APPLICATION NOTE:

S–PARAMETER MODEL FOR SINUSOIDAL MOTION

AN-0140 Rev B
Date: August 11, 2009

Model Numbers:
40202C 40204C 40206C
40202D 40204D 40206D
50202C 50204C 50206C
50202D 50204D 50206D

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1. <u>Safety:</u>

The Moog motor is capable of producing high forces and velocities. Always follow appropriate safety precautions when installing and applying these motors. Equipment should be designed and utilized to prevent personnel from coming in contact with moving parts and electrical contacts that could potentially cause injury. Read all cautions, warnings and notes in the applicable users' manuals before attempting to operate these devices.

Follow all applicable codes and standards when utilizing this equipment.

2. Scope:

This applications note will help the user compare Moog motors for sinusoidal movements.

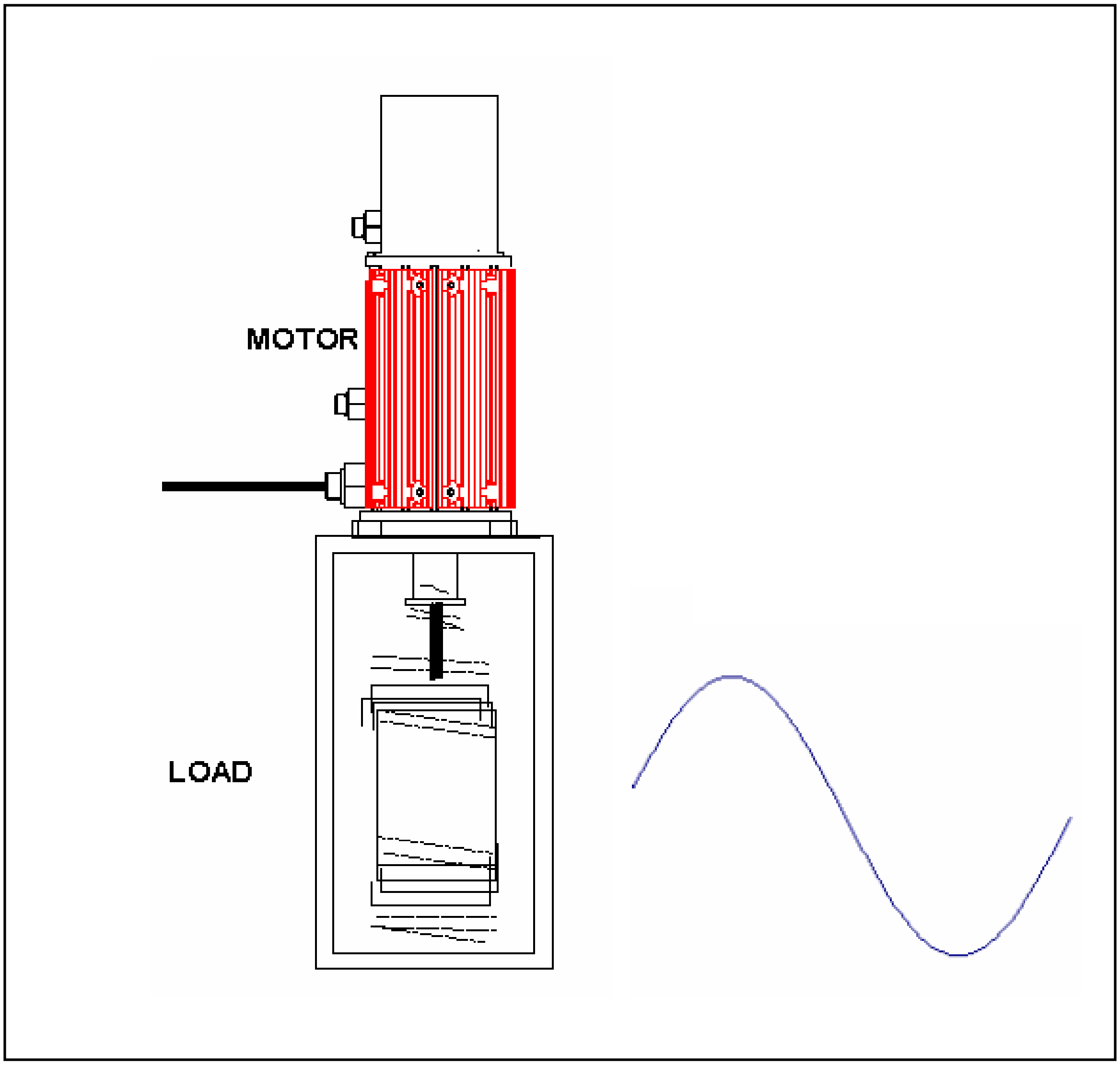


Fig. 2-1.
C & D series Motors and Rapid Sinusoidal Motion

3. Factors Affecting Motor Performance:

3.1. Motor Mount:

All mounts and couplings must be extremely stiff in order to avoid potential servo loop instabilities.

3.2. Mains Power:

This Applications Note references operating conditions in which the motor drive is supplied by 220 VAC. Lower Voltage will result in lower peak dynamic performance.

3.3. Motor Drive Components:

This applications note will assist only in comparing relative open loop performance of motors. The closed loop response of the Moog motor will be a function of all elements in the servo loop such as position sensors, load cells, servo amplifier gains and the mechanical compliances and resonances in the machine frame.

Care should be taken in predicting motor peak dynamic performance when using drive cables longer than 10 feet.

3.4. Load Mass:

The total moving mass in LB is obtained by adding your Load Mass to the shaft mass from the appropriate Interface Control Drawing (ICD) for the motor under consideration. An additional 2 LB must be added for the position sensor assembly if the motor is ordered with the Linear Encoder option LCA, LCB, LCC, LCD or LCE.

The ICD for the 4020 series motors will provide the same shaft mass as the 5020 series motors, so ICDs of either series can be used.

3.5. Limitations of this Model:

This analysis technique assumes that there is no force applied to the load other than that required to accelerate the moving load mass. No shaft motion will occur if the drive frequency is too high to permit sufficient drive current to overcome stiction and friction.

The model does not account for commutation reactance, which limits achievable frequency above displacements which are greater than a significant fraction of the shaft commutation cycle pitch of 0.922 inches.

Shaft length limits peak stroke displacement to one half the total stroke capability of the motor.

Motor power losses, and therefore motor heating, greatly depend upon drive force and velocity which combine in a nonlinear manner to produce power losses. For information on controlling motor heating, please refer to Moog applications notes as needed.

4. Example:

To compare motors for peak open loop sinusoidal displacement perform the following steps in a hypothetical example: A motor with an encoder installed is required to drive a 10 LB mass at an oscillation frequency of 20 Hertz and a total stroke displacement of 2.0 inches (peak to peak), or a Peak displacement of 1.0 inches. The application additionally requires that a total stroke displacement of 8 inches be available.

1. Determine the total moving mass of the motors in LB per section 3.4. Add encoder and load mass to the shaft mass from the Interface Control Drawings for the 40202, 40204 and 40206 motors for the required 8 inch total required stroke displacement:

Motor Model	Shaft Mass	Encoder mass	Load mass	**Total Moving Mass**
40202	12	2	10	**24**
40204	15	2	10	**27**
40206	18	2	10	**30**

2. Narrow the number if charts to analyze using the table from step 1. The nearest masses greater than or equal to the 24, 27 and 30 LB moving masses are the 25 LB moving mass in Charts 2 and 6 and the 50 LB moving mass in Charts 3 and 7.

3. On the selected charts, compare only those motors with curves above the 20 Hz, 1.0 inch point. The following motors meet these criteria:

    a. Chart 2; 40202C, 40202D, 40204D.
    b. Chart 3; 40202D, 40204D.
    c. Chart 6; 50202C, 50202D, 50204D.
    d. Chart 7; 50202D, 50204D, 50206D.

4. As much margin as possible should be allowed. The 40202D and the 50202D in charts 2 and 6 offer the greatest peak displacement at 20 Hz and should be given consideration as acceptable motors.

5. Motors 40202D and the 50202D can now be further compared for other parameters such as dynamic power loss, continuous power dissipation, thrust and mechanical features. The 50202D motor, for example, will handle greater continuous static thrust, but may show greater continuous dynamic loss under high frequency motion. The 40202D motor, on the other hand, will fit a smaller physical envelope and will weigh less.

Appendix 1. Open Loop Motor Model – Plots:

The following S – Parameter Models assume: No energy transmitted to load, no commutation, 220 VAC Mains.

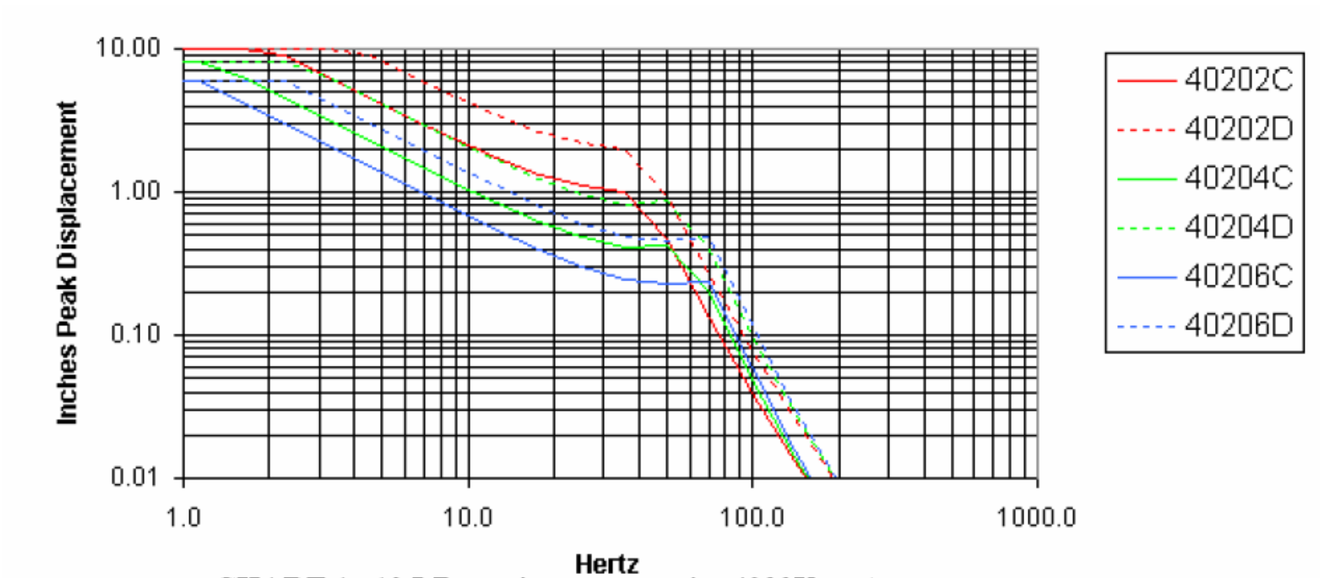


CHART 1. 10 LB moving mass, series 4020X motors.

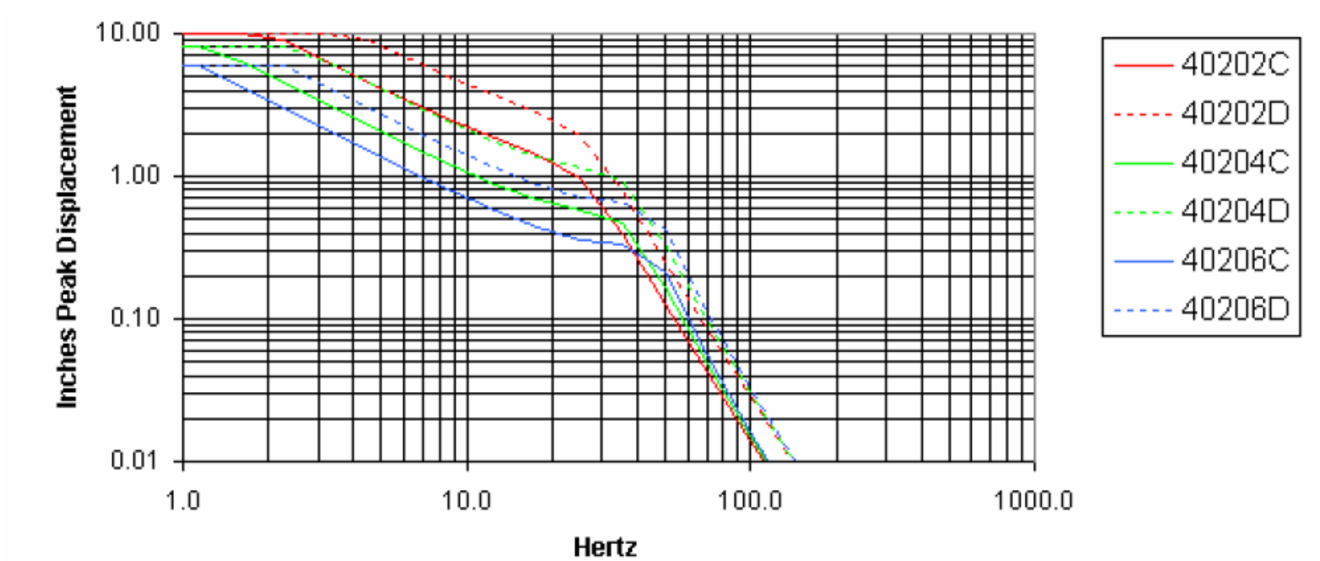


CHART 2. 25 LB moving mass, series 4020X motors.

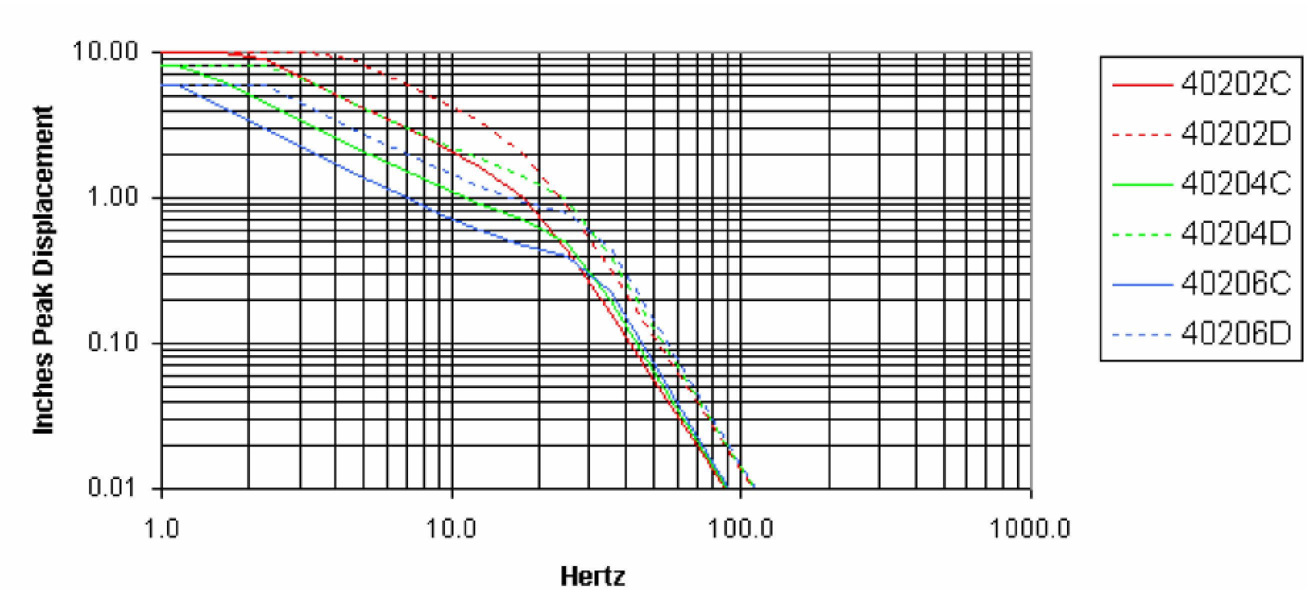


CHART 3. 50 LB moving mass, series 4020X motors.

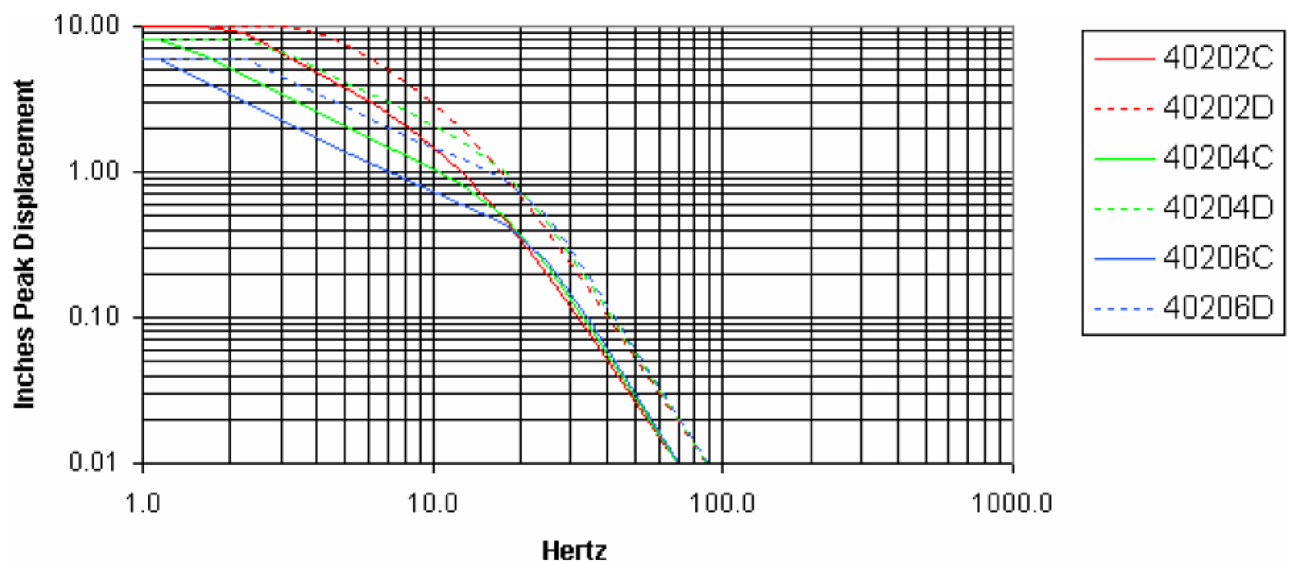


CHART 4. 100 LB moving mass, series 4020X motors.

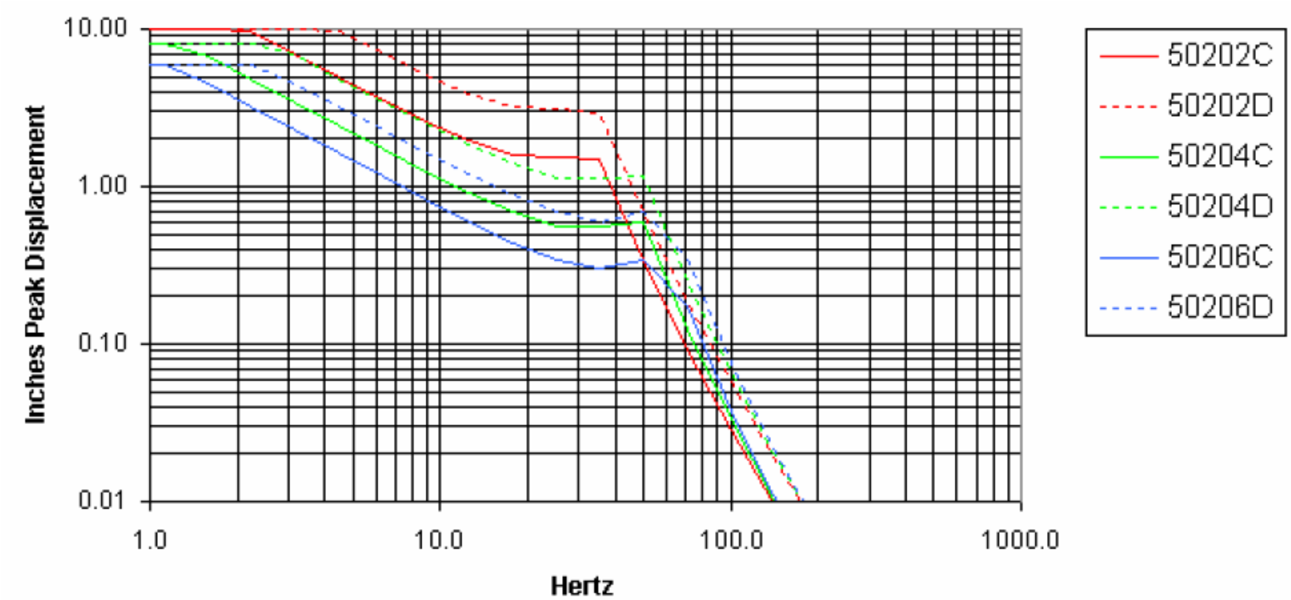


CHART 5. 10 LB moving mass, series 5020X motors.

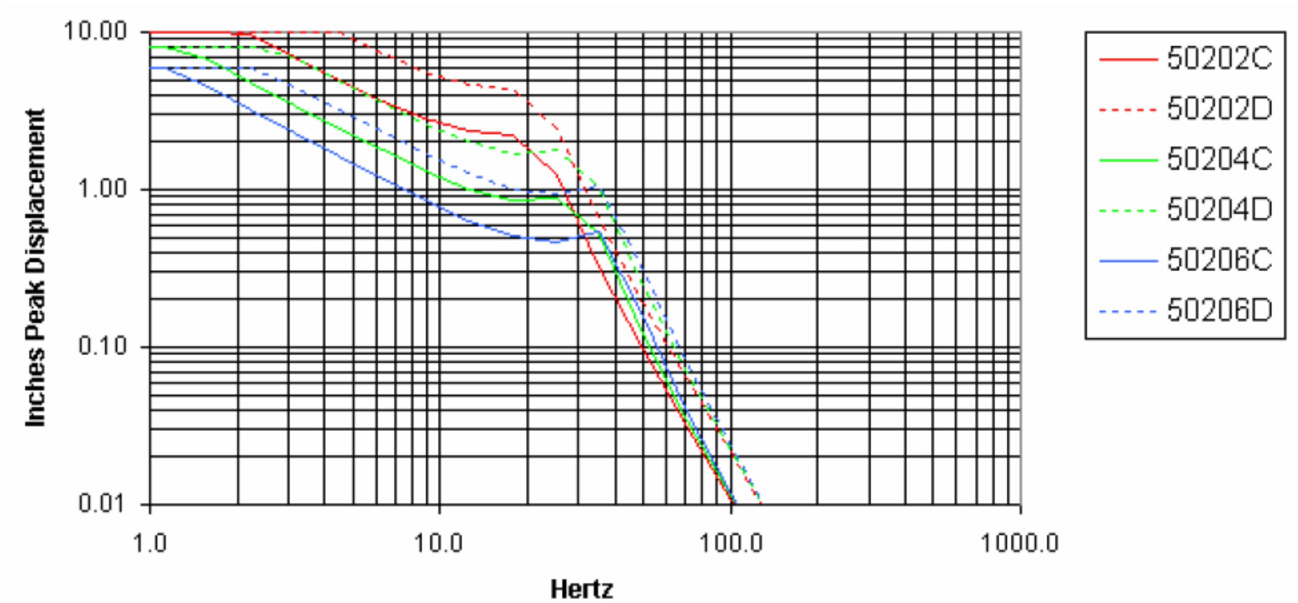


CHART 6. 25 LB moving mass, series 5020X motors.

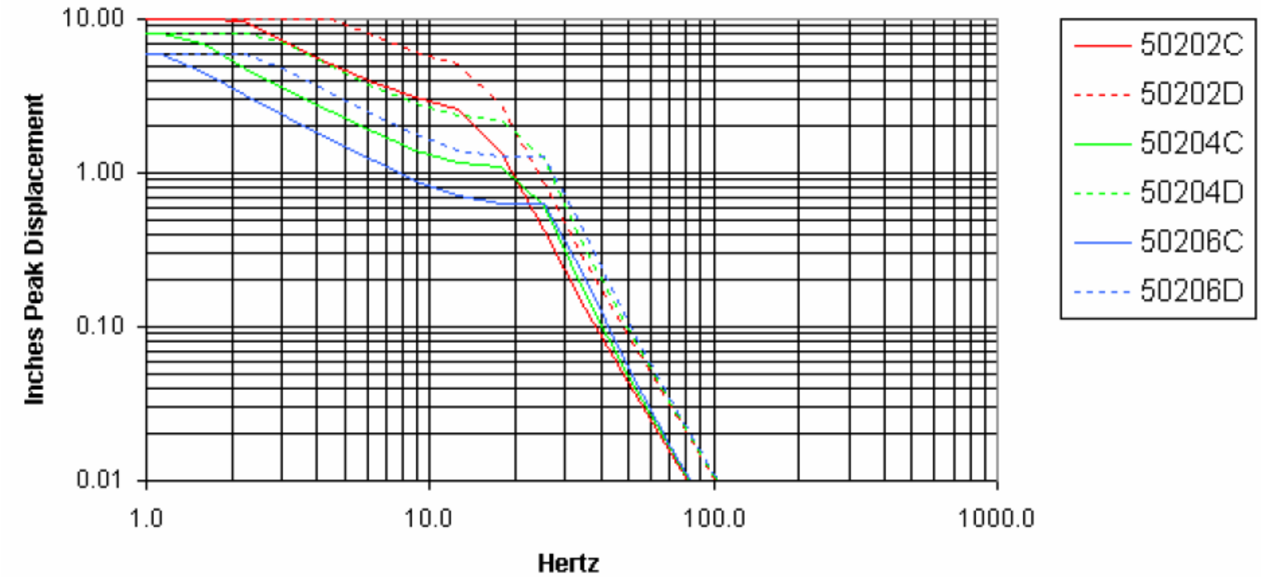


CHART 7. 50 LB moving mass, series 5020X motors.

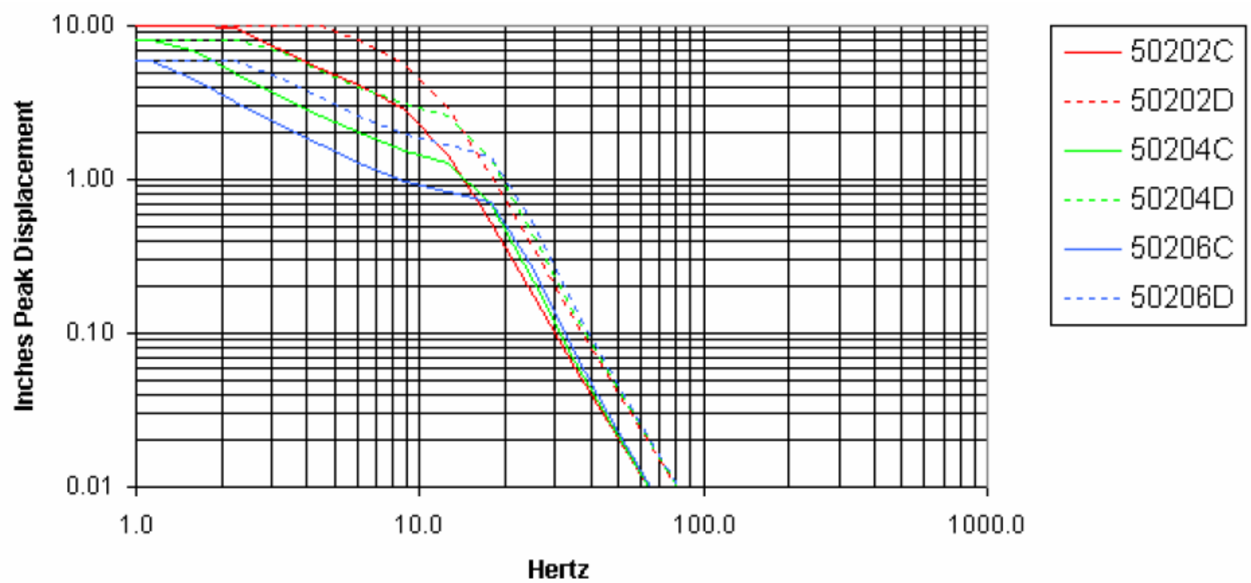


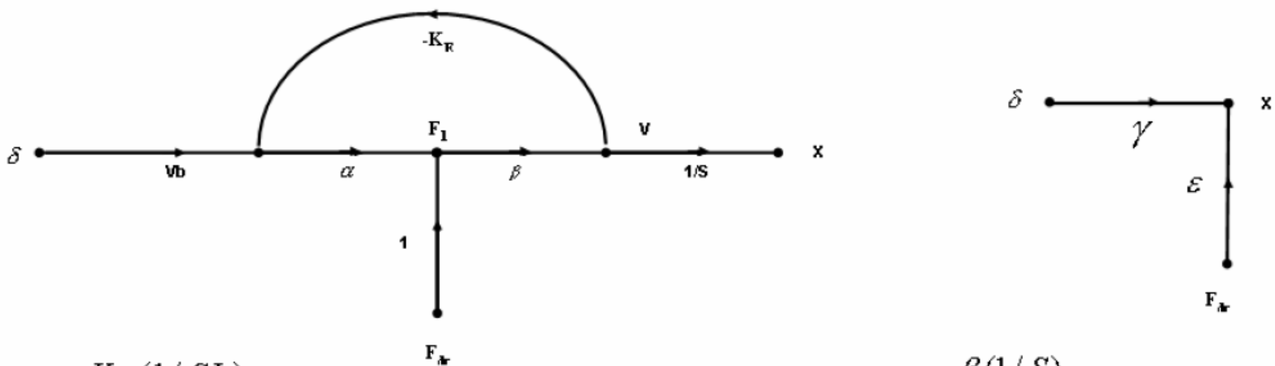
CHART 8. 100 LB moving mass, series 5020X motors.

Appendix 2. Open Loop Motor Model – S – Parameter Flow Graph:

S-Parameter Linear motor model

Description: This model describes the open loop positional amplitude / PWM amplifier duty cycle transfer function as a function of frequency.
It takes into account Winding reactance, motor back-emf and a first order viscous drag coefficient.
It does not take into account commutation reactance, second order viscous drag coefficient or Winding AC Resistance coefficients.

To determine Response Amplitude X at angular frequency S, multiply factor Gamma by 1.0. This will yield the absolute maximum amplitude that is achievable, but in practice, less than one half of this is achievable above roughly 10 Hz.
To simulate realistic controllability above 10 Hz, set Vb equal to one-half of its typical value, or 160 VDC.



$$\alpha = \frac{K_E(1/SL)}{(1+R/SL)}$$

$$\varepsilon = \frac{\beta(1/S)}{(1+K_E\alpha\beta)}$$

$$\beta = \frac{(1/SM)}{(1+D/SM)}$$

$$\gamma = \frac{V_b\alpha\beta(1/S)}{(1+K_E\alpha\beta)}$$

Parameter		SI units	Description			
F_1	variable	N	Thrust, no Friction or Drag	D	N/M/S	First Order Dynamic Drag Coefficient
S	variable	imag.	jw	F_{dr}	N	Bearing Drag
V	variable	M/S	Shaft Velocity amplitude	K_E	V/M/S	Back-EMF Constant, Vpk ph-ph
X	variable	M	Displacement Amplitude	L	Hy	1.5 x Phase to neutral Inductance
				M	KG	Shaft plus Load Mass
δ	0 - 1	none	Amplifier PWM Duty Cycle	R	Ohms	1.5 x Phase to neutral DC Resistance
Vb	320	V	Amplifier Bus Voltage			

Typical Values by Motor model number

	40202C	40202D	40204C	40204D	40206C	40206D	50202C	50202D	50204C	50204D	50206C	50206D
D	178	178	356	356	534	534	200	200	400	400	600	600
F_{dr}	44	44	100	100	222	222	44	44	100	100	222	222
K_E	82	41	161	80	254	127	76	38	159	80	238	119
L	0.015	0.004	0.030	0.008	0.045	0.011	0.015	0.004	0.029	0.007	0.044	0.011
M	4.0	4.0	5.3	5.3	6.5	6.5	4.0	4.0	5.3	5.3	6.5	6.5
R	2.18	0.53	4.43	1.13	6.6	1.65	1.2	0.30	2.4	0.60	3.6	0.90