INSTRUCTION MANUAL

Models
300B, 300B-LR, 305B, 305B-LR, 309B, 310B, 310B-LR

Dual-Mode Lever Arm Systems

June 28, 2004, Revision 16

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1.0 Introduction

The 300B Series systems were designed to enable physiology researchers to study the dynamic mechanical characteristics of muscle tissue. These systems are capable of generating forces of 0.5 N for the 300B system, 1.0 N for the 300B-LR, 5.0 N for the 305B system, 10.0 N for the 305B-LR system, 20.0 N for the 309B system, 50.0 N for the 310B system and 100.0 N for the 310B-LR system. All systems are dual-mode, which means that they control and measure both length and force. In-vivo experiments are possible since force is measured without the requirement of a force transducer at the opposite end of the muscle.

A notable feature of these instruments is the ability to make the transition from length control to force control without the slightest transient on either the force or position signals. Making the transition from force control to length control is equally smooth.

Take note of the fact that all dual-mode instruments have a preferred direction of force application. This direction is set at the factory as follows. The load should be attached to the lever arm such that a muscle contraction will pull the lever arm in a counterclockwise direction (when viewed from the shaft end of the motor). Contracting muscle forces should always result in positive voltages being measured at FORCE OUT. If the voltage at FORCE OUT is negative then you are applying force in the wrong direction. The system can measure force in both the clockwise and counterclockwise directions but the amount of force that can be generated in the clockwise direction is often a small fraction of that available in the counterclockwise direction. In addition force control can only be achieved for forces that try to pull the arm in a counterclockwise direction. If the experimental set-up doesn't allow the motor and lever arm to be positioned correctly then please contact ASI for a model 300-FD motor cable. This cable attaches between the servo controller and the motor cable and reverses the direction of force control.

The heart of these systems is a very high performance rotary moving coil motor. The rotor of the motor is supported by precision ball bearings, having very low friction. A high performance capacitive position detector senses length. A three-meter cable connects the motor to the rack-mountable electronics. The motor is protected against various overload conditions by the electronics. In addition there are mechanical stops inside the motor to prevent gross over travel.

Note: The motors are high performance devices that require some special handling. Never let them impact a hard surface especially on the front shaft. Do not pull or push with anything other than light finger pressure on the front shaft or damage to the front bearing can occur. Do not expose the motor to extremes of temperature outside the operating limits shown in the specifications section 2.0. Do not let any foreign material, e.g. dust, dirt, solvents, water, oil, etc. come in contact with the front bearing. The bearing is located just behind the front cover on the front of the motor where the shaft exits the cover. Foreign material inside the bearing will reduce bearing life.

2.0 Specifications

Models: 300B, 300B-LR, 305B, 305B-LR, 309B, 310B, 310B-LR

Length Excursion:	300B, 300B-LR:	10 millimeters
	305B, 305B-LR:	20 millimeters
	309B:	25 millimeters
	310B, 310B-LR:	40 millimeters
Length Signal Resolution:	All models:	1 micron
Length Signal Linearity:	300B, 300B-LR:	0.1% over the center 2 millimeters 0.5% over the entire 10 mm range
	305B, 305B-LR:	0.1% over the center 4 millimeters 0.5% over the entire 20 mm range
	309B:	0.1% over the center 5 millimeters 0.5% over the entire 25 mm range
	310B, 310B-LR:	0.1% over the center 8 millimeters 0.5% over the entire 40 mm range
Length Scale Factor:	300B, 300B-LR:	0.5 millimeters per volt ±2%
	305B, 305B-LR:	1.0 millimeters per volt ±2%
	309B:	1.25 millimeters per volt ±2%
	310B, 310B-LR:	2.0 millimeters per volt ±2%
Length Step Response Time:	300-2B:	1.0 millisecond
(1% to 99% critically damped.)	300-3B, 300B-LR:	1.3 milliseconds
	305B, 305B-LR:	2.0 milliseconds
	309B:	5.0 milliseconds
	310B, 310B-LR:	8.0 milliseconds
Force Range:	300B:	0 to 0.5 N
	300B-LR:	0 to 1.0 N
	305B:	0 to 5.0 N
	305B-LR:	0 to 10.0 N
	309B:	0 to 20.0 N
	310B:	0 to 50.0 N
	310B-LR:	0 to 100.0 N
Force Signal Resolution:	300B, 300B-LR:	0.3 mN
	305B, 305B-LR:	1.0 mN
	309B:	4.0 mN
	310B, 310B-LR:	10.0 mN

Force Signal Linearity:	All models:	0.2% of force change
Force Signal Scale Factor:	300B:	50.0 mN per volt ±2%
	300B-LR:	100.0 mN per volt ±2%
	305B:	500.0 mN per volt ±2%
	305B-LR:	1.0 N per volt ±2%
	309B:	2.0 N per volt ±2%
	310B:	5.0 N per volt ±2%
	310B-LR:	10.0 N per volt ±2%
System Friction:	300B, 300B-LR:	0.2 mN over any 2 millimeters 0.8 mN over full 10-mm range
	305B, 305B-LR:	1.0 mN over any 4 millimeters 3.0 mN over full 20-mm range
	309B:	4.0 mN over any 5 millimeters 8.0 mN over full 25-mm range
	310B, 310B-LR:	10.0 mN over any 8 millimeters 20.0 mN over full 40-mm range
Force Step Response Time:	300B, 300B-LR:	1.3 milliseconds
(1% to 99% critically damped.)	305B, 305B-LR:	2 milliseconds
	309B:	4 milliseconds
	310B, 310B-LR:	8 milliseconds
Velocity Signal Scale Factor:	300B, 300B-LR:	1000 mm/s per volt ±2%
	305B, 305B-LR:	200 mm/s per volt ±2%
	309B:	500 mm/s per volt ±2%
	310B, 310B-LR:	400 mm/s per volt ±2%
dF/dt Signal Scale Factor:	300B:	10.0 N/s per volt ±2%
	300B-LR:	20.0 N/s per volt ±2%
	305B:	100.0 N/s per volt ±2%
	305B-LR:	200.0 N/s per volt ±2%
	309B:	400.0 N/s per volt ±2%
	310B:	1,000.0 N/s per volt ±2%
	310B-LR:	2,000.0 N/s per volt ±2%
Warm Up Time:	All models:	1 minute to rated accuracy
Power Requirements:	All models:	120VAC ±10%, 50/60Hz, 5 amps max. 100VAC, 220VAC, and 240VAC available

Dimensions, Electronics Enclosure: 48cm wide (standard 19-in. rack mount) x 32cm deep x 13cm high

Weight:	Electronics:	All models:	10 kg
	Motor:	300B, 300B-LR:	320 gm
		305B, 305B-LR:	1 kg
		309B:	3.5 kg
		310B, 310B-LR:	12 kg

3.0 First Time Operation

The following procedure is recommended to verify that the 300B Series system is operating properly.

1. Attach the male end of the 3-meter cable to the rear panel of the blue electronics box and the other end to the motor. Use the screws supplied on either end of the cable to firmly fix the cable to the motor and electronics.
2. With the power switch located on the blue electronics box in the OFF (down) position, plug the instrument into an appropriate AC source using the detachable line cord.
3. Turn the front panel FORCE OFFSET control fully clockwise until the turns-counting dial displays 10. Turn the LENGTH OFFSET control until the turns-counting dial displays 5.
4. Slip the arm provided onto the motor shaft and tighten the screw/screws using the Allen key provided. (The arm should slide onto the shaft with little or no resistance. Do not force the arm onto the shaft as this can damage the bearings.) Once the arm is tight on the shaft gently rotate the arm back and forth. It should move freely until the mechanical stops are reached. Be careful when placing the motor on a surface that the arm can not contact anything during operation.
5. Flip the power switch ON. Both the POWER ON and FAULT LEDs should illuminate. After a few seconds the FAULT LED should turn off. If the INHIBIT LED lights then press the black INHIBIT switch to enable the instrument.
6. Turn the LENGTH OFFSET control back and forth a turn or so. The arm should move in proportion to the turning of the control.

The model 310B-LR uses an external power supply in addition to the power supplies located in the electronics box. Ensure that the external power supply is plugged into an appropriate AC source and also into the back panel of the electronics box. When turning the instrument on be sure to turn the external power supply on before powering the electronics box. When turning off the instrument turn off the electronics power switch first and then the power to the external power supply.

This concludes the initial instrument checkout procedure.

3.1 Mounting the Motor

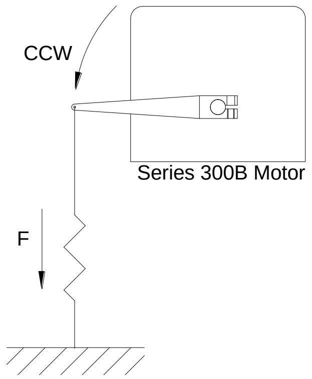
The customer must provide an adequate path for conducting heat generated by the motor away from the motor body. The maximum temperature that the motor body should be allowed to attain is 50°C. This is below the temperature at which a person feels pain, thus the motor should **never** get too hot to touch!

The only valid mounting surface is the bare aluminum surface on the underside of the motor. See the appropriate outline drawing at the end of this manual. The motor must be mounted by this surface to adequately transfer the heat out. For the motor mount, a flat plate that covers the entire bottom of the motor is recommended. The mount should be made from metal and should contact as much of the motor's mounting surface as possible to minimize the thermal resistance.

Note: Because of the capacitive position sensor, the motor body needs to be electrically isolated from the chassis ground for best performance. The motor comes with a thin Mylar insulator and some rubber washers that enable the customer to electrically isolate the motor from the mount.

3.2 Correct Force Direction

All ASI muscle lever systems have a preferred direction of force application. This direction is set at the factory as follows. The load should be attached to the lever arm such that a muscle contraction will pull the lever arm in a counterclockwise direction (when viewed from the shaft end of the motor). The force from a contracting muscle should always result in a positive voltage being measured at FORCE OUT. If the voltage at FORCE OUT is negative then you are applying force in the wrong direction. The system can measure force in both the clockwise and counterclockwise directions but the amount of force that can be generated in the clockwise direction is often a small fraction of that available in the counterclockwise direction. In addition force control can only be achieved for forces that try to pull the arm in a counterclockwise direction. If the experimental set-up doesn't allow the motor and lever arm to be positioned correctly then please contact ASI for a model 300-FD motor cable. This cable attaches between the servo controller and the motor cable and reverses the direction of force control.



Contracting muscle pulls Lever Arm in a CCW direction.

FORCE OUT is a positive voltage.

Factory Setting of Force Direction

4.0 General Operating Procedure

The best way to understand the operation of the 300B Series is to think of it as a length controller that is precision force-limited. This force limit can be set to any value from zero to its maximum by changing the input voltage to FORCE IN or by turning the FORCE OFFSET control. To put it another way, the 300B Series wants to be a length controller and will only be a force controller if an external load attempts to pull harder than the level of force set by the FORCE IN and FORCE OFFSET control.

The setting of the FORCE OFFSET control and the input voltage at FORCE IN are summed internally to set the total isotonic force level. If it is desired that the force level be controlled exclusively by the input voltage level at FORCE IN such that 0 grams force = 0 volts then the FORCE OFFSET control should be turned fully counter clockwise. Conversely, if FORCE IN is left unconnected (or better yet, shorted) then the isotonic force level will be determined solely by the setting of FORCE OFFSET. Both FORCE IN and FORCE OUT are positive going voltages when muscle tension is increasing, and both have a scale factor as shown in the specification section.

LENGTH OUT is a bipolar signal capable of swinging symmetrically about zero volts. The center of the mechanical range is when LENGTH OUT is at zero volts. If an experiment requires a length change of more than a few millimeters, try to make use of the center portion of the range rather than just one side of the mechanical center. A lengthening of the muscle will cause LENGTH OUT to become more positive. When the system is in the length control mode, a +1.0 volt change to LENGTH IN will cause a +1.0 volt change to LENGTH OUT. So, in order to lengthen a muscle, LENGTH IN must be driven with a positive going voltage. A lengthening could also be accomplished by turning the LENGTH OFFSET in a clockwise direction. Both LENGTH IN and LENGTH OUT have a scale factor that is shown in the specifications section.

4.1 Controlling Length and Measuring Force

Set FORCE IN and/or FORCE OFFSET to a level higher than what the muscle is capable of generating. The system will now change length in direct proportion to a change in LENGTH IN or LENGTH OFFSET. Force generated by the muscle can be monitored by observing the change of voltage at FORCE OUT.

4.2 Controlling Force and Measuring Length

Set FORCE IN and/or FORCE OFFSET to the desired force level. This force might be a constant force or some particular waveform such as a ramp, sinewave or step function or even an arbitrary waveform. Set LENGTH IN and/or LENGTH OFFSET to a length greater than what the muscle is capable of. The system will now be in the constant force (isotonic) mode.

4.3 Switching from Length Control to Force Control

One of the best features of the 300B Series is the ability to make the transition from the length control to force control smoothly, without the slightest length transient. This mode change will be described by way of an example: The "Quick Release" is a classic muscle mechanics experiment. The muscle is initially held at constant length in a relaxed state. The muscle is stimulated and begins to develop tension. When the tension reaches a certain level the system switches to the isometric peak tension. To do this experiment FORCE IN and/or FORCE OFFSET is first set to a value higher than the desired maximum pre-load force. This keeps the muscle at constant length. After the muscle is stimulated and tension has increased to the desired pre-load value (as measured by FORCE OUT) FORCE IN is set to the desired afterload force. The muscle will now contract with constant force at the set value.

4.4 Switching from Force Control to Length Control

After an isotonic contraction it might be desired to return the muscle to its original isometric length or stop the contraction at a certain minimum length. In either case the system must make the transition from force control to length control. In order to do this LENGTH IN must be set to the desired length and FORCE IN and/or FORCE OFFSET set to a value higher than what the muscle can produce. Use caution however, the motor is capable of high step speeds. Muscle tissue could be damaged by quick changes in length. If it is desired to bring a muscle back to the original isometric length without unduly stressing it, set LENGTH IN to the desired length. Then, rather than setting force to an instantaneously high value which would cause a rapid stretch, ramp force up at a modest rate. The muscle will lengthen in a controlled way until the preset length is reached.

4.5 Velocity Measurement

The velocity of arm is available at the VELOCITY OUT BNC connector located on the front panel. This output is the derivative of the position signal and has a scale factor given in the specifications, section 2.0.

4.6 dF/dt Measurement

The rate of change of force with respect to time is available at the dF/dt OUT BNC connector located on the front panel. This output is the derivative of the force signal and has a scale factor given in the specifications, section 2.0.

4.7 Controlling the System with External Electronics

Most experiments will require that FORCE IN and LENGTH IN be driven with external devices. Although a "Quick Release" could be accomplished in smooth muscle by just adjusting the FORCE OFFSET control to the desired afterloaded force level. A better way would be to use a computer and a data acquisition board to control the instrument. Software can then be written that will monitor FORCE OUT and drive FORCE IN to the desired afterloaded level when the set preload is reached. The cost of computers and data acquisition circuit boards have dropped to such a level that they are the best way to control the 300B Series. Two analog inputs and two analog outputs are all that is required to control the instrument. However if velocity and dF/dt are also to be measured then an additional two analog inputs are required. An A/D resolution of 12 bits (1 part in 4096) is common and is adequate.

Aurora Scientific Inc. offers a software package that controls, takes data from and then analyzes the data from series 300B instruments. The first program is the Dynamic Muscle Control and Acquisition (DMC) software that includes all of the standard muscle physiology test protocols. This program is written using National Instrument’s LabView programming software. The second program, Dynamic Muscle Analysis (DMA), provides an easy-to-use graphical analysis capability that allows data taken with the DMC program to be analyzed and saved in various formats. The user does not need to own LabView to use the two programs since they come in a stand-alone executable format. Currently the software is only available for IBM-type PCs.

4.8 Inhibit Shutdown

The 300B Series system includes an inhibit circuit which interrupts the current drive to the motor and lights the INHIBIT LED. When the instrument is inhibited all external control inputs (Length In, Force In, Length Offset, Force Offset) are disconnected internally, the lever arm is then positioned at the centre of its range and the servo feedback is greatly reduced. The result of this is that the arm will try to remain at the centre position but very little force will be available to hold it there (about 20% of full-scale force). The arm will be quite “mushy” (it can be moved back and forth quite easily but it will always tend to return to the centre position). The inhibit function is quite useful when attaching a muscle preparation since the arm can be pulled and pushed on without causing any unwanted oscillations of the arm. If the system is not inhibited when the muscle is being attached to the lever arm the instrument can sometimes oscillate in reaction to non-compliant loading of the tip of the arm.

There are two methods of inhibiting the instrument the first is to use the manual push button located on the front panel. This is a push on/push off switch. One push will inhibit the system; a second push will re-activate the system. The second method of inhibiting the instrument is to supply a positive voltage to the INHIBIT BNC connector labeled DIGITAL INPUT. This voltage must be greater than +1.5 volts but should not be greater than +15 volts. Note: the polarity of the inhibit signal is critical do not reverse polarity. The outer ring of the BNC connector must be ground with the central conductor a positive voltage. Also note that the INHIBIT BNC connector is electrically isolated from the rest of the instrument. After re-activation the FAULT LED may light for about 2 seconds while the system attempts to restart see section 4.9 below.

4.9 Overload Shutdown

The 300B Series system contains protection circuitry to protect the motor and electronics from various types of overloads. If an overload is detected, current drive to the motor is interrupted and the FAULT LED lights. After about 2 seconds the system will attempt to restart but will quickly go back into the overload mode if the condition that caused the overload remains.

When the power switch is first turned on the overload circuitry is activated. This ensures that power-on transients are eliminated. If the motor is driven to a position much outside its legal range of ±10 volts an overload will be triggered. The length-input command must be reduced before the system will restart. If the force at the tip of the arm exceeds maximum force an overload will be triggered. If the motor is not connected to the electronics an overload will be triggered.

The overload circuitry is also triggered when the power switch is flipped off. Since current to the motor is interrupted quickly, there is little or no turn-off transient in the motor when power to the instrument is removed.

5.0 Calibration

The calibration procedure involves measuring the output scale factors of the LENGTH OUT and FORCE OUT signals.

5.1 Calibrating Length Out

In order to calculate the output scale factor of LENGTH OUT the user must cause the arm to move a known amount and compare this value with the voltage measured at LENGTH OUT. One method of achieving this is the following.

1) Apply a 6-volt peak-to-peak square wave to LENGTH IN at the frequency shown in table 5.1.

System	Frequency (Hz)
300B, 300B-LR	30
305B, 305B-LR	25
309B	10
310B, 310B-LR	5

Table 5.1 Square Wave Test Frequency

2) Using a finely divided ruler, measure the deflection at the tip of the lever arm as it moves back and forth. The amount of movement should be close to that shown in table 5.2 below. Record the actual movement.

System	Peak-to-Peak Motion (mm)
300B, 300B-LR	3
305B, 305B-LR	6
309B	7.5
310B, 310B-LR	12

Table 5.2 Deflection

3) Using an oscilloscope measure the peak-to-peak voltage at LENGTH OUT.

4) Calculate the length scale factor as follows.

   Length Scale Factor = actual movement measured / LENGTH OUT voltage

   Example: For a model 300B system the actual movement is measured as 3.1 mm and LENGTH OUT is measured as 5.96 volts. Therefore the Length Scale Factor will be 3.1 mm/5.96 volts = 0.520 mm/volt.

Ensure that a non-contact method of measuring the length is used. Touching a micrometer or other non-compliant instrument to the lever arm will often cause the arm to oscillate. Alternate methods of measuring the movement include using an optical reticule or a traveling stage microscope. Another method of calibrating the length would be to simply use the LENGTH OFFSET control on the front panel of the instrument. In this case the user would set the offset control near one end of the range of motion, use a voltmeter to measure the voltage at LENGTH OUT and mark the position of the lever arm tip. Then set the offset control to a point near the other end of the range of motion and once again record the LENGTH OUT voltage. Mark the final position of the lever arm and then measure the distance between the marks. Use this information to calculate the scale factor. By mounting a finely divided ruler behind the lever arm the LENGTH OFFSET control can be adjusted such that the lever tip lines up with a division on the ruler. Then move the offset control until the tip lines up with another division. This saves having to mark the positions and then measuring them.

5.2 Calibrating Force Out

In order to calculate the output scale factor of FORCE OUT the user must apply a known force to the arm and compare this value with the voltage measured at FORCE OUT. The simplest method of achieving this is the following.

1) Mount the lever arm such that it is horizontal and pointing to the left side of the motor (when viewed from the shaft end).

2) Fashion a hook from a small-gauge piece of wire (20 to 24 AWG wire works well) and use it to hang a rubber band (elastic band) from the lever arm. Note: there is a small hole present near the tip of all of our lever arms and this can be used to suspend the hook and rubber band.

3) Record the voltage at FORCE OUT.

4) Hang a known weight from the rubber band and record the voltage at FORCE OUT.

5) Calculate the force scale factor as follows.

   Force Scale Factor = actual mass / (FORCE OUT voltage with the mass – FORCE OUT voltage without the mass).

   Example: For a model 300B system the voltage measured with the hook and rubber band attached is 0.043 volts. When a 20 gm mass is suspended from the rubber band the FORCE OUT is 4.050 volts. Therefore the Force Scale Factor will be 20 gm/(4.050 – 0.043) volts = 4.991 gm/volt. This scale factor can be converted to force by multiplying the mass by the acceleration due to gravity as follows. 4.991 gm/volt x 981 cm/s^2 = 4896 gm-cm/s^2 /volt = 49 mN/volt.

In is critically important that a compliant link (a rubber band) is used to suspend the mass from the arm. Failure to include a compliant link can result in large, high frequency oscillations of the lever arm. Do not operate the system with a dead weight directly connected to the arm. This can result in severe motor damage.

6.0 Instrument Tuning

***** CAUTION: Lethal voltages are exposed during this procedure. *****
Use caution whenever the top cover of the electronics box is removed.

The 300 Series product has been tuned at the factory before shipment. It should not need re-tuning over the life of the instrument. This procedure is written to help those customers that want to readjust their 300 Series product for various reasons. Some of these reasons may be a) a change in the load inertia, i.e., a mass has been added or removed from the lever arm, b) the adjustment pots on the CB6500 or the CB1060 circuit boards have inadvertently been altered, or c) the researcher wants the system step response slightly faster or slower.

Please read this entire procedure before attempting any changes. It is possible to damage the motor if the procedure is not understood completely. If there are any questions, please contact Aurora Scientific Inc.

The following materials are needed:

a. Dual-trace oscilloscope
b. 3-1/2 digit DVM
c. Function generator
d. Phillips screwdriver
e. Flat-tip screwdriver (small)
f. Several BNC cables

1.) Ensure the power switch located on the front panel of the electronics box is turned **OFF**. Attach the power cable to the back of the box and to the appropriate power.

2.) Firmly attach the cable between the electronics box and motor using the captured screws on the cable. Place the arm on the motor such that it swings about the same distance to either side of the motor centerline. Tighten the arm's clamp.

***** CAUTION: Lethal voltages are exposed during this procedure. *****
Use caution whenever the top cover of the electronics box is removed.

3.) Remove the two Phillips-head screws that are located on the back panel along the top edge of the electronics box. Slide the top cover back and remove it from the box. Connect scope CH1 to LENGTH OUT and connect scope CH2 to CR9 (non-band end). Connect function generator to LENGTH IN. Connect voltmeter to FORCE OUT.

Setup of Length Control - Adjustments Made on CB6500 PCB

Note: if only minor adjustments are to be made to the dynamic tuning of the system then skip down to step (10) below.

4.) On the CB6500 turn R25, R28, R31, and R59 CCW 30 turns or until a click is heard. Adjust R1, R13 and R97 to the center of their range (15 turns from either stop). Turn R78 fully CW.

5.) Turn the front panel FORCE OFFSET pot fully CW. Turn the front panel LENGTH OFFSET to the center of its range (5 turns from either stop).

6.) Disable servo by shorting cathode of CR25 (band end) to C13 (+). Turn on power.

7.) Measure voltage (L side) R10 to ground; adjust R1 to 0.000v. Measure voltage (L side) R14 to ground; adjust R13 to 0.000v.

8.) Observe LENGTH OUT while moving the arm back and forth. LENGTH OUT should change positively for CW rotation.

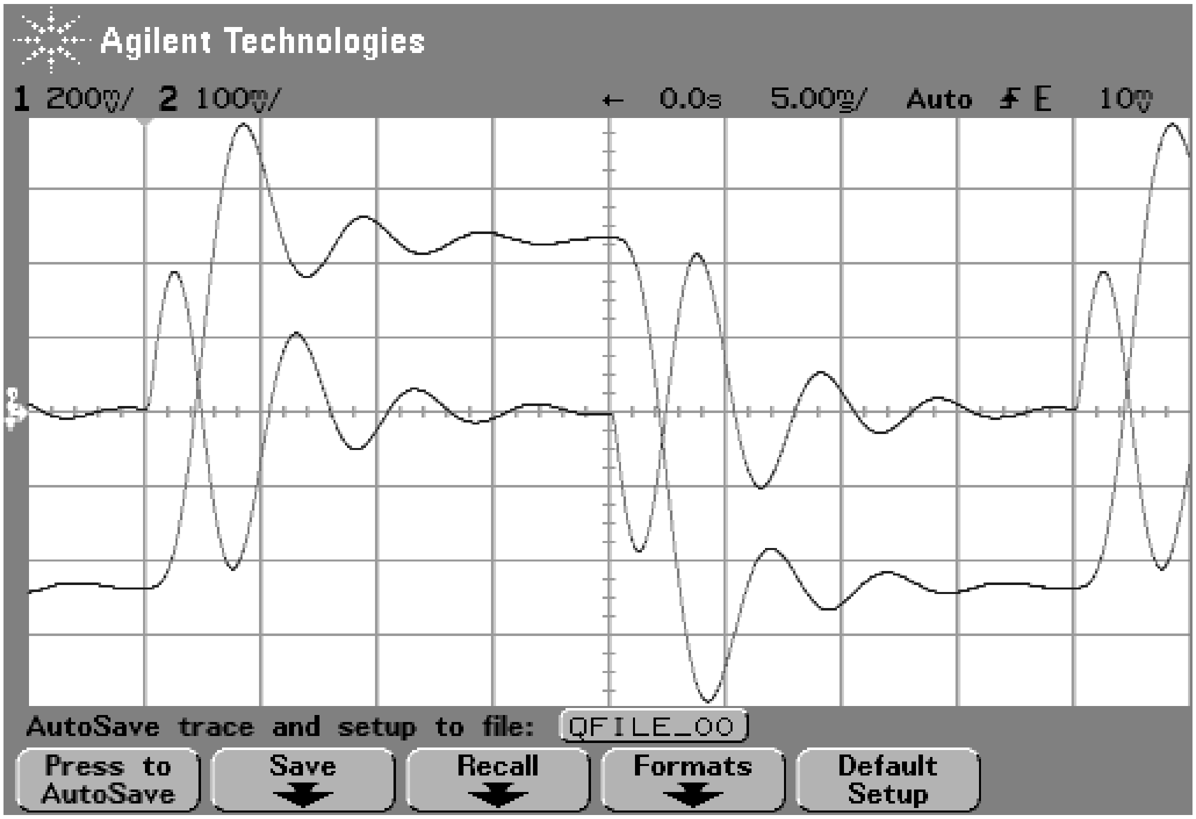
9.) Turn the power OFF and remove short (CR25-C13). While holding the motor and arm such that the arm is prevented from moving an excessive amount, turn the power ON. Turn R59 and R25 2 turns CW. Turn R28 2 turns CW. The arm should now want to sit close to the center of the range (R28 brings arm to center - leave a small offset initially). The FAULT lamp should light up for a few seconds and then turn off.

10.) Apply a 1-volt peak-to-peak square wave to LENGTH IN at the frequency shown in table 6.1.

System	Frequency (Hz)
300B, 300B-LR	30
305B, 305B-LR	25
309B	10
310B, 310B-LR	5

Table 6.1 Square Wave Test Frequency

While carefully monitoring LENGTH OUT with the oscilloscope synced to the function generator, slowly turn R31 CW until the motor begins to respond to the signal input. Continue to turn R31 CW until the waveform looks under damped (see figure 1, in the figure the larger amplitude signal is Length Out and the signal centered at the mid-point of the screen is the current measured at CR9). Monitoring both the LENGTH OUT signal and the motor current signal during the tuning procedure makes it easier to tune the system because small oscillations tend to be amplified on the current trace.



1 200mV/ 2 100mV/ ← 0.0s 5.00ms/ Auto E 10mV

AutoSave trace and setup to file: QFILE_00

Figure 1 Under Damped Response

11.) The four stability pots R31, R28, R25, and R59 should now be alternately turned in a generally CW direction until a critically damped squarewave with a step response time as shown in table 6.2 is achieved. (This requires practice and an intuitive feel for what these four controls do). In general the four pots have the following effect:

  a. R31 is the error integrator potentiometer. It controls the servo gain or the speed of the system. As this pot is turned up, the system will respond more quickly to a step input. During tune-up, this pot causes the step response time to decrease, or in other words it causes the speed of the system to increase.
  b. R28 is the error amplifier potentiometer. It produces an electrical spring that acts like a restoring force on the motor. This restoring force always acts in the direction of the final commanded position. During tune-up, this pot acts to limit the overshoot of the system.
  c. R25 is the position differentiator potentiometer. This provides low frequency damping to the system. Turning this CW will increase damping during the beginning of the tuning process, but soon runs out of bandwidth. At that point R59 should be turned up in conjunction with R25.
  d. R59 is the current integrator potentiometer. It provides high frequency damping to the system. Use this pot in conjunction with R25 to dampen an underdamped waveform after R25 alone loses its effectiveness.

The tuning procedure normally involves increasing the gain, R31 (figure 1), then increasing the damping R28 to eliminate the initial over shoot (figure 2), then increasing R59 to remove the first oscillation after the overshoot (2nd order "bump") (figure 3), then increasing R25 to remove the 3rd order "bump" (figure 4). After these adjustments there will be an overshoot so R28 will need to be adjusted again (figure 5). Now the system should look close to critically damped but the speed (rise time) will not meet the specification of table 6.2, so now increase R31 again (figure 6) and then repeat all the previous adjustments to retune the system to a critically damped condition. The finished state should look like Figure 7 with a rise time equal or better than that specified in Table 6.2.

System	**Step Response Time (ms)**
300B, 300B-LR with 2cm arm	1.0
300B, 300B-LR	1.3
305B, 305B-LR	2.0
309B	5.0
310B, 310B-LR	8.0

Table 6.2 Step Response Time

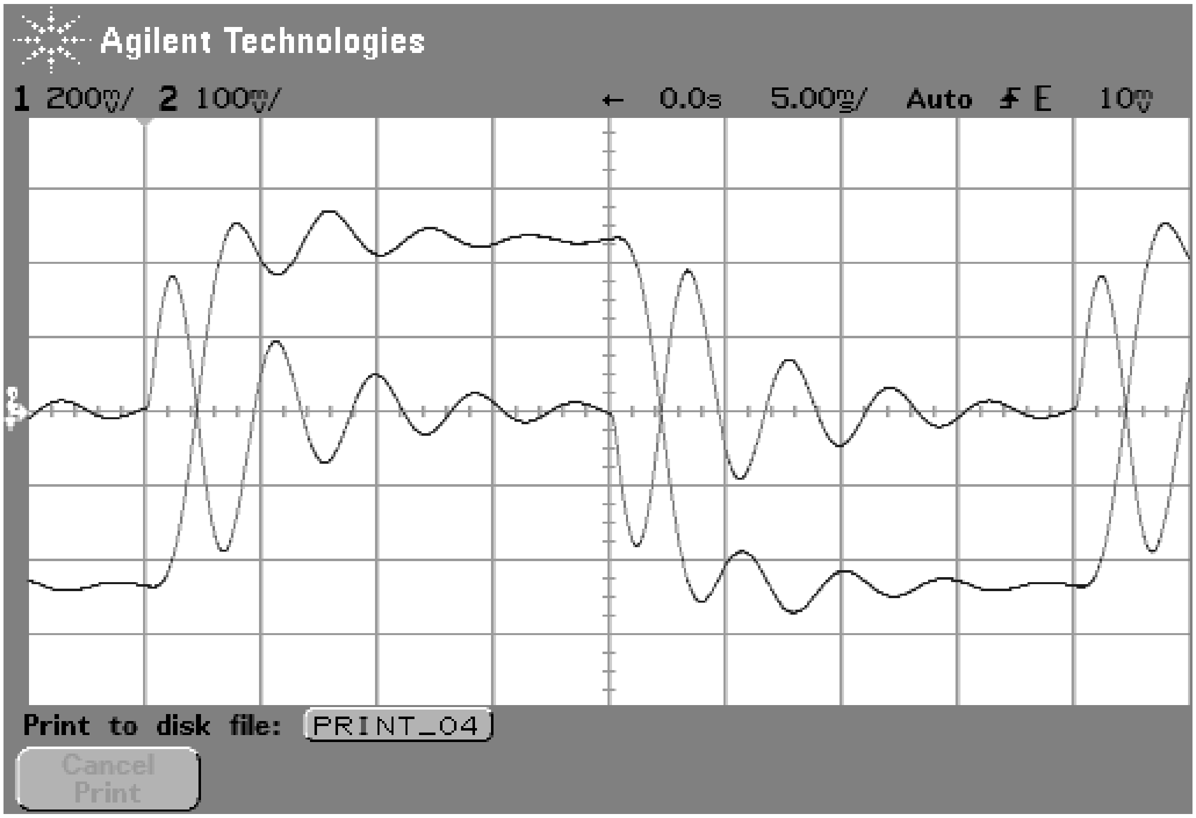
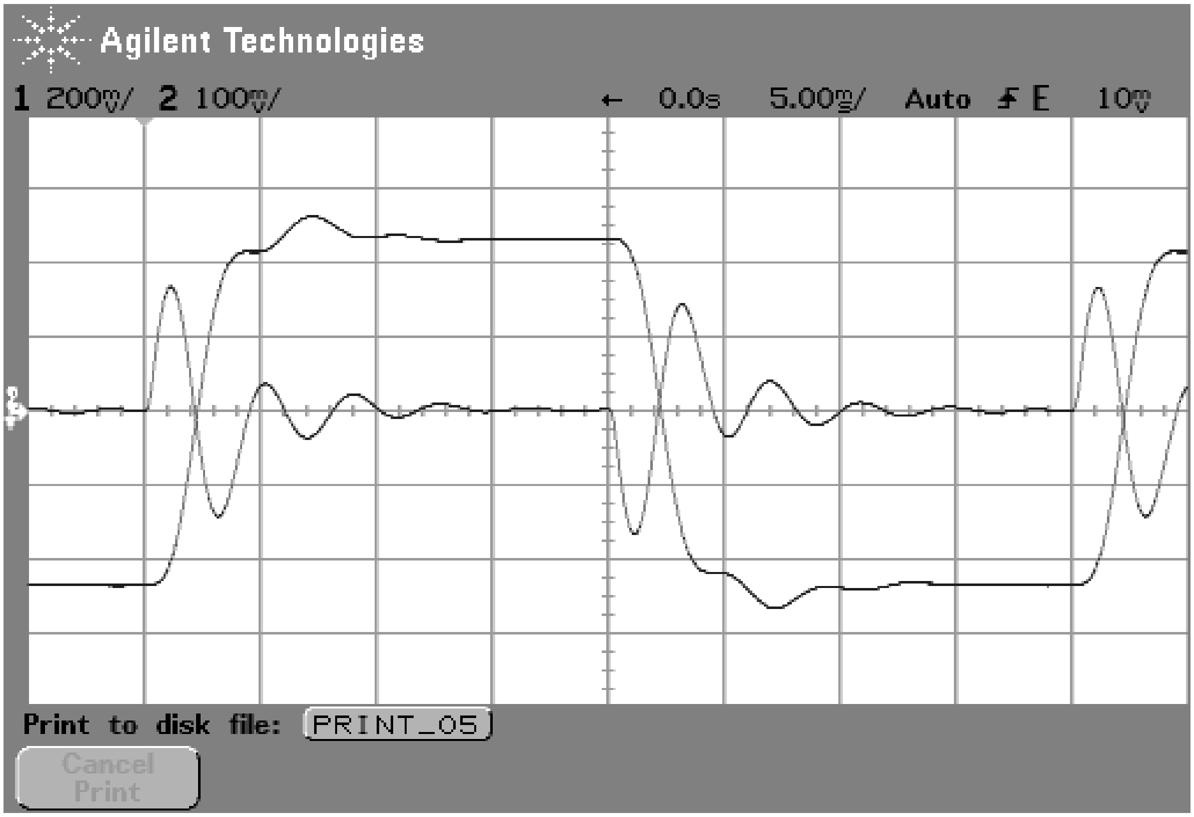
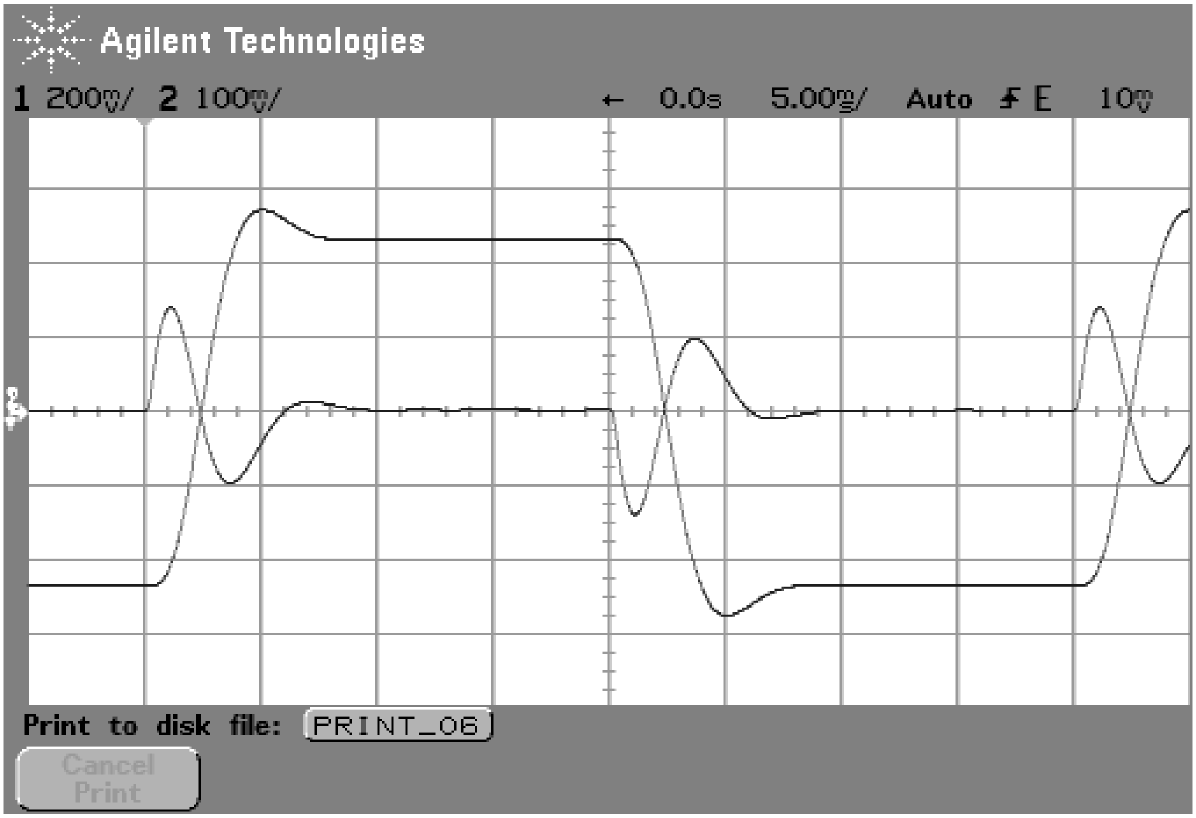


Figure 2 R28 Adjusted to Remove Over Shoot



Print to disk file: PRINT_05

Figure 3 R25 Adjusted to Remove Low Frequency Oscillations



Print to disk file: PRINT_06

Figure 4 R59 Adjusted to Remove High Frequency Oscillations

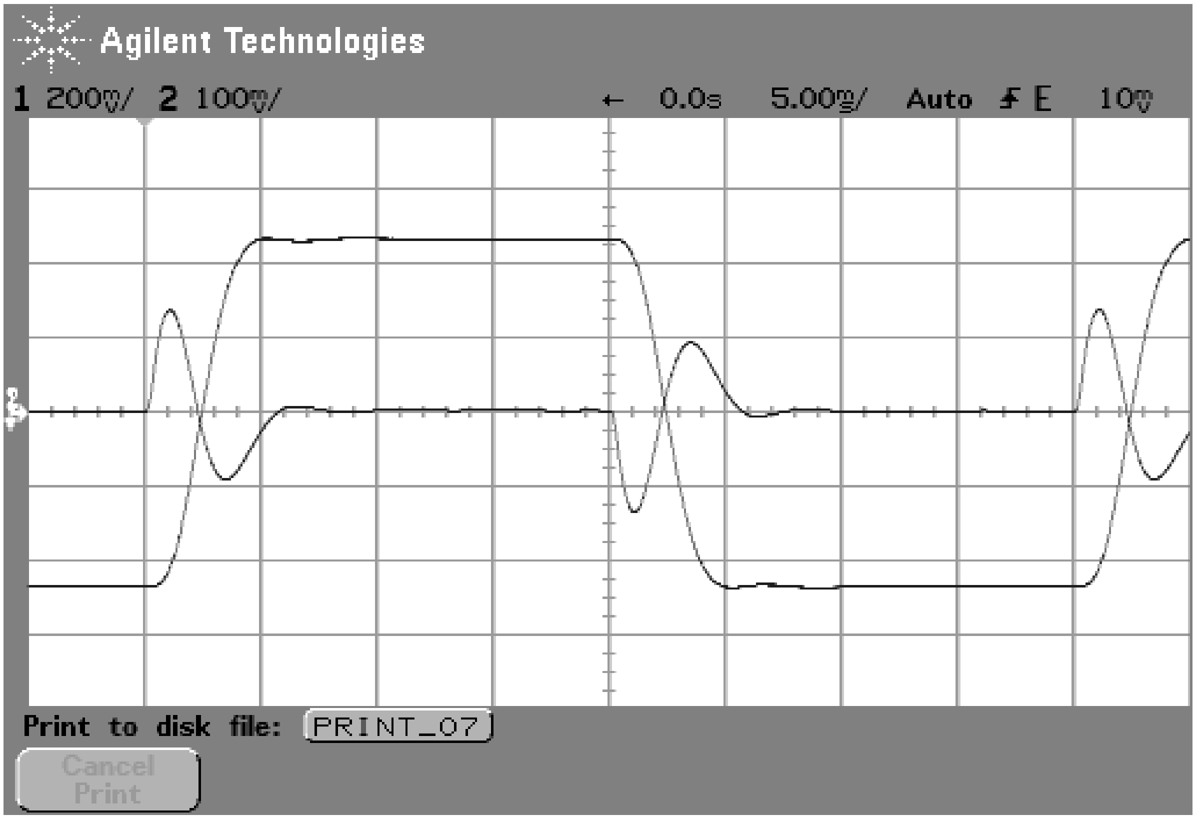


Figure 5 R28 Adjusted to Remove Over Shoot

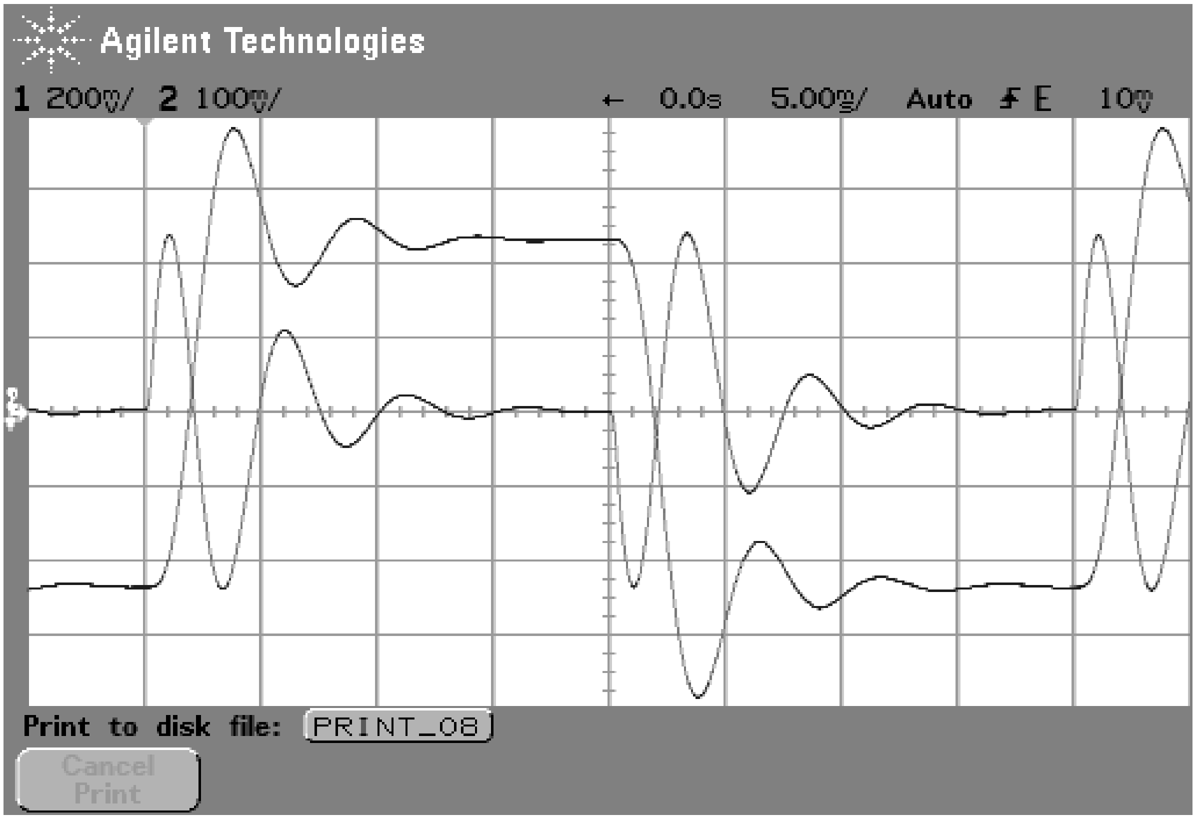
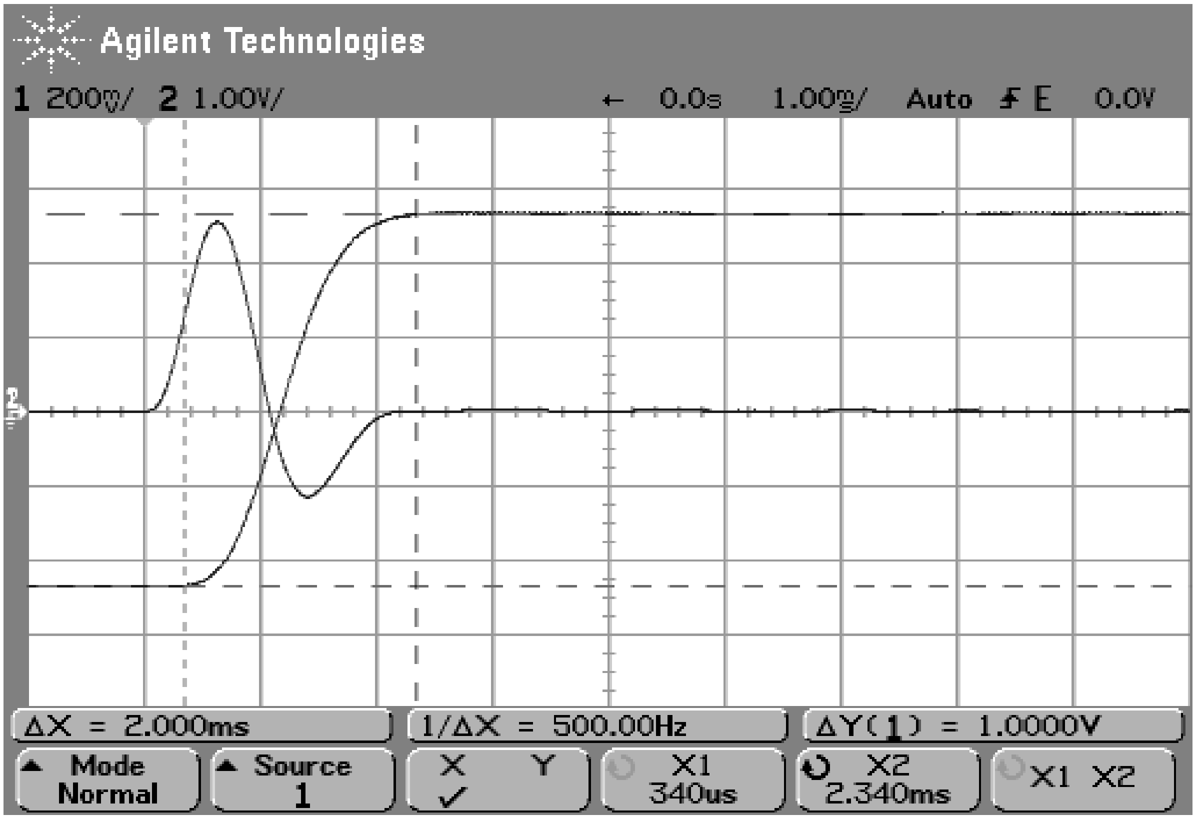


Figure 6 R31 Adjusted to Increase System Speed



1 200mV/ 2 1.00V/ ← 0.0s 1.00ms/ Auto ⨍ E 0.0V

ΔX = 2.000ms 1/ΔX = 500.00Hz ΔY(1) = 1.0000V

Figure 7 Tuning Finished - Critically Damped Response of 305B with Correct Rise Time

12.) When the servo is properly tuned, the following points should be checked:
  a. The output response should look critically damped with no overshoot or undershoot.
  b. There should be no ringing on the position signal or on the current signal. If there is, the loop gain is probably turned up too high.
  c. It is always best to use the least amount of loop gain possible to get the job done.
  d. There should be no audible ringing heard from the motor. If there is, the loop gain is probably turned up too high. There might be a small amount of hissing heard. That is a normal condition and should be ignored. It also will go up as the loop gain is increased.

13.) Connect the second channel of the oscilloscope to the fuse mounted on the circuit board. The connection can be made on either side of the fuse. This connection will allow the +MOTOR current to be monitored. Slowly increase the length-input signal from the function generator. Monitor +MOTOR and use the slew rate limiter, R78, to remove any distortion at the +MOTOR signal peak. Turn R78 in a counter-clockwise direction to limit the slew rate. Continue to increase the length-input signal all the way to its maximum of □10 volts as you monitor the +MOTOR signal and continue to remove any signal distortion using R78. If R78 is adjusted then go back and re-tune the servo (step 11).

Adjusting the Fieldsize

14.) Apply a 6-volt peak-to-peak squarewave to LENGTH IN at the frequency shown in table 6.1. Adjust R13 such that the tip of the lever arm moves the amount shown in table 6.3. If any adjustments were made to R13, go back and check the step response again. Ensure that the system is still critically damped (step 11).

System	Peak-to-Peak Motion (mm)
300B, 300B-LR	3
305B, 305B-LR	6
309B	7.5
310B, 310B-LR	12

Table 6.3 Deflection

15.) Measure the voltage at U9, pin 14. It should be between +5.0VDC and +11.5VDC. If the voltage is outside of this range there is probably a scanner problem. Contact Aurora Scientific Inc.

Setup of Force Control - Adjustments Made On CB1060 PCB

Adjusting the Force Scale

1.) Turn the function generator off. Turn the motor onto its side such that the arm is horizontal and hanging over the edge of the table.

2.) Connect a voltmeter to FORCE OUT and adjust R18 such that FORCE OUT = 0.000VDC.

3.) Using a small rubber band hang the weight specified in table 6.4 off the end of the lever arm. (Note: a compliant link must be used i.e. a rubber band. If a non-compliant link is used to suspend the weight then oscillation of the system will be seen.) Adjust R11 such that FORCE OUT is equal to the value shown in table 6.4.

System	Weight (gm)	Force Out (volts)
300B	20	4.000
300B-LR	50	5.000
305B	200	4.000
305B-LR	500	5.000
309B	1000	5.000
310B	2000	4.000
310B-LR	2000	2.000

Table 6.4 Calibration Weight and Output Voltage

4.) Remove the weight. Orient the motor such that the arm points down towards the floor. Adjust R18 so that FORCE OUT = 0.000VDC.

Canceling the Motor's Inertia and Mechanical Spring

5.) Turn the function generator back on and drive LENGTH IN with a 6-volt peak-to-peak triangle (not squarewave) at the frequency shown in table 6.5 below. Observe FORCE OUT with an oscilloscope. Adjust R9 (inertia canceling pot) such that the transients at the peaks and troughs of the triangle wave are minimized. One should be able to cancel about 90% of the transients. Adjust R34 (mechanical spring canceling pot) to eliminate the triangular component of deflection. What remains should look like an ugly squarewave. The amplitude should be less than 30 millivolts peak-to-peak. The amplitude is the peak-to-peak value of the friction.

System	Frequency (Hz)
300B, 300B-LR	20
305B, 305B-LR	5
309B	4
310B, 310B-LR	3

Table 6.5 Triangle Wave Test Frequency

Canceling the Motor's Electrical Spring

6.) Turn the function generator OFF. Set the front panel FORCE OFFSET control 1/4 turn from the CCW stop. Set the LENGTH OFFSET knob fully CW. While monitoring FORCE OUT with a voltmeter, push the lever arm CCW several millimeters (i.e. through its normal range) very slowly and then back to the original position. Adjust R24 such that the voltage measured by the DVM stays constant (within a few millivolts) as you move the arm through its normal range.

Adjusting the Force Input Scale Factor

7.) Turn the FORCE OFFSET knob 3 turns CW. Set the LENGTH OFFSET knob back to the center of its range. Apply a 1.0-volt peak-to-peak squarewave to FORCE IN at the frequency show in table 6.1. Monitor FORCE OUT with an oscilloscope. Push the lever arm into the constant force mode with your finger (push the lever arm CCW a few millimeters). Adjust R23 such that the FORCE OUT signal is 1.0 volts peak-to-peak.

8.) Turn the function generator off. While gently touching the lever arm, turn the front panel FORCE OFFSET control fully CCW. Turn the LENGTH OFFSET knob fully CW. Push the lever arm back and forth. Adjust R30 such that the arm appears completely "dead" (i.e. the lever arm stays in whatever position it is pushed to). When R30 is properly adjusted, the arm should stay where it is pushed in the center of its range, but may have the slightest of negative spring throughout the rest of the range.

9.) Monitor FORCE OUT with a voltmeter. Push the lever arm CCW into the constant force mode and then start turning the FORCE OFFSET control CW. Check that the force generated by the arm in constant force mode corresponds to at least 1 volt/turn of the FORCE OFFSET knob.

This completes the tuning of the system. If you experience any difficulties while tuning your system please contact Aurora Scientific Inc.

7.0 Warranty

The 300B Series Dual-Mode Lever Arm System is warranted to be free of defects in materials and workmanship for three years from the date of shipment. Aurora Scientific Inc. will repair or replace, at our option, any part of the 300B Series system that upon our examination is found to be defective while under warranty. Obligations under this warranty are limited to repair or replacement of the instrument. Aurora Scientific Inc. shall not be liable for any other damages of any kind, including consequential damages, personal injury, or the like. Opening the motor assembly itself will void this warranty. Damage to the system through misuse will void this warranty. Aurora Scientific Inc. pursues a policy of continual product development and improvement therefore we reserve the right to change published specifications without prior notice.

8. 0 Terms and Conditions for Returning Equipment

1. Aurora Scientific Inc. **will not** accept any equipment returned without prior authorization in the form of a return material authorization number.

1. **Please call Customer Service at (905) 727-5161 or toll free at 1-877-878-4784 to obtain an RMA#. Please specify the product line.**

2. Please package equipment properly. Goods that are damaged in shipment are the responsibility of the shipper.

3. **Aurora Scientific, Inc. withholds the right to assess charges for the repair or replacement of such damaged goods, regardless of warranty status.**

4. Warranty repairs will be shipped back to the customer via FedEx. If you require or request another form of shipment, the cost of such service is your full responsibility.

5. Aurora Scientific, Inc. **will not** be responsible for any return or replacement **shipping charges** incurred due to an incorrect order placed by the customer.

Return Shipping Address:

Aurora Scientific Inc.
360 Industrial Pkwy. S., Unit 4
Aurora, ON, Canada
L4G 3V7
Attn: RMA Returns

Drawings

This section consists of the following drawings:

1)	Outline Drawing of Model 300B Motor	A6350
2)	Outline Drawing of Model 305B Motor	A6650
3)	Outline Drawing of Model 309B Motor	A6900
4)	Outline Drawing of Model 310B Motor	A6400
5)	Model 300-3B Lever Arm for 300B	C0003-1520, Rev. B
6)	Model 300-4B Lever Arm for 305B	C03-2073, Rev. 0
7)	Model 300-5B Lever Arm for 309B	A309-001, Rev.0
8)	Model 300-8B Lever Arm for 310B	A0006-2090, Rev. A