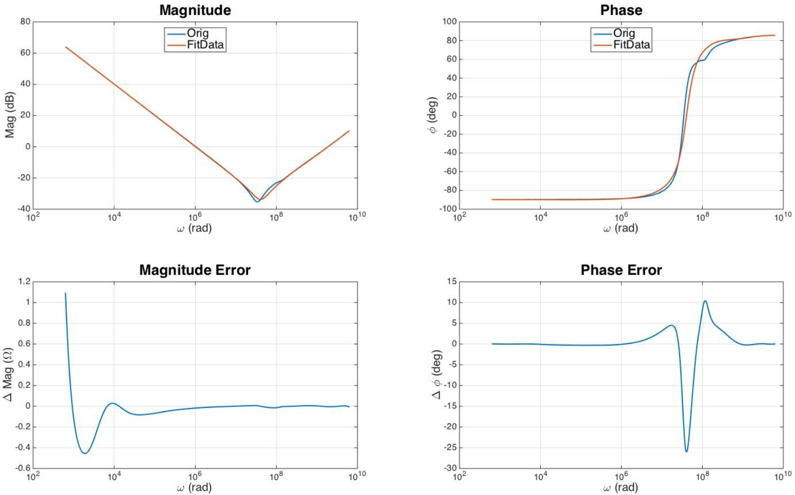


Figure: 6 Term Model: Good Initilization

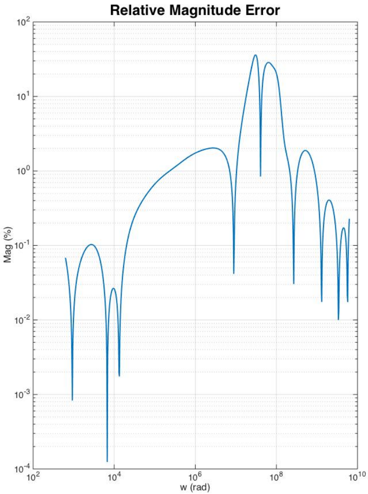


Figure: 6 Term Model: Relative Error

Modeling

Future Work

E. C. Levy.
Complex-curve fitting.
Automatic Control, IRE Transactions on, AC-4(1):37–44, 1959.

C. K. Sanathanan and J. Koerner.
Transfer function synthesis as a ratio of two complex polynomials.
Automatic Control, IEEE Transactions on, 8(1):56–58, Jan 1963.

Sim surfing.
`http://ds.murata.co.jp/software/simsurfing/en-us/index.html?intcid5=com_xxx_xxx_cmn_nv_xxx`.