1394-GMC / MAGNUM

E-STOP / LIGHT CURTAIN INTERCONNECT WITH DYNAMIC BRAKING

APPLICATION NOTE **DATE: JUNE 8, 1999**

Background on Safety Design

There are numerous safety standards regarding machine design. These standards include OSHA, ANSI, NFPA and the Machinery Directive. The Machinery Directive is the European safety standard and tends to lead the international standards. European safety standard EN1050 defines how the machine builder must analyze the RISK of using the machine. This is done by analyzing the processes that pose hazards to the machine operators. Machinery Directive EN954 defines how to determine the safety requirements by categorizing the risk.

If you are unfamiliar with safety standards and the Machinery Directive, it is highly recommended to review Understanding the Machinery Directive, SHB-900, to understand how to properly design safety circuits according to international requirements.

Application Information

BOM for GMC Dynamic Braking Application

For 24 Volt dc applications

Description	Quantity/Machine	Part Number	Make
Dynamic Brake Contactors (1/axis)	x	100-A18NZ2422	Allen-Bradley
"light curtain" control relay CR10 (1/axis) Timer Deck	x	700-CF220DJ 100-FPTA30	Allen-Bradley
CR12 control relay	x	700-CF400DJ	Allen-Bradley
Auxiliary Contact Adder Deck for M1 contactor (Side Mount)	1	195-BA10	Allen-Bradley
Surge Suppresser for Control Relay (one for each AC coil)	x	199-FSMA9	Allen-Bradley
Auxiliary Contacts (one per DB contactor)	x	195-FA11	Allen-Bradley
Dynamic Brake Resistors (one per DB contactor)	x	See cross ref.	User Specified Bonitron Bosch

BOM for GMC Dynamic Braking Application

For 120 Volt ac (60Hz) applications

Description	Quantity/Machine	Part Number	Make
Dynamic Brake Contactors (1/axis)	x	100-A18ND22	Allen-Bradley
"light curtain" control relay CR10 (1/axis) Surge Suppressor Timer Deck	x	700-CF22OD 100-FSC280 100-FPTA30	Allen-Bradley
CR12 control relay Surge suppressor	x	700-CF400D 100-FSC280	Allen-Bradley
Auxiliary Contact Adder Deck for M1 contactor (Side Mount)	1	195-BA10	Allen-Bradley
Surge Suppresser for Control Relay (one for each AC coil)	1	199-FSMA1	Allen-Bradley
Auxiliary Contacts (one per DB contactor)	x	195-FA11	Allen-Bradley
Dynamic Brake Resistors (one per DB contactor)	x	See cross ref.	User Specified Bonitron Bosch

Interconnect & Programming Guide Lines

for 1394-GMC E-stop & Light Curtain Stopping

1. The dynamic braking (DB) resistors *must* be used whenever contactors are used in the motor power conductors. The resistors not only provide dynamic brake for rotating motors, but they prevent continuous arcing across the contacts when breaking DC currents as the motor stalls. The recommended interconnect attached must be followed.
2. Cable shielding is very important on all power wiring between the motor and drive. The cable shield and drain wire need to be carried through between the drive and motor. If the cable is cut to wire in the contactor make sure the overall shield and drain wire are tied together. A shielded cable from the contactor to the DB resistors must also be used to prevent electrical emissions into the electrical cabinet. See Figure 1 for wiring example. The motor contactors must be isolated from low voltage signal wire, communication cables, power supplies, etc. as they will radiate high frequency emissions.
3. The timing diagrams attached need to be followed. The drive module *must* be disabled before the contactor is de-energized and the contactor *must* be energized before the axis module is enabled.
4. GML can be programmed for category 1 safety stopping. Category 1 is defined as a "controlled stop" of the axis, then lock (or remove power from) the axis actuator. Machine safety is defined by the machine builder through a risk analysis of the machine and application. Typical conditions that the machine builder must consider include but are not limited to:
    - E-stop control of moving axes
    - E-stop control of vertical uncounter balanced axes Fault conditions of a moving axes
    - Power outages
    - Operator intervention of an active axis (light curtain)

5. A sample GML program called Db_brake is available on the Motion directory of MKESLAFS. Customer programs will vary dependent on the application. The example program demonstrates E-stop and operator intervention (light curtain) program control. GML controls sequencing of the dynamic brake contactor(s). Time delay relays provide a hard wired backup to the software control should the program fail or lockup. The programming philosophy should follow this basic sequence:

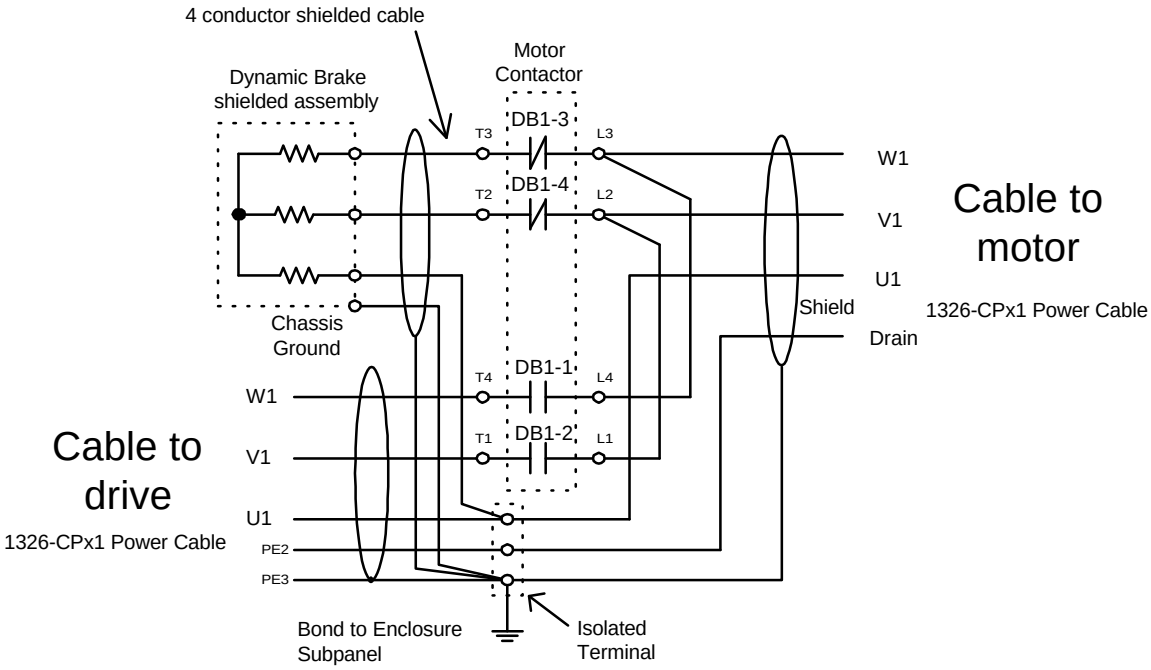
   E-stop trip or light curtain trip

   - When an E-Stop or "light curtain" event occurs, GML should immediately stop all other tasks and allow the independent E-stop or "light curtain" task to complete as quickly as possible.
   - GML should always attempt to stop the axis (controlled stop) with the Stop Motion command upon E-stop or "light curtain" interrupt.
   - After a controlled stop is completed, GML should disable the axis. GML can monitor the system axis enable flag for verification of this.
   - After the axis is disabled, the dynamic brake contactor can safely be de-energized.

   Axis Enabling

   - Energize the dynamic brake contactor to close the contacts between the drive and motor which opens the dynamic brake contacts.
   - GML should monitor the flex I/O input for the dynamic brake contactor to verify the contactor is picked up.
   - GML can now enable the axis with the Feedback On command.
   - GML can resume program execution with the "Resume Task" block.
6. Time delay relay setting: The TD control relays are hardwired backup control to software, so the time setting must be set longer than it takes for the GML program to sequence the outputs. The GML program is going to vary by the application, therefore the circuit timing will vary between applications. It is recommended that the machine builder tests the control logic and timing of the E-stop circuit and verify the timing is within limits of the machine risk analysis. The machine builder must determine the Time Delay (TD) settings based on the logic timing and the machine risk analysis. It is important to have a sufficient timing buffer between the logic control and the TD relay to avoid switching contactors under power.

Figure 1
Dynamic Brake & Contactor interconnection



NOTE: DB Resistors must be enclosed in ground enclosure or properly isolated, as they will radiate high frequency emissions. Wiring to the resistors must be shielded.

Dynamic Braking (DB) Resistor Selection

Explanations of values and definations for the following Tables :

1. Maximum Peak DB current for 1326AB-Bxxx and 1326AS-Bxxx motors, listed is the maximum current value which will not cause motor magnet demagnetization.
2. The resistance is calculated using the maximum 460 volt speed rating and a motor load inertia = 1 times motor inertia.
3. DB 'Minimum' or 'Optimum' value is the value of resistance which will
   - Stop the motor with the least amount of shaft revolutions while remaining within the safe current level will have (opt) following the resistance value listed

     OR
   - Stop the motor using the maximum allowable current and as a result not resulting in the least amount of shaft rotations will have (min) following the resistance value listed
4. Instantaneous peak resistor watts is the rating the DB resistor must be able to disapate without changing value.
5. RMS energy dissipated per stop is the RMS value of the watts dissipated in each DB resistor over the stopping time of the motor shaft.
6. Actual wattage of the resistor is dependent on repetition or cycling frequency of the DB resistors.
7. Motor Torque (in-lb) @ 10 RPM is the estimated amount of shaft torque remaining in that part of the DB E-Stopping cycle. **NOTE**: If this value is an important factor, it is recommended that the actual machine with the true mechanical situation be measured.
8. If the application has different speed requirements, load inertia etc. please contact the factory for recalculated values based on the users application. Call 1-603-443-5419 and have a case logged to the MQ_Motion_ Pre-sale queue.
9. Listed below are some commercially available DB resistors modules from Robert Bosch Company Phone Number: 1- 860-409-7070. These are only listed for reference.

Bosch[9] DB Part Number	Bosch Resistance (Ohms per leg)	Resistor Energy Dissipation (Watt Sec.)
105/913544	8.2	57
1070 913 546	5.6	261
1070 913 547	3.3	785
1070 914 767	1.0	785

Table 1
Optimum Dynamic Brake Resistor Values for 1326AB-Bxxx-xx

1326AB Motor Type	Maximum Speed Rating (rpm)	Maximum Peak DB Current (amps)	DB Minimum / Optimum Resistance (Ohms per leg)	Instantaneous Peak Energy Dissipated (Watts)	RMS Energy Dissipated Per Stop (Watts)	Motor Torque (in-lb) @ 10 RPM	Motor Shaft Revs to Stop	Stopping Time (Sec)
B410J	7250	20.88	12 (opt)	642.7	217.8	0.15	14.5	0.35
B410G	5000	14.7	18 (opt)	592.4	176.7	0.19	8.9	0.30
B420H	6000	18.0	6 (opt)	1216	355.6	0.43	7.4	0.25
B420E	3000	17.04	6 (opt)	452.9	123.7	0.88	1.6	0.12
B430G	5000	33.6	4.0 (opt)	1836	477.1	1.14	4.0	0.18
B430E	3000	23.4	4.0 (opt)	748	196	1.39	1.6	0.12
B515G	5000	52.25	2.5 (opt)	2750	645.5	1.24	10.16	0.5
B515E	3000	34.1	3.0 (opt)	1555	440	2.4	3.5	0.25
B520F	3500	48.4	3.0 (opt)	2847	663	2.1	5.2	0.35
B520E	3000	36.85	3.0 (opt)	2100	603	3.2	3.5	0.25
B530E	3000	52.25	2.0 (opt)	3353	933	4.9	3.7	0.27
B720E	3500	87.5	1.5 (opt)	7776	1956	6.2	5.3	0.35
B730E	3350	114.0	1.0 (opt)	8720	2643	9.5	6.3	0.39
B740C	2200	104.5	1.0 (opt)	7044	2252	19.5	2.7	0.25

NOTE: The resistors listed in the table differ from original release of this tech note. That does not mean that they are incorrect. The original components can still be used however the results, unless the value is the same, will be different.

Table 2
Minimum Dynamic Brake Resistor Values for 1326AS-Bxxx-xx

1326AS Motor Type	Maximum Speed Rating (rpm)	Maximum Peak DB Current (amps)	DB Minimum / Optimum Resistance (Ohms per leg)	Instantaneous Peak Energy Dissipated (Watts)	RMS Energy Dissipated Per Stop (Watt)	Motor Torque (in-lb) @ 10 RPM	Motor Revs to Stop	Stopping Time (Sec)
B220H	5500	1.7	1.0 (min)	1.46	0.7	0.11	4.2	0.12
B310H	6200	2.4	36 (min)	211	38	0.04	2.8	0.12
B330H	6500	6.0	23 (min)	925	154	0.11	2.1	0.08
B420G	5250	7.8	16 (min)	971	218	0.25	2.9	0.12
B440G	5250	16.2	10 (min)	2727	417	0.43	2.5	0.12
B460F	4300	18.6	9.0 (min)	3048	490	0.71	1.9	0.1
B630F	4500	18.5	11.0 (min)	3834	552	0.58	3.6	0.2
B660E	3000	29.8	6.0 (min)	5082	635	1.84	1.4	0.14
B690E	3000	41.3	4.5 (min)	7641	907	1.60	1.4	0.14
B840E	3000	39.5	4.0 (min)	5846	1098	2.60	2.7	0.2
B860C	2000	44.4	3.0 (min)	5692	1170	3.3	1.2	0.12

Table 3
Dynamic Brake Resistor Values for 1326AB-Bxxx-xx
Bonitron DB Braking Unit Resistance

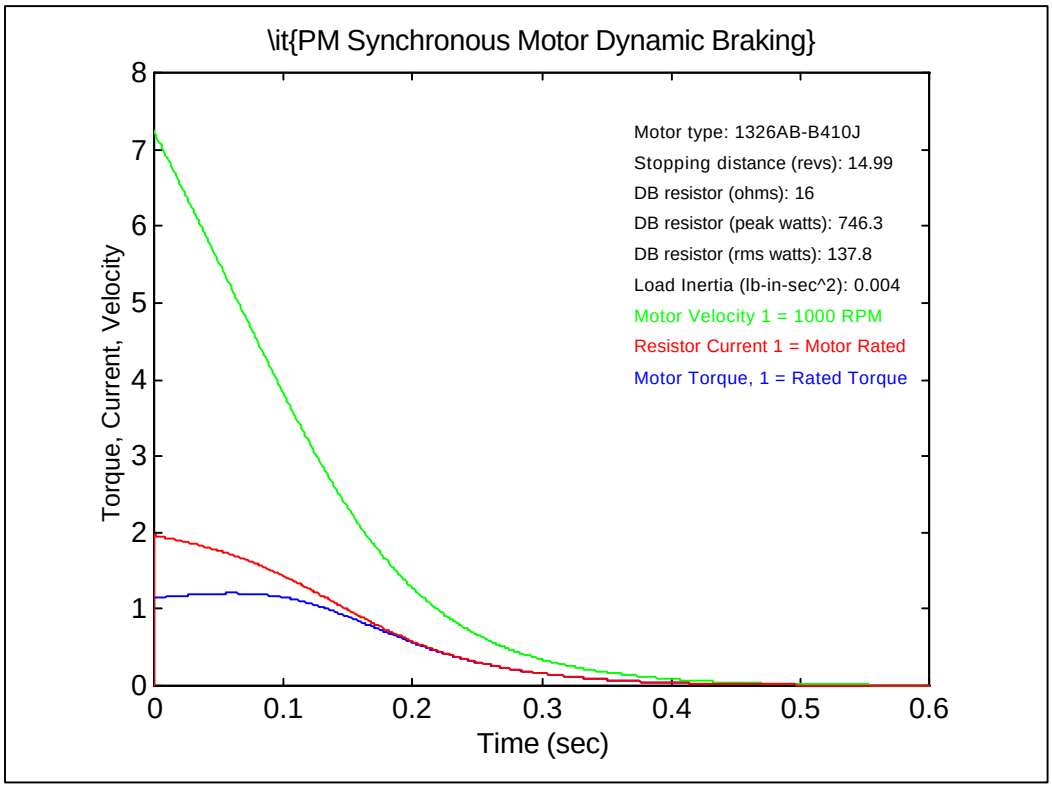
1326AB Motor Type	Maximum Speed Rating (rpm)	Maximum Peak DB Current (amps)	DB Resistance (Ohms per leg)	Instantaneous Peak Energy Dissipated (Watts)	RMS Energy Dissipated Per Stop (Watts)	Motor Torque (in-lb) @ 10 RPM	Motor Shaft Revs to Stop	Stopping Time (Sec)
B410J	7250	6.83	16	746.3	137.8	0.1158	14.99	0.6
B410G	5000	5.59	16	500	119.6	0.2328	6.26	0.3
B420H	6000	14.23	6	1216	297.7	0.38	7.46	0.3
B420E	3000	7.49	6	451.9	98.3	0.93	1.64	0.13
B430G	5000	22.42	3	1508	433.7	1.04	4.04	0.18
B430E	3000	14.1	3	596.7	171.7	1.66	1.59	0.12
B515G	5000	31.83	3	3039	677.7	1.79	10.35	0.50
B515E	3000	22.76	3	1555	366.9	2.46	3.51	0.30
B520F	3500	30.81	3	2847	580.2	2.07	5.12	0.4
B520E	3000	26.45	3	2100	603.3	3.19	3.51	0.25
B530E	3000	37.45	3	4209	808.4	3.43	3.82	0.35
B720E	3500	77.11	1	5946	1746	6.2	5.46	0.36
B720F	5000	97.31	1	9469	2496	4.23	12.60	0.6
B730E	3350	93.38	1	8720	2104	9.09	6.40	0.45
B740C	2200	83.93	1	7044	1877	18.9	2.73	0.3
B740E	3400	125.78	1	15820	3266	9.27	6.40	0.5

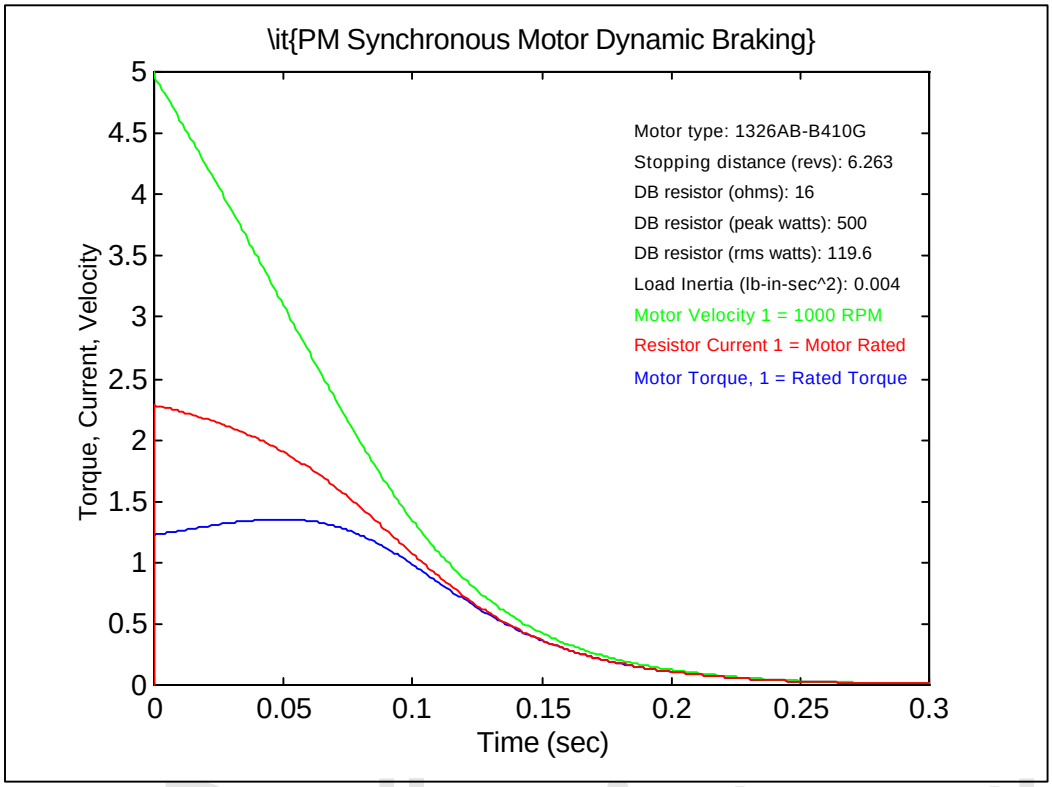
Table 4
Dynamic Brake Resistor Values for 1326AS-Bxxx-xx
Bonitron DB Braking Unit Resistance

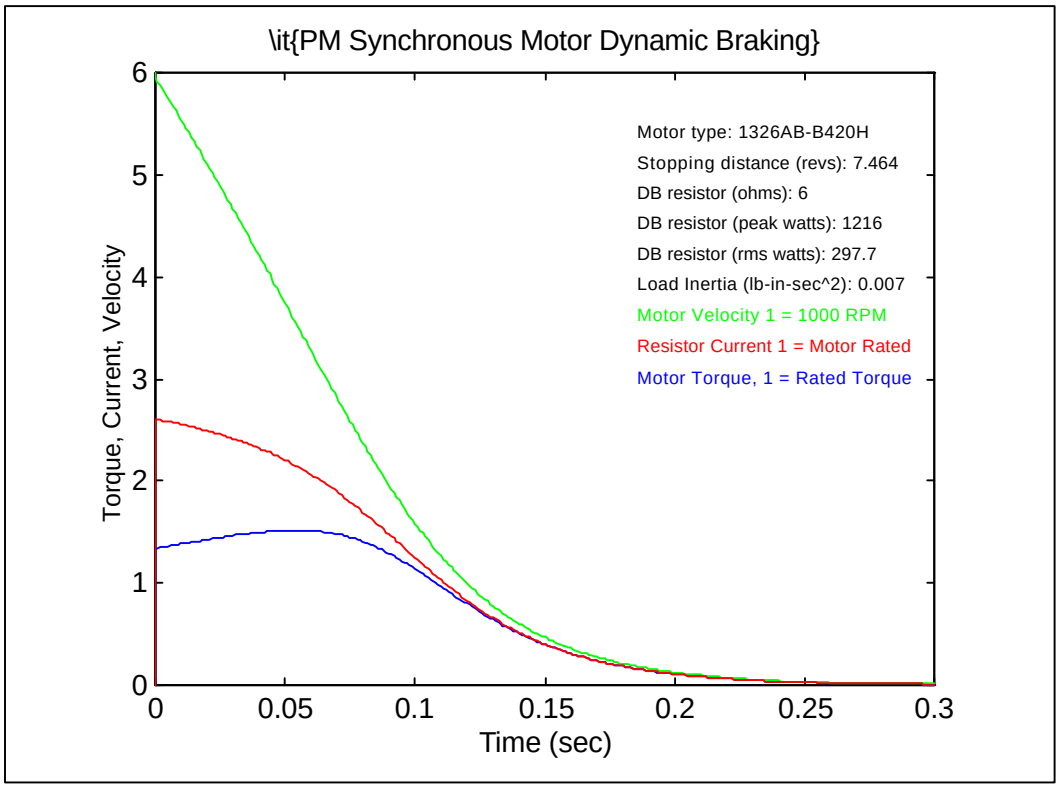
1326AS Motor Type	Maximum Speed Rating (rpm)	Peak DB Current (amps)	DB Resistance (Ohms per leg)	Instantaneous Peak Energy Dissipated (Watts)	RMS Energy Dissipated Per Stop (Watt)	Motor Torque (in-lb) @ 10 RPM	Motor Revs to Stop	Stopping Time (Sec)
B220H	5500	1.3	1	1.46	0.6	0.05	4.22	0.14
B310H	6200	2.4	36	208	32.6	0.05	2.8	0.14
B330H	6500	4.9	36	879	88.6	0.08	2.7	0.15
B420G	5250	7.8	16	971	146	0.25	3.0	0.18
B440G	5250	12.1	16	2323	210	0.26	3.5	0.25
B460F	4300	12.6	16	2538	235	0.40	2.5	0.22
B630F	4500	14.0	16	3120	281	0.40	4.9	0.4
B660F	4500	31.2	6	5851	519	1.21	3.0	0.25
B660E	3000	29.1	6	5082	597	2.0	1.4	0.15
B690E	3000	33.2	6	6585	648	2.04	1.7	0.2
B840E	3000	29.1	6	5088	558	1.75	2.7	0.4
B860C	2000	43.6	3	5692	1009	0.6	1.1	0.14

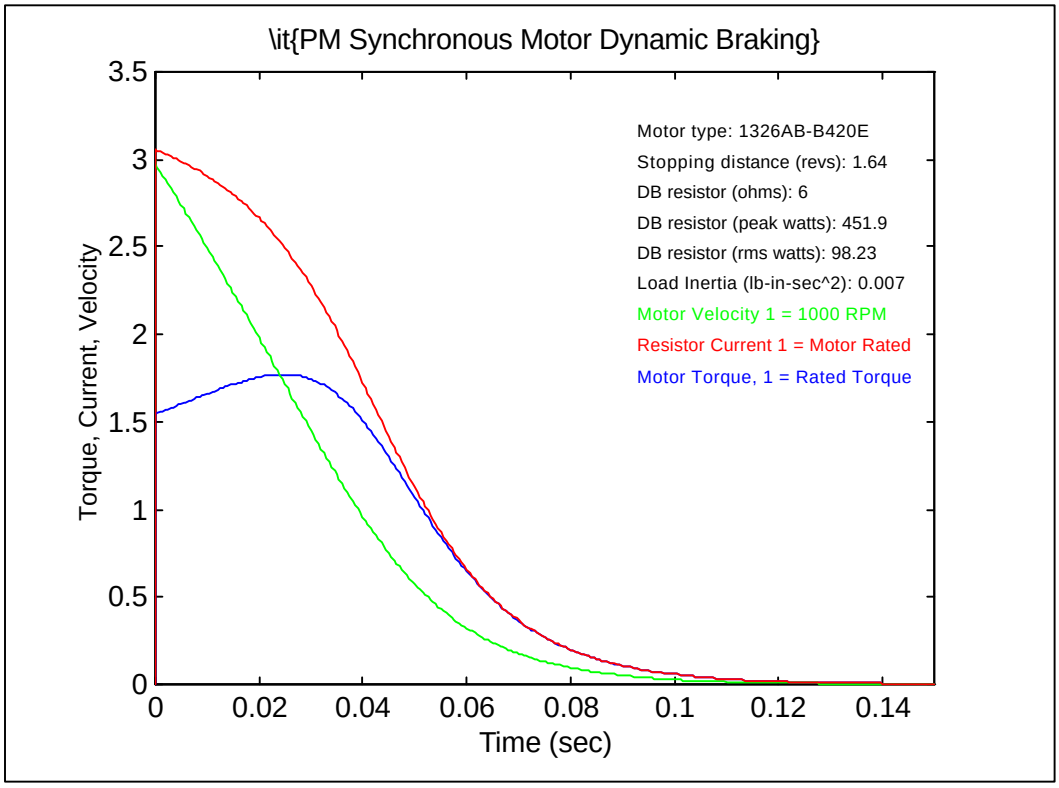
Explanation of graphs on the Following pages

1. The curves which follow show a profile of the motor velocity, DB resistor current and shaft torque.
2. The scaling of the graphs on the Y Axis is "Per Unit" values. Per unit maens that the particular axis has been "normalized". For instance on the current scale a value of 1 = I motor rated rms, velocity scaling a value of 1 = 1000 rpm, and torque scale a value of 1 = Rated torque at stall.
3. The plots are shown using the Bonitron DB Braking Units.






\it{PM Synchronous Motor Dynamic Braking}
Motor type: 1326AB-B420H
Stopping distance (revs): 7.464
DB resistor (ohms): 6
DB resistor (peak watts): 1216
DB resistor (rms watts): 297.7
Load Inertia (lb-in-sec^2): 0.007
Motor Velocity 1 = 1000 RPM
Resistor Current 1 = Motor Rated
Motor Torque, 1 = Rated Torque
Torque, Current, Velocity
Time (sec)
0
1
2
3
4
5
6
0
0.05
0.1
0.15
0.2
0.25
0.3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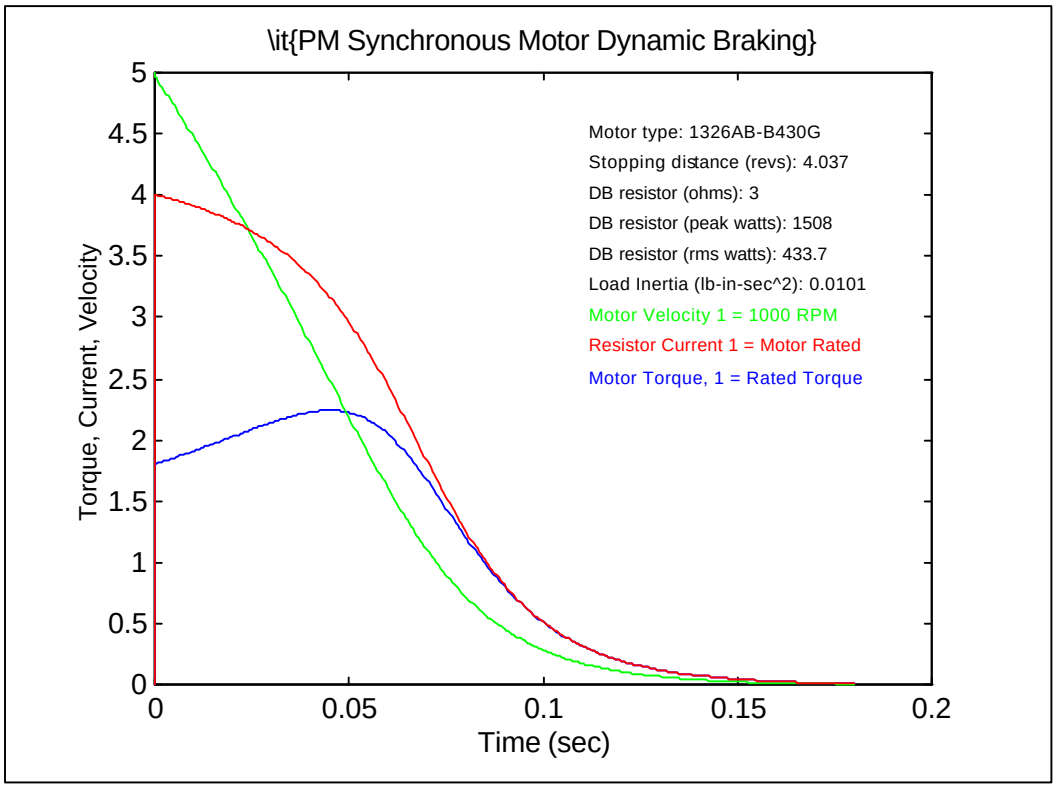
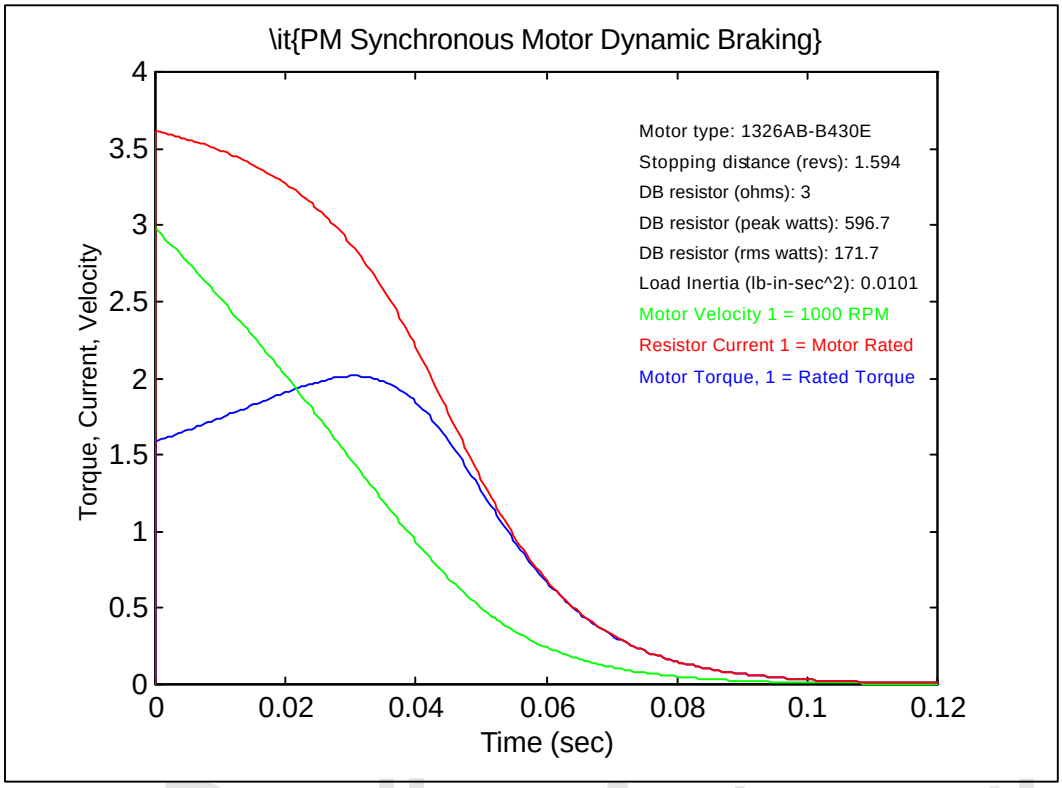
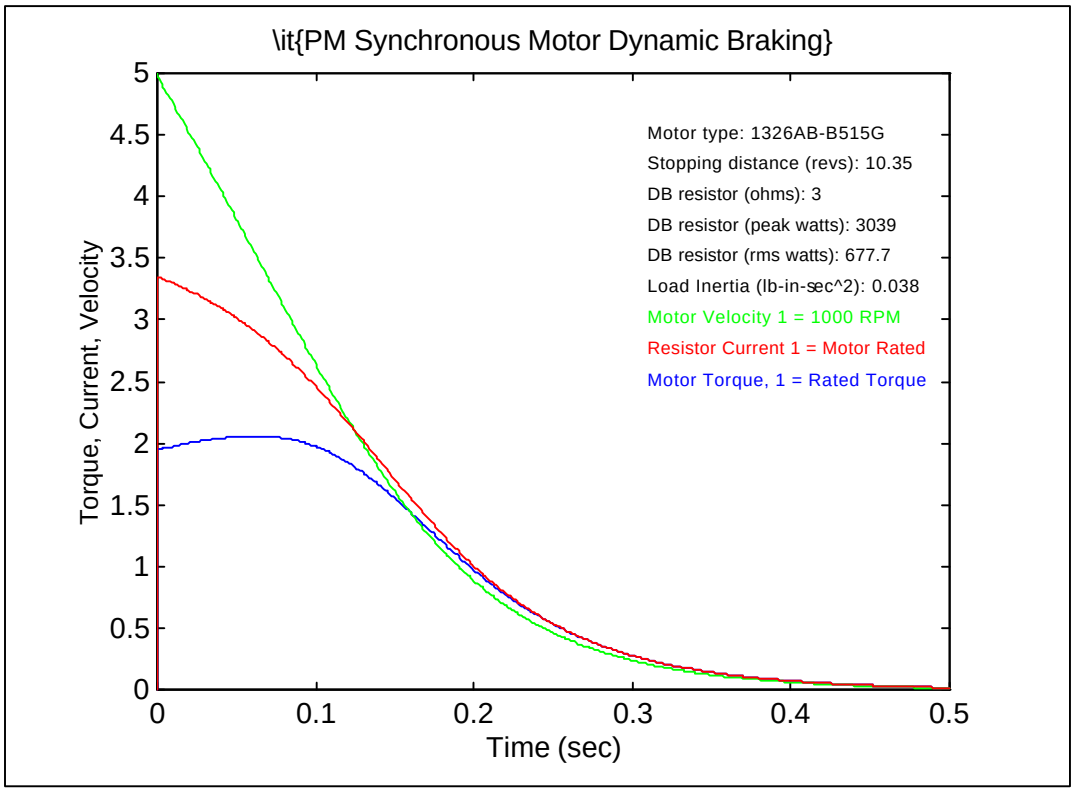
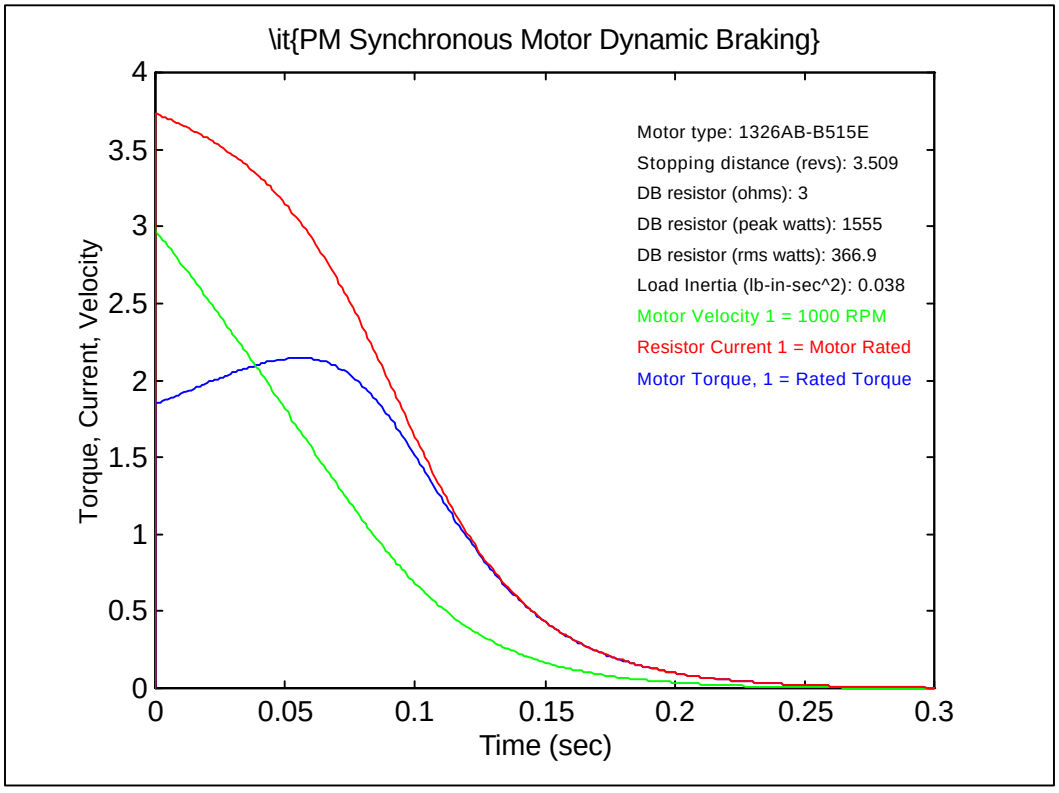
Motor type: 1326AB-B420E
Stopping distance (revs): 1.64
DB resistor (ohms): 6
DB resistor (peak watts): 451.9
DB resistor (rms watts): 98.23
Load Inertia (lb-in-sec^2): 0.007
Motor Velocity 1 = 1000 RPM
Resistor Current 1 = Motor Rated
Motor Torque, 1 = Rated Torque
Torque, Current, Velocity
Time (sec)
0
0.5
1
1.5
2
2.5
3
3.5
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14






\it{PM Synchronous Motor Dynamic Braking}
Torque, Current, Velocity
Time (sec)
Motor type: 1326AB-B515G
Stopping distance (revs): 10.35
DB resistor (ohms): 3
DB resistor (peak watts): 3039
DB resistor (rms watts): 677.7
Load Inertia (lb-in-sec^2): 0.038
Motor Velocity 1 = 1000 RPM
Resistor Current 1 = Motor Rated
Motor Torque, 1 = Rated Torque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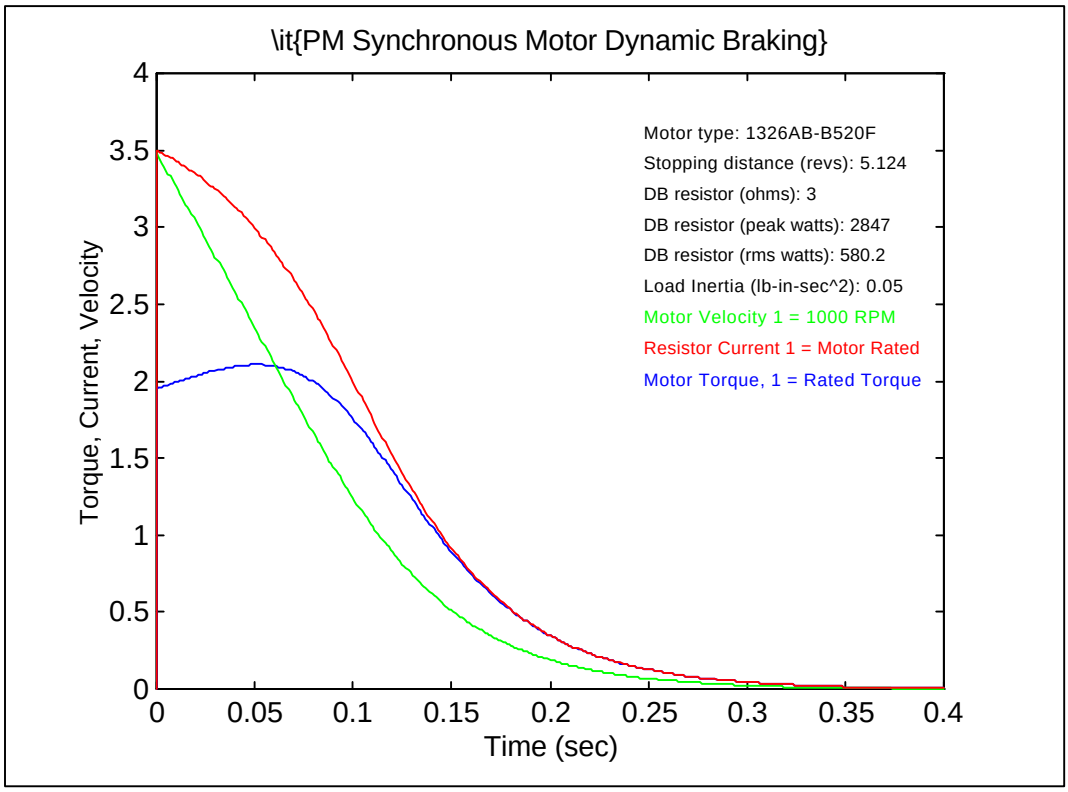
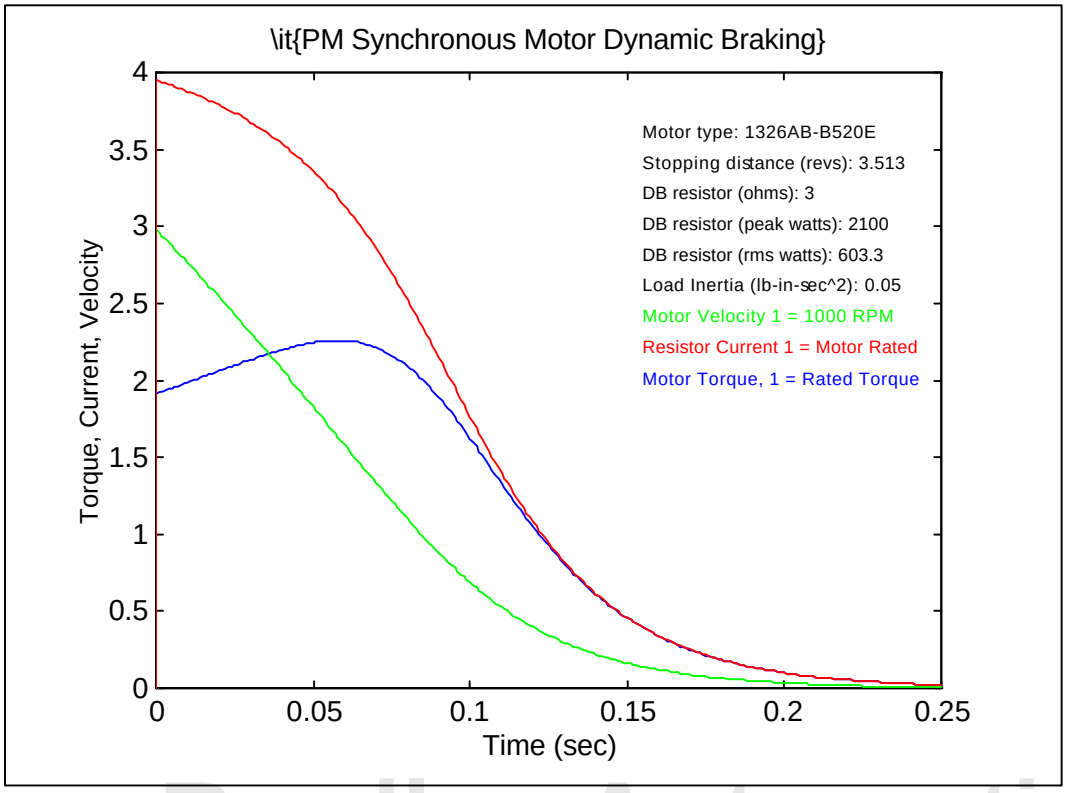
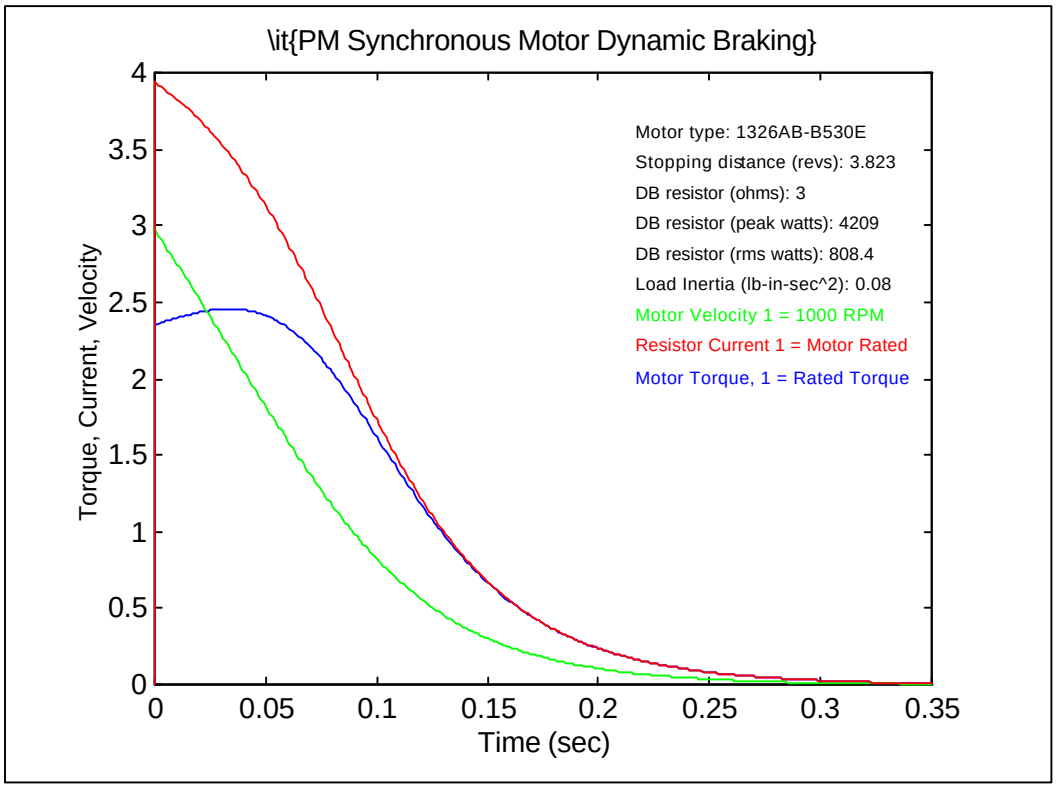
Torque, Current, Velocity
Time (sec)
Motor type: 1326AB-B515E
Stopping distance (revs): 3.509
DB resistor (ohms): 3
DB resistor (peak watts): 1555
DB resistor (rms watts): 366.9
Load Inertia (lb-in-sec^2): 0.038
Motor Velocity 1 = 1000 RPM
Resistor Current 1 = Motor Rated
Motor Torque, 1 = Rated Torque



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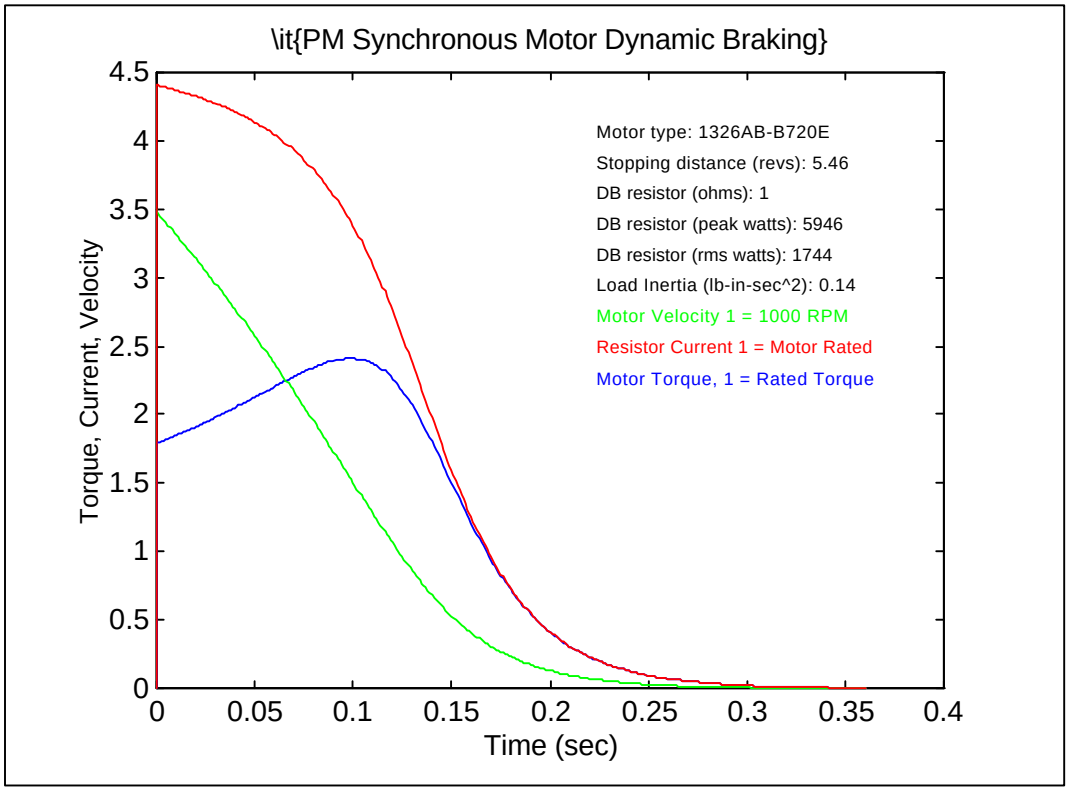
Motor type: 1326AB-B530E
Stopping distance (revs): 3.823
DB resistor (ohms): 3
DB resistor (peak watts): 4209
DB resistor (rms watts): 808.4
Load Inertia (lb-in-sec^2): 0.08
Motor Velocity 1 = 1000 RPM
Resistor Current 1 = Motor Rated
Motor Torque, 1 = Rated Torque
Torque, Current, Velocity
Time (sec)
0
0.5
1
1.5
2
2.5
3
3.5
4
0.05
0.1
0.15
0.2
0.25
0.3
0.35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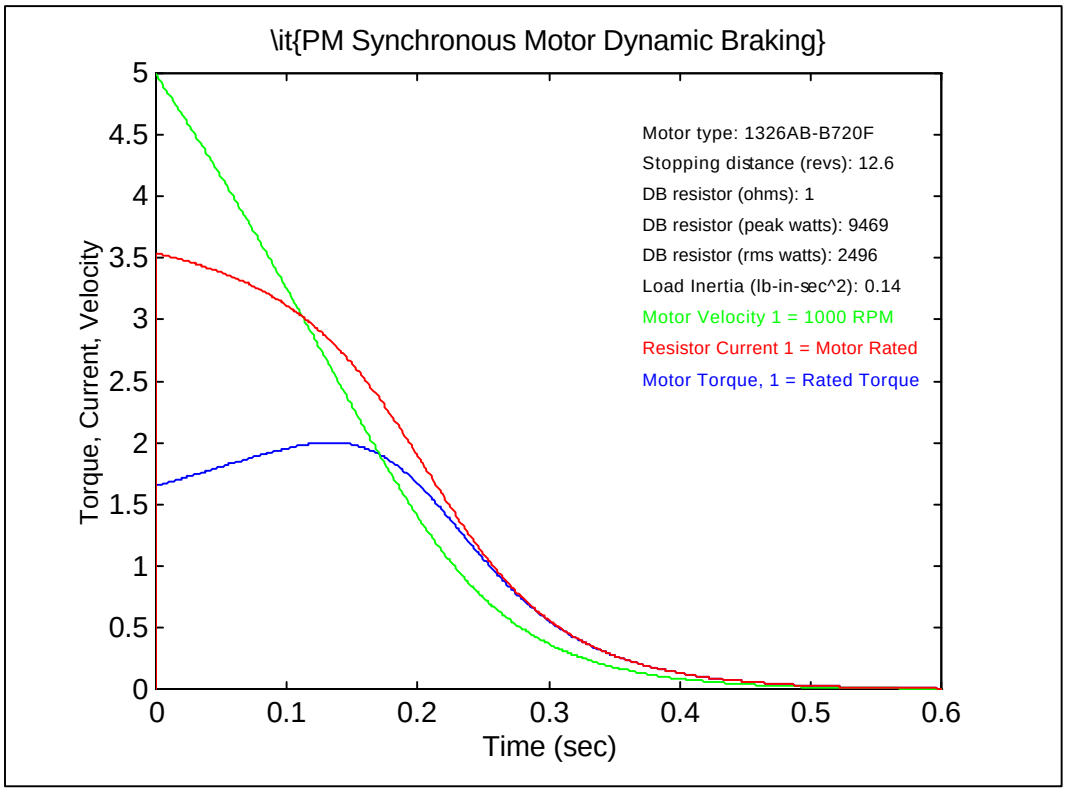
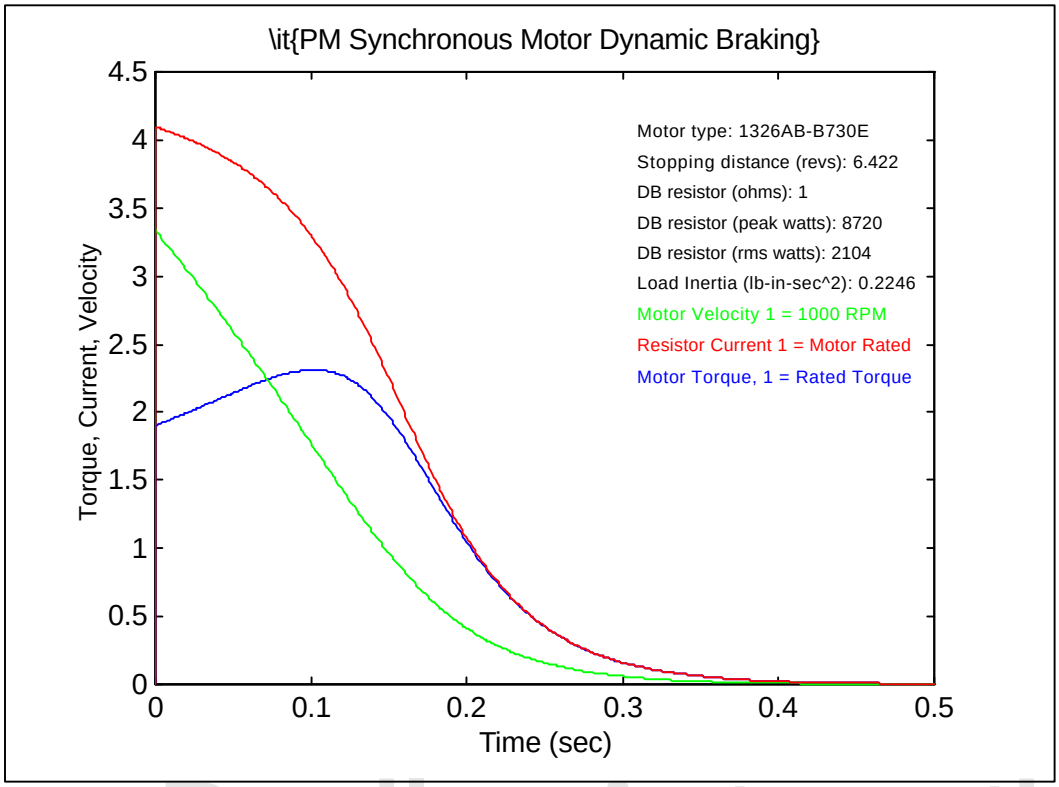
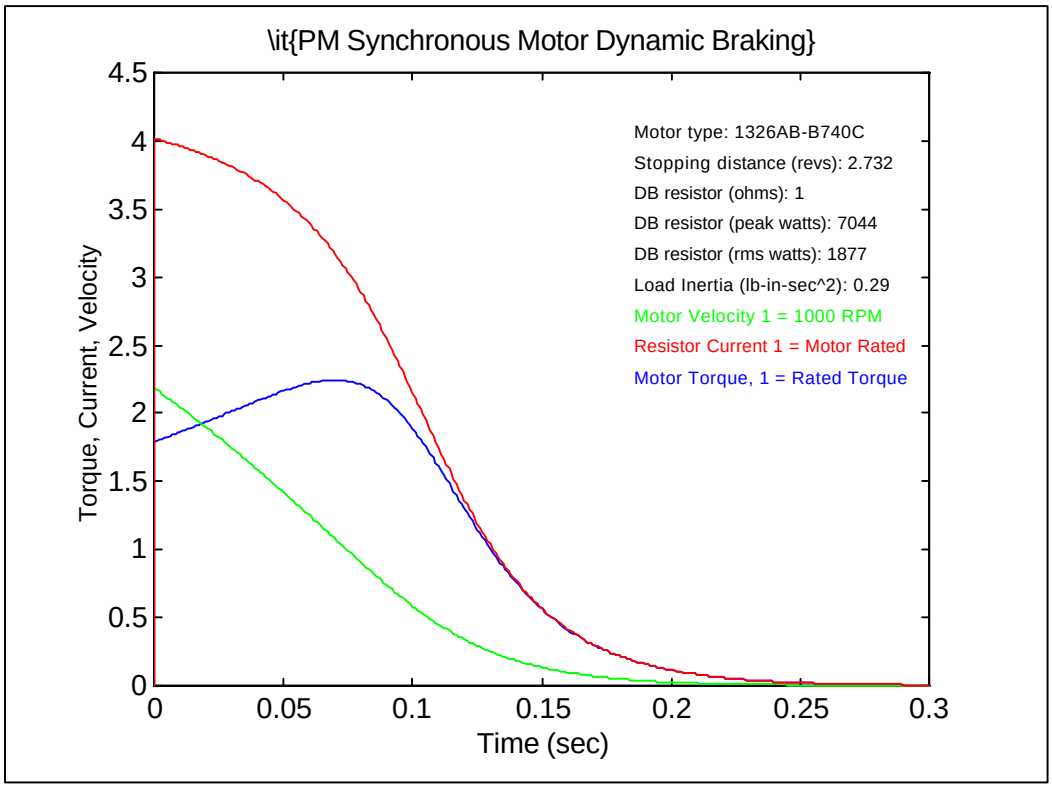
Motor type: 1326AB-B720E
Stopping distance (revs): 5.46
DB resistor (ohms): 1
DB resistor (peak watts): 5946
DB resistor (rms watts): 1744
Load Inertia (lb-in-sec^2): 0.14
Motor Velocity 1 = 1000 RPM
Resistor Current 1 = Motor Rated
Motor Torque, 1 = Rated Torque
Torque, Current, Velocity
Time (sec)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4



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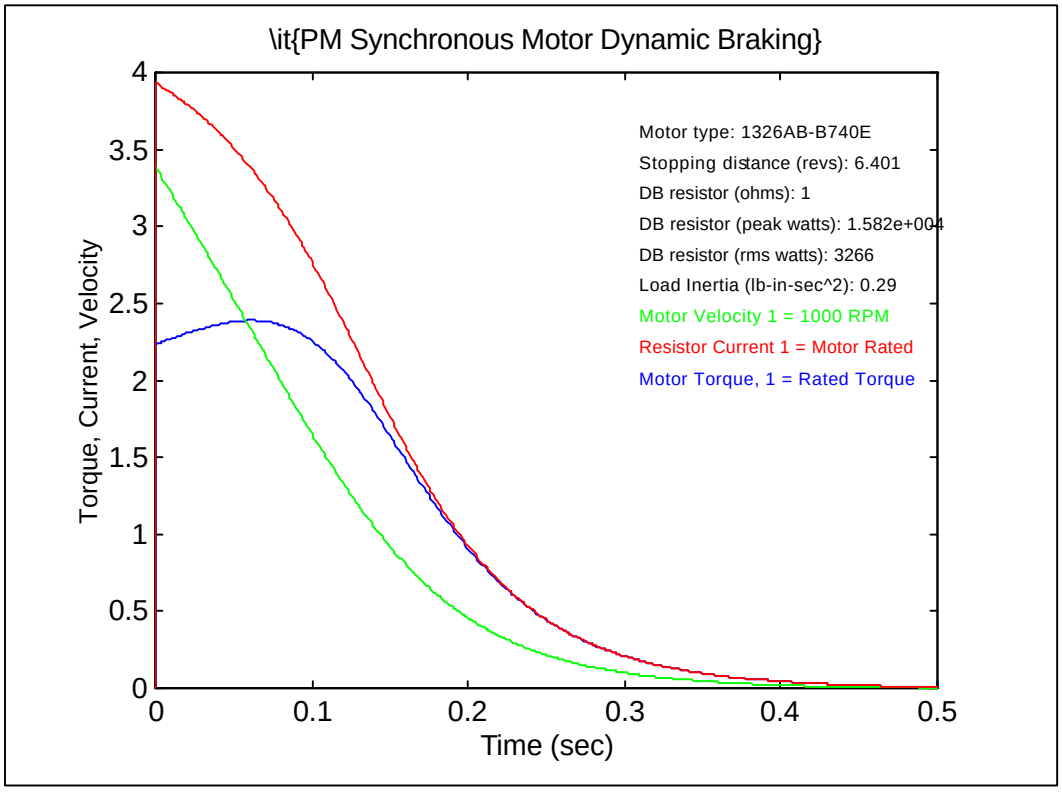
Stopping distance (revs): 2.732
DB resistor (ohms): 1
DB resistor (peak watts): 7044
DB resistor (rms watts): 1877
Load Inertia (lb-in-sec^2): 0.29
Motor Velocity 1 = 1000 RPM
Resistor Current 1 = Motor Rated
Motor Torque, 1 = Rated Torque
Torque, Current, Velocity
Time (sec)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0.05
0.1
0.15
0.2
0.25
0.3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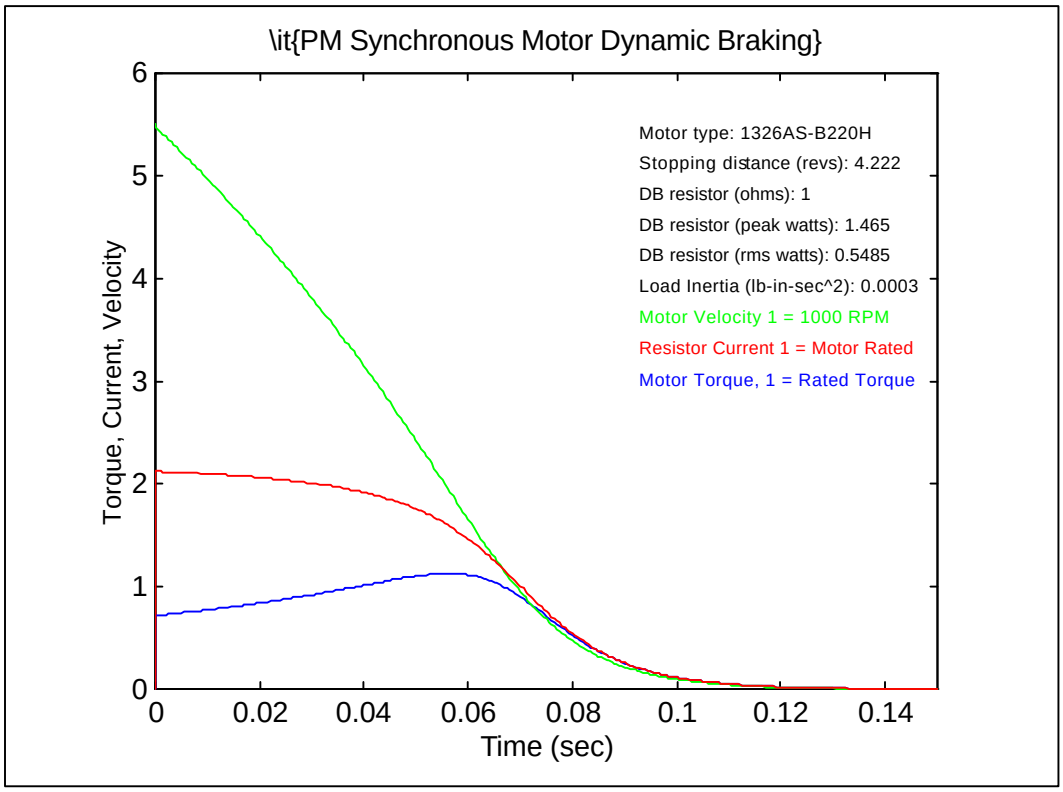
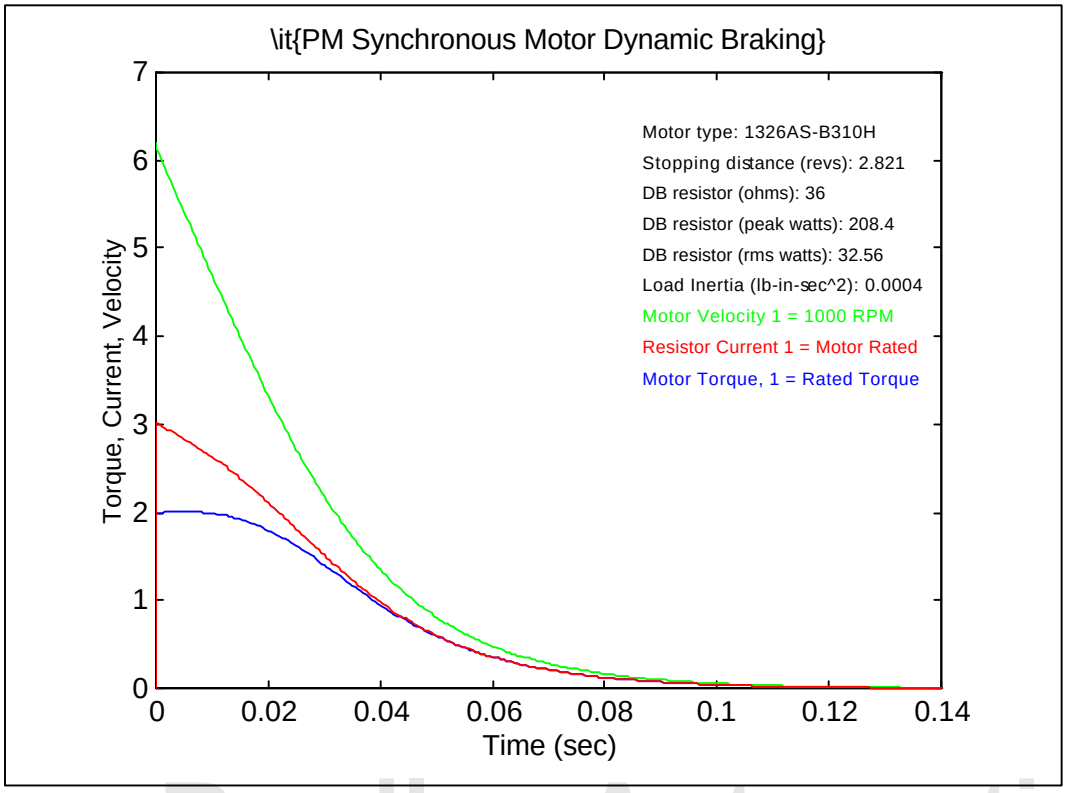
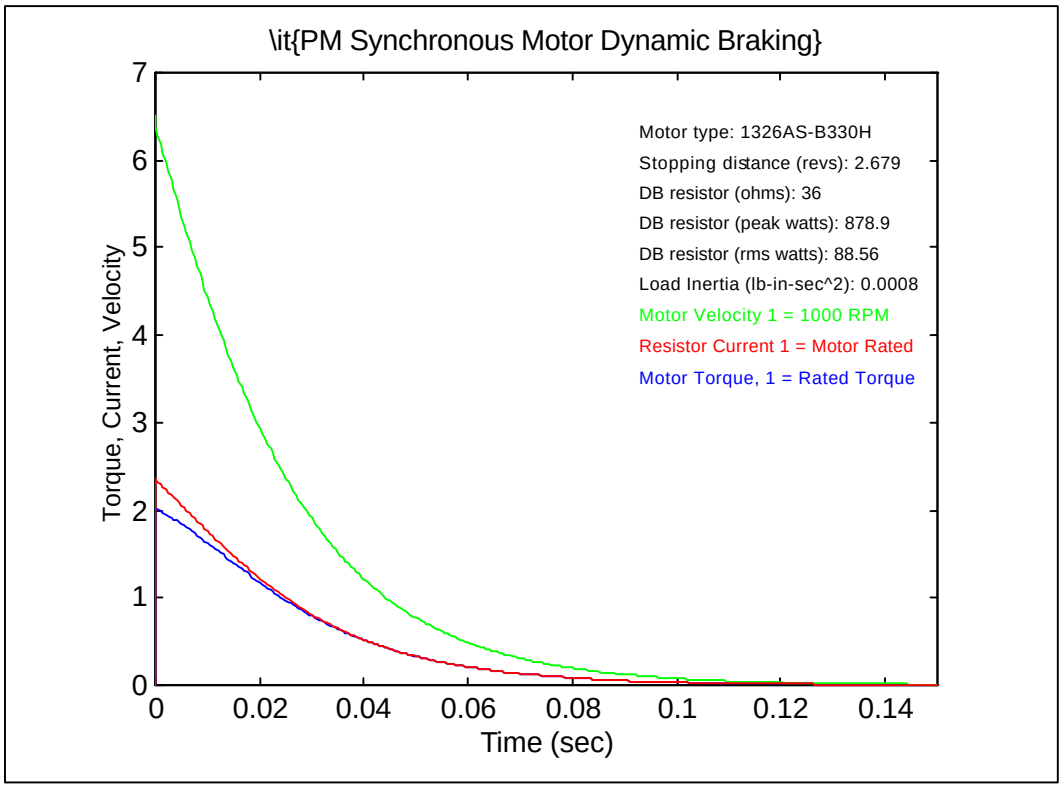
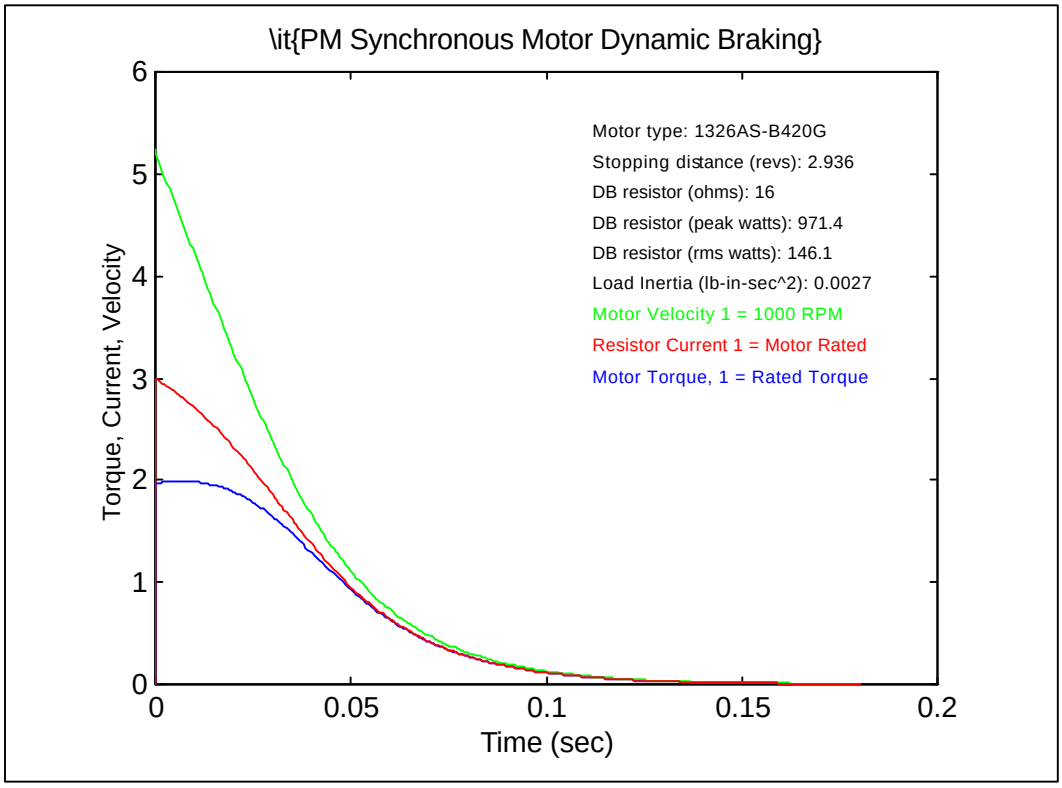
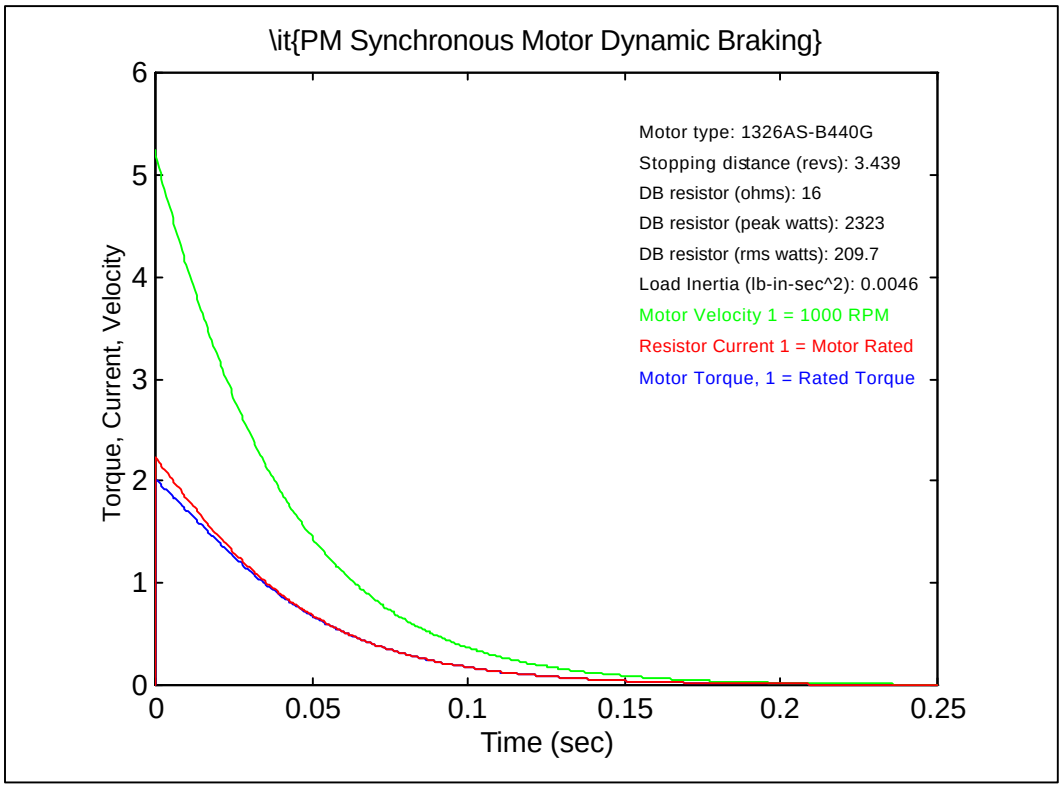
Motor type: 1326AB-B740E
Stopping distance (revs): 6.401
DB resistor (ohms): 1
DB resistor (peak watts): 1.582e+004
DB resistor (rms watts): 3266
Load Inertia (lb-in-sec^2): 0.29
Motor Velocity 1 = 1000 RPM
Resistor Current 1 = Motor Rated
Motor Torque, 1 = Rated Torque
Torque, Current, Velocity
Time (sec)
0
0.5
1
1.5
2
2.5
3
3.5
4
0.1
0.2
0.3
0.4
0.5

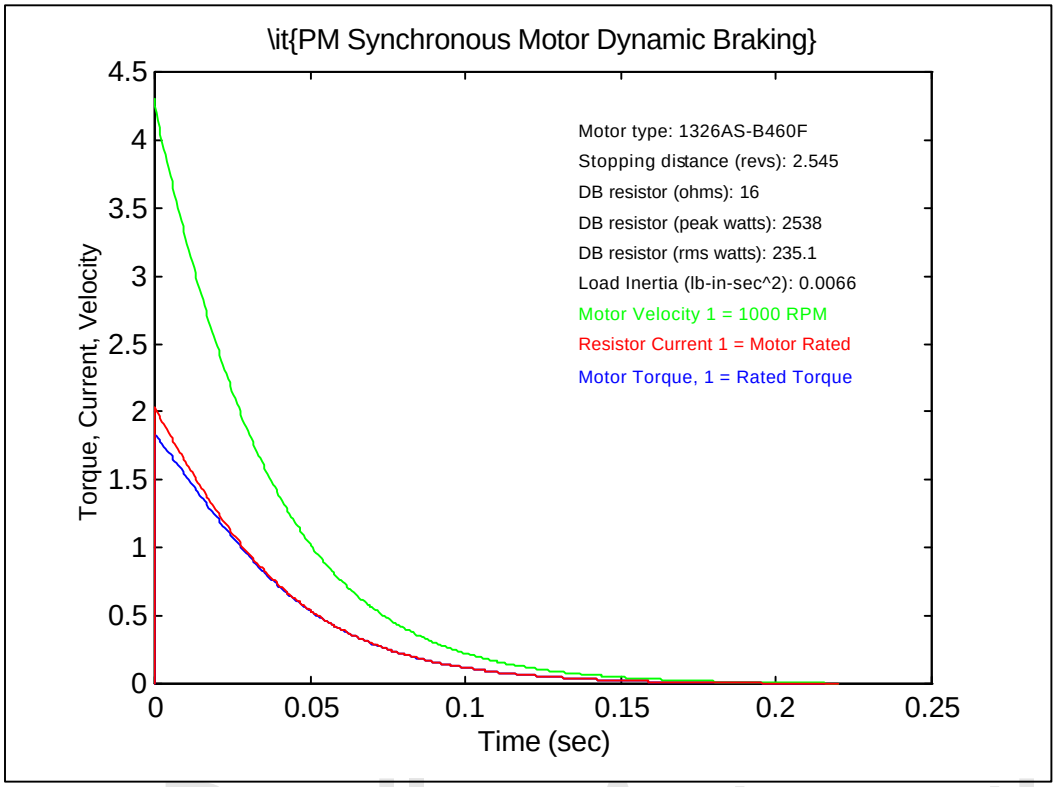


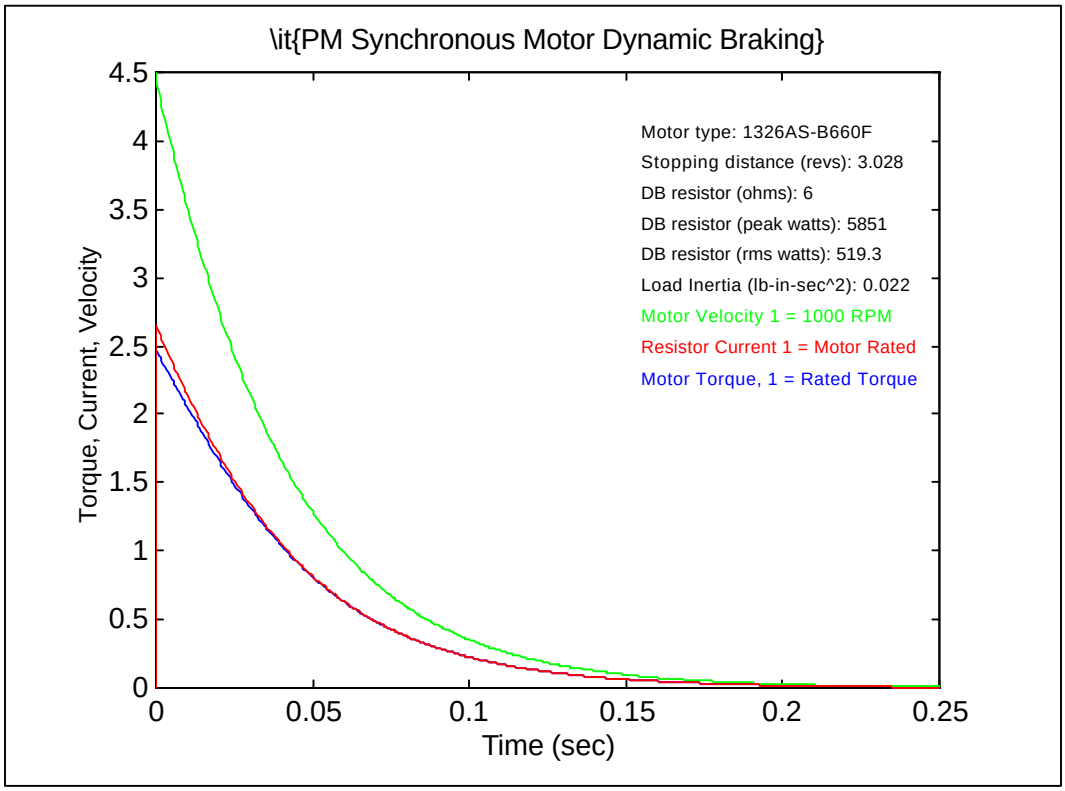


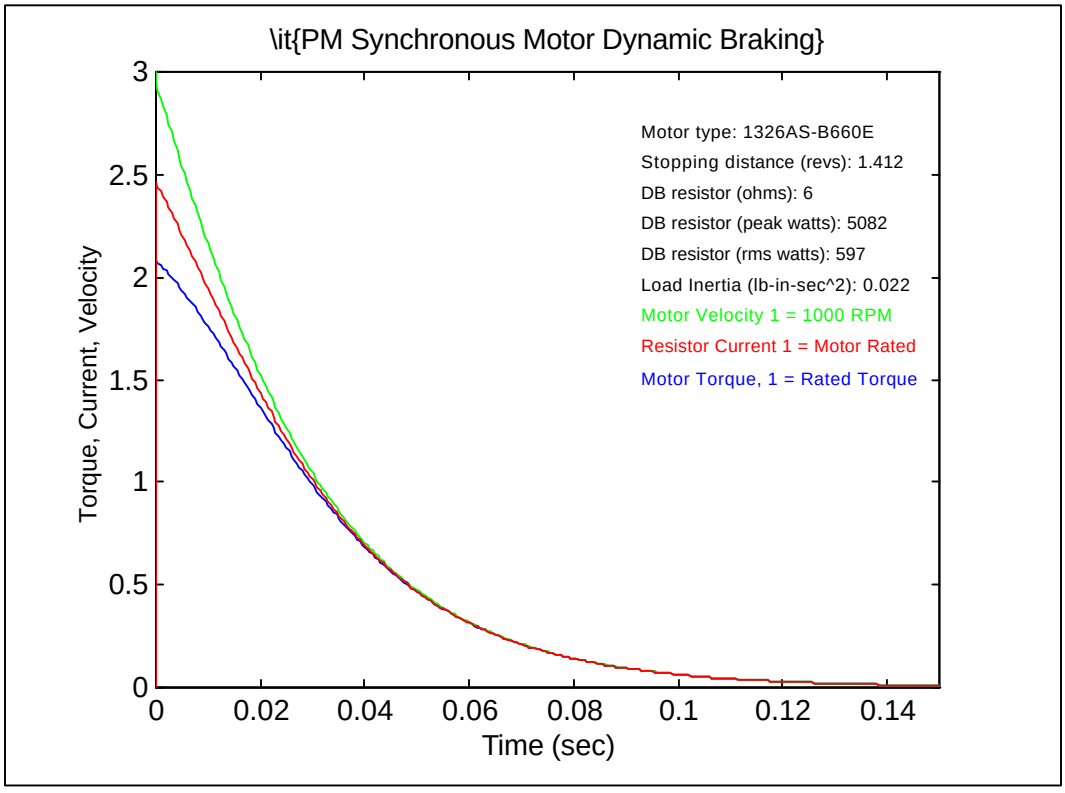

\it{PM Synchronous Motor Dynamic Braking}
Motor type: 1326AS-B330H
Stopping distance (revs): 2.679
DB resistor (ohms): 36
DB resistor (peak watts): 878.9
DB resistor (rms watts): 88.56
Load Inertia (lb-in-sec^2): 0.0008
Motor Velocity 1 = 1000 RPM
Resistor Current 1 = Motor Rated
Motor Torque, 1 = Rated Torque
Torque, Current, Velocity
Time (sec)
0
1
2
3
4
5
6
7
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14

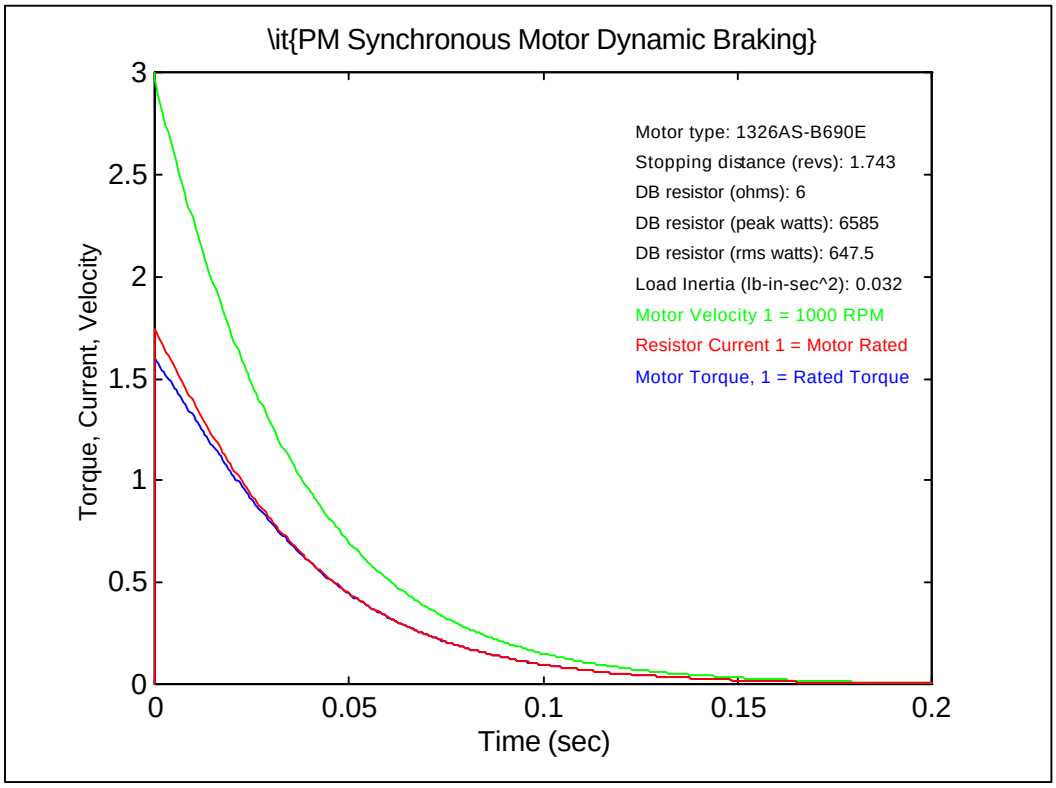

\it{PM Synchronous Motor Dynamic Braking}
Motor type: 1326AS-B420G
Stopping distance (revs): 2.936
DB resistor (ohms): 16
DB resistor (peak watts): 971.4
DB resistor (rms watts): 146.1
Load Inertia (lb-in-sec^2): 0.0027
Motor Velocity 1 = 1000 RPM
Resistor Current 1 = Motor Rated
Motor Torque, 1 = Rated Torque
Torque, Current, Velocity
Time (sec)
0
1
2
3
4
5
6
0
0.05
0.1
0.15
0.2

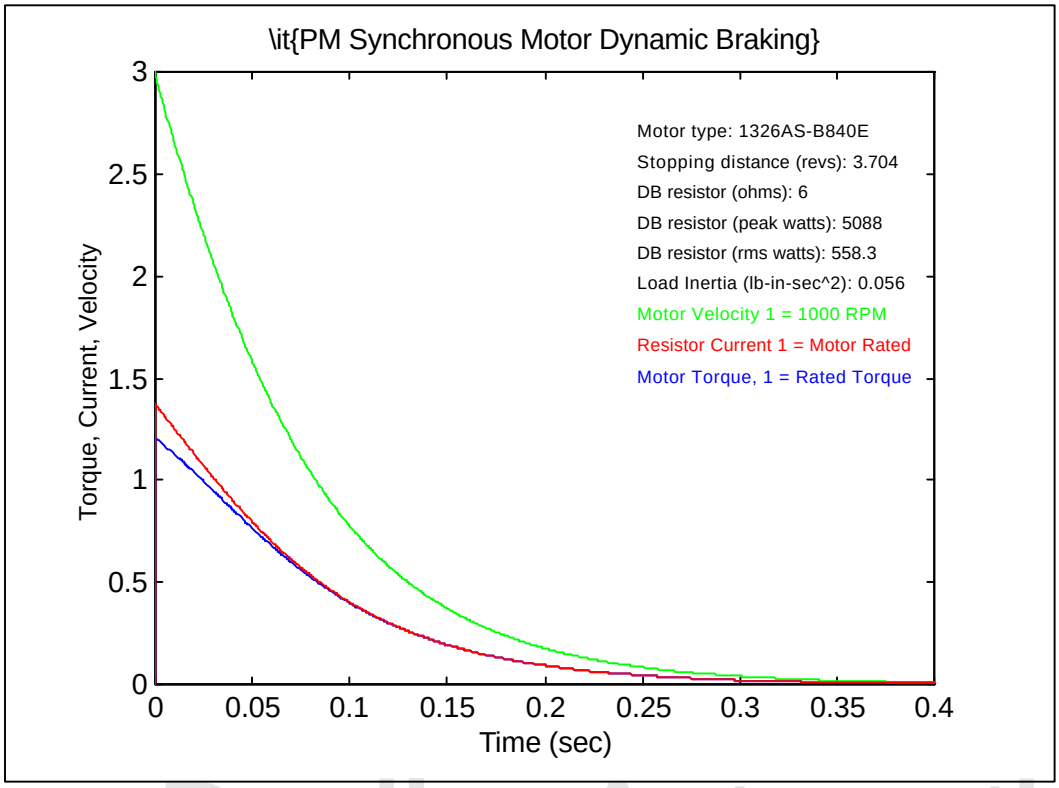


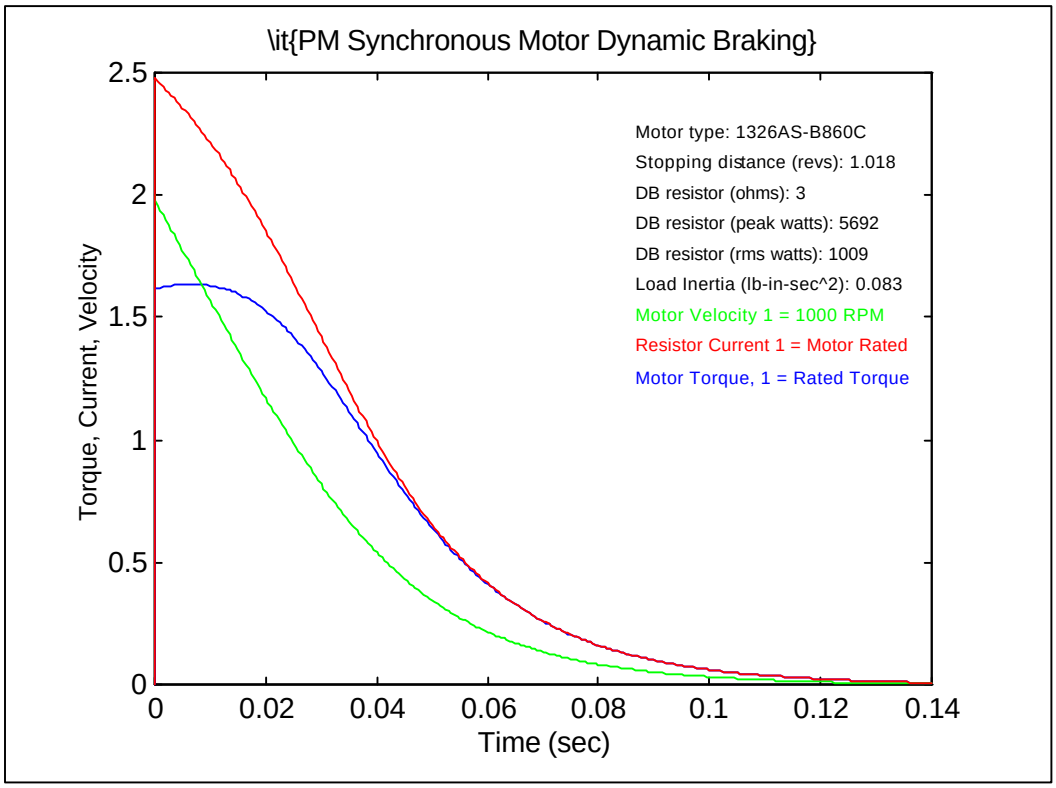



\it{PM Synchronous Motor Dynamic Braking}
Motor type: 1326AS-B660F
Stopping distance (revs): 3.028
DB resistor (ohms): 6
DB resistor (peak watts): 5851
DB resistor (rms watts): 519.3
Load Inertia (lb-in-sec^2): 0.022
Motor Velocity 1 = 1000 RPM
Resistor Current 1 = Motor Rated
Motor Torque, 1 = Rated Torque
Torque, Current, Velocity
Time (sec)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0.05
0.1
0.15
0.2
0.25

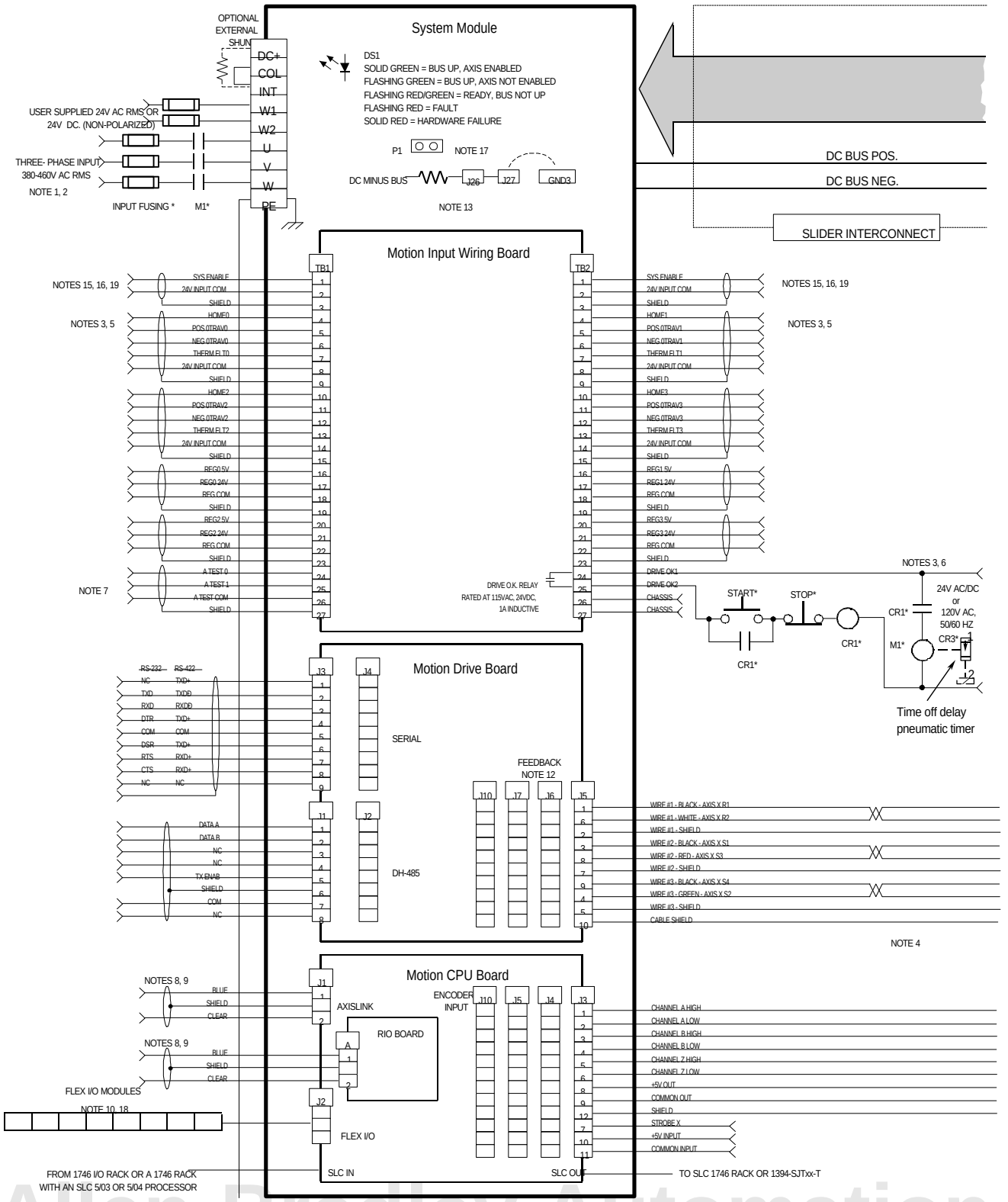

\it{PM Synchronous Motor Dynamic Braking}
Motor type: 1326AS-B660E
Stopping distance (revs): 1.412
DB resistor (ohms): 6
DB resistor (peak watts): 5082
DB resistor (rms watts): 597
Load Inertia (lb-in-sec^2): 0.022
Motor Velocity 1 = 1000 RPM
Resistor Current 1 = Motor Rated
Motor Torque, 1 = Rated Torque
Torque, Current, Velocity
Time (sec)
0
0.5
1
1.5
2
2.5
3
0.02
0.04
0.06
0.08
0.1
0.12
0.14



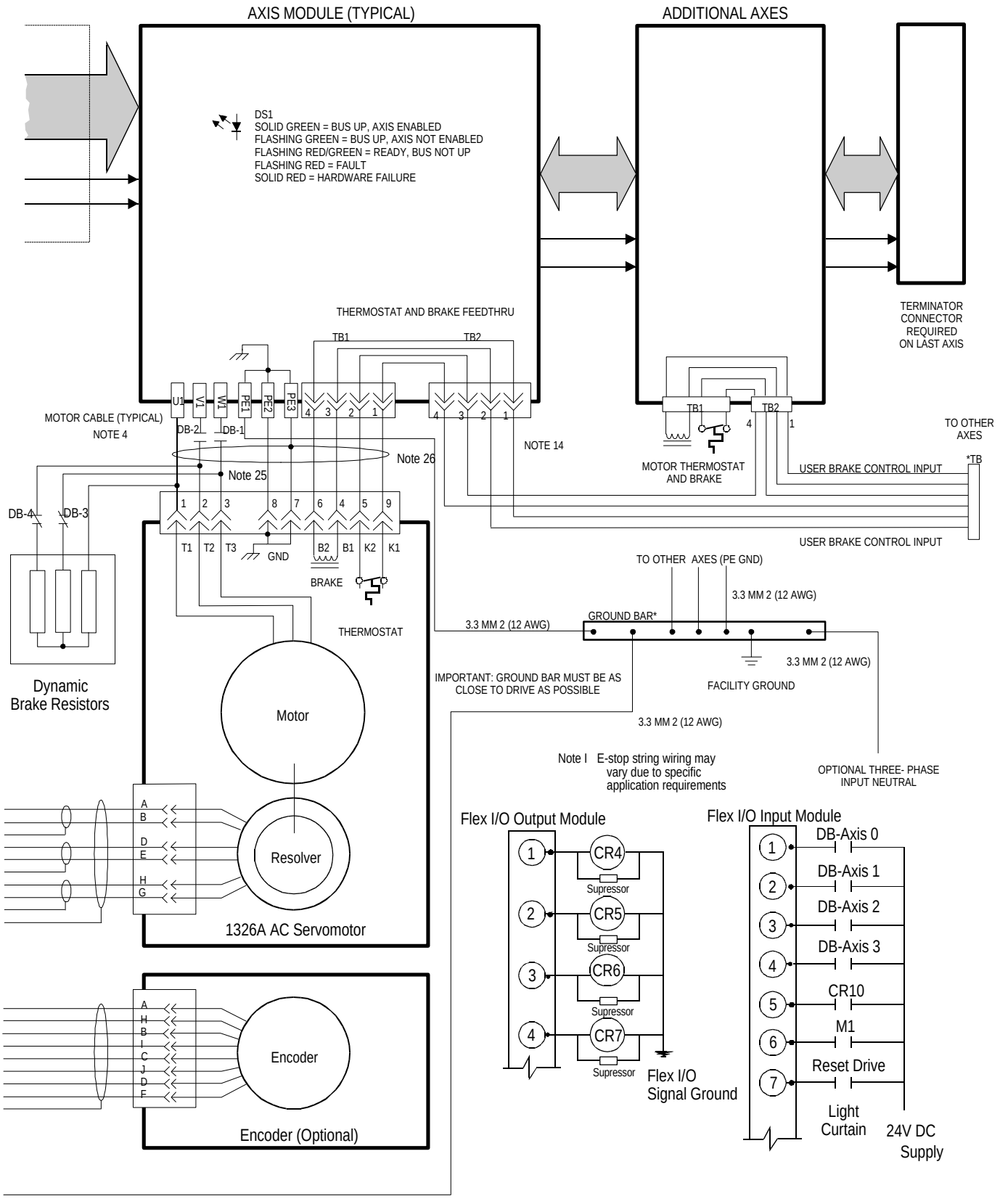



\it{PM Synchronous Motor Dynamic Braking}
Torque, Current, Velocity
Time (sec)
2.5
2
1.5
1
0.5
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
Motor type: 1326AS-B860C
Stopping distance (revs): 1.018
DB resistor (ohms): 3
DB resistor (peak watts): 5692
DB resistor (rms watts): 1009
Load Inertia (lb-in-sec^2): 0.083
Motor Velocity 1 = 1000 RPM
Resistor Current 1 = Motor Rated
Motor Torque, 1 = Rated Torque

1394-GMC Interconnect

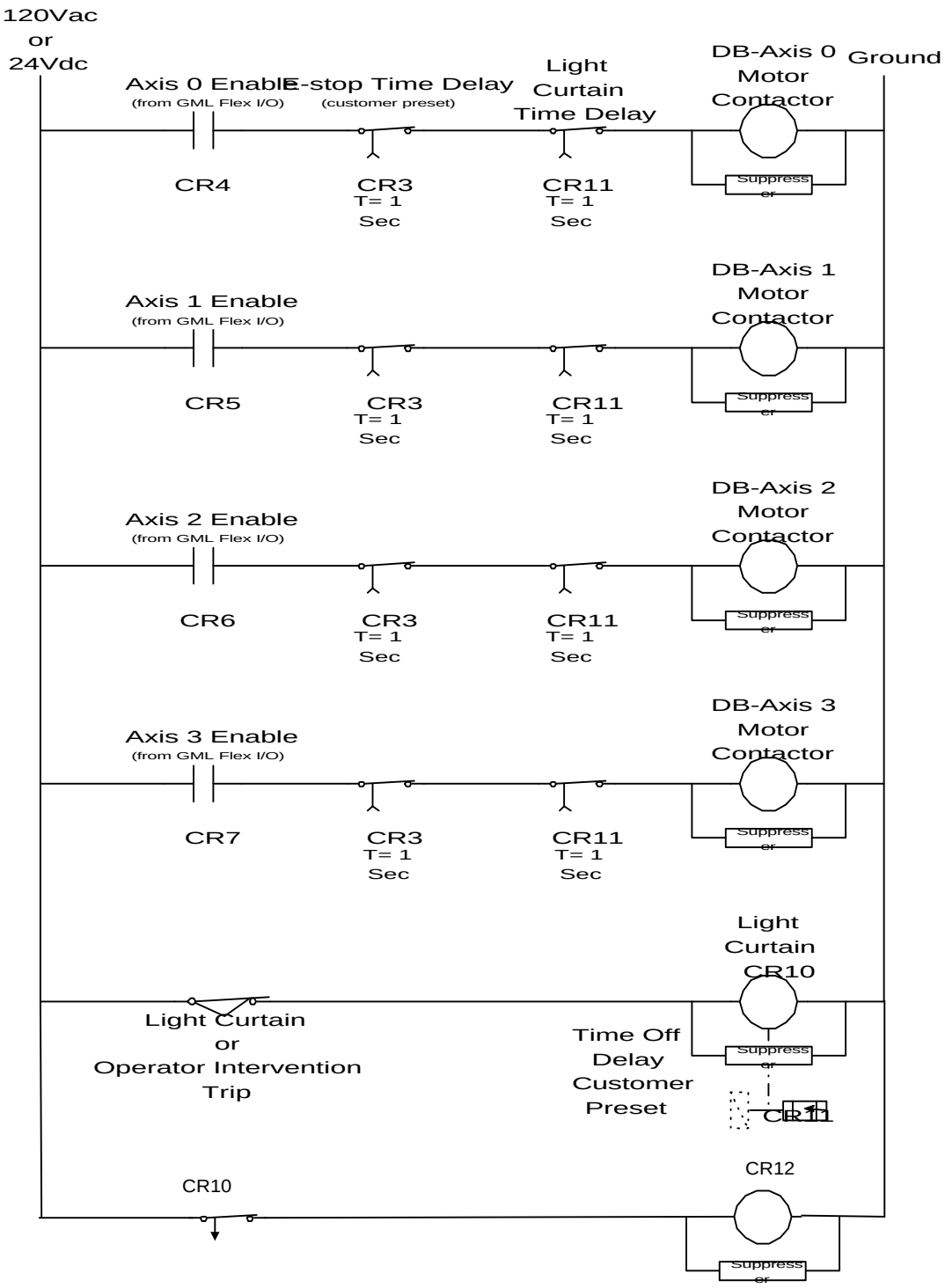


1394-GMC Interconnect



* INDICATES USER SUPPLIED COMPONENT

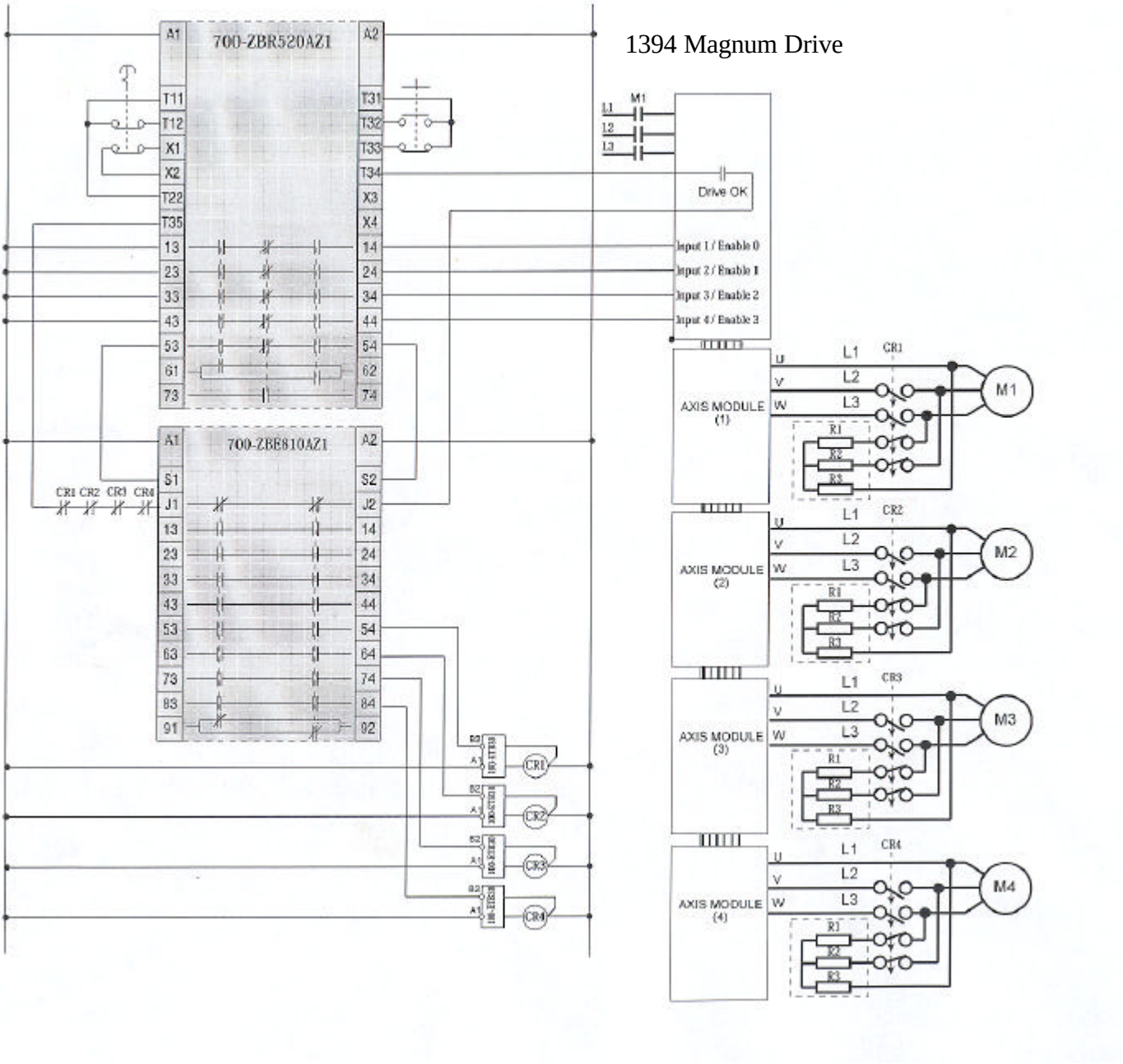
1394-GMC Light Curtain Control Circuit Diagram



1394 Magnum Safety Interconnect

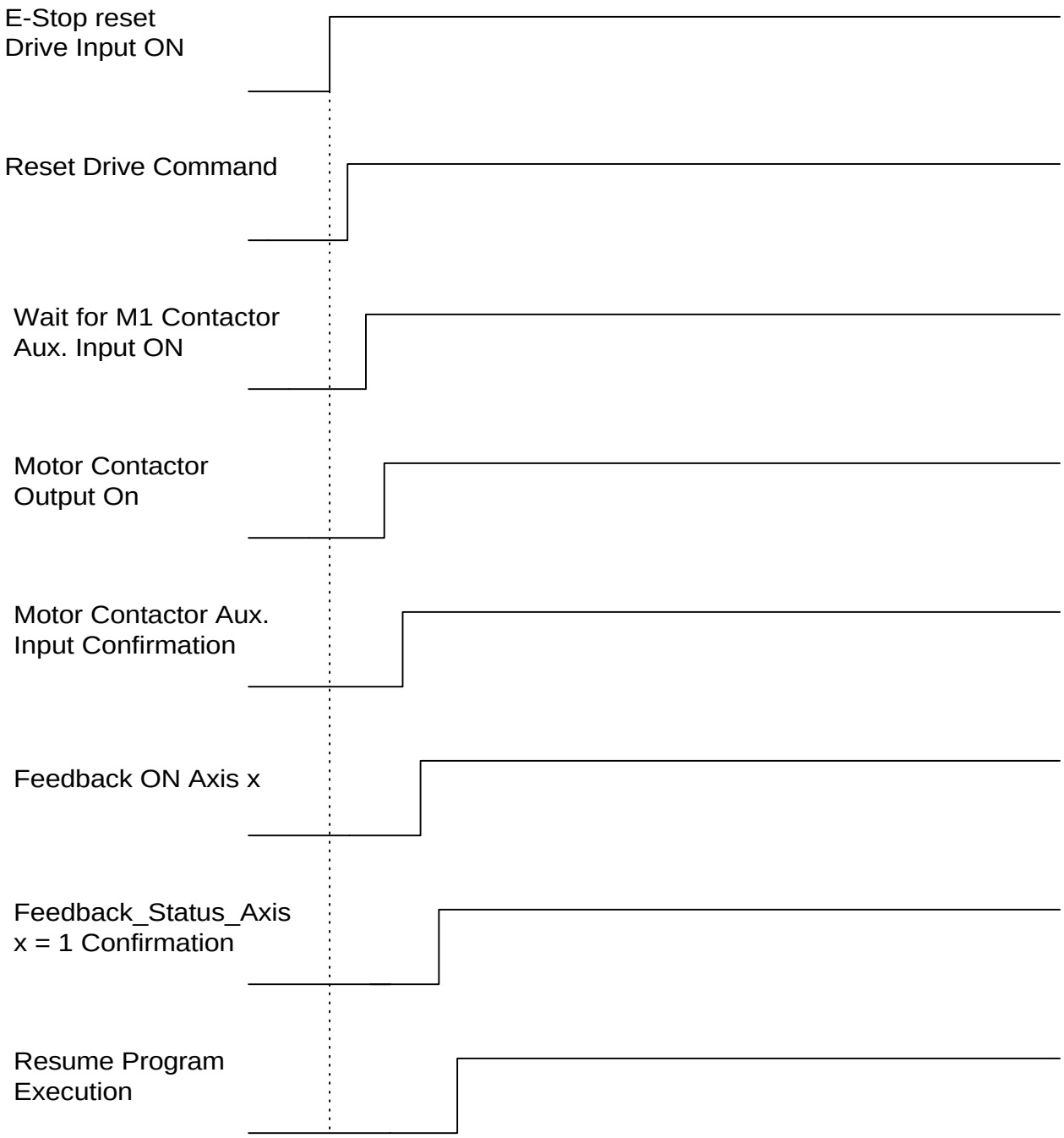
AB 700 series safety Relays and timers

1394 Magnum Drive



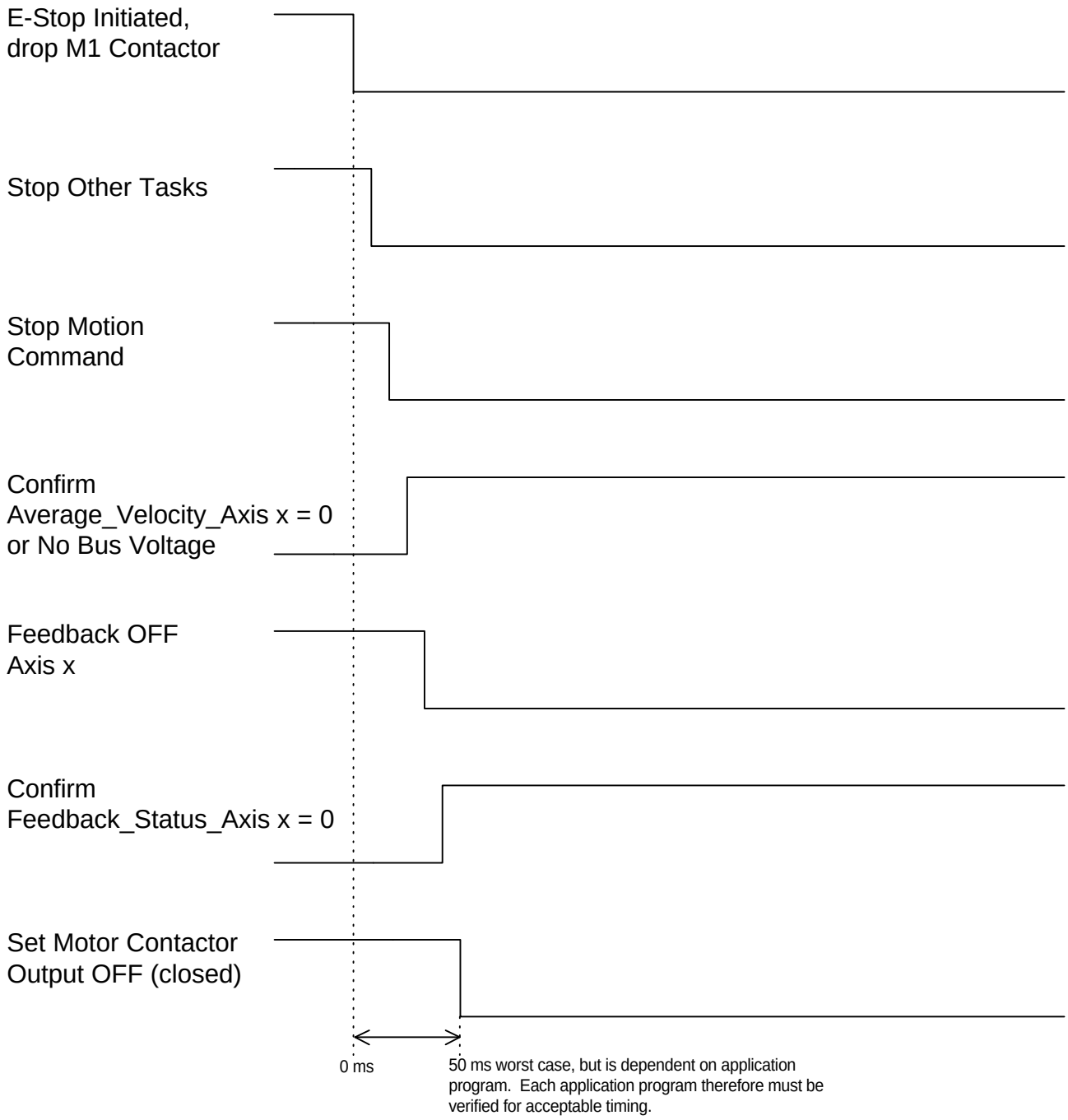
E-STOP RESET SEQUENCE

FOR 1394-GMC



E-STOP TRIP SEQUENCE

FOR 1394-GMC



LIGHT CURTAIN OPERATION

(Operator Intervention)

FOR 1394-GMC

Light Curtain Trip Sequence