Amplifier Current Loop Tuning Procedure
(intended for Analog input PWM output amplifiers)

The standard tuning values used in Advanced Motion Controls amplifiers are conservative and work well in over 90% of applications. However some applications and some motors require more complete current loop tuning to achieve the desired performance.

Since most AMC amplifiers close the current loop internally, poor current loop tuning cannot be corrected with tuning from an external controller. The current loop must be tuned by changing the current loop components on the amplifier. Only after the current loop tuning is complete can optimal performance be achieved with the velocity and position loops.

This guide is intended to show the proper procedure for tuning the current loop of Advanced Motion Controls amplifiers.

Disclaimer:
The following procedure is intended for advanced users of high performance applications only. It is recommended to contact the factory to discuss application requirements and proper amplifier tuning prior to making any adjustments.

CAUTION:

1. **IMPROPER CURRENT LOOP TUNING MAY RESULT IN PERMANENT AMPLIFIER AND MOTOR DAMAGE REGARDLESS OF AMPLIFIER CURRENT LIMITS!**

2. **ALWAYS REMOVE THE POWER SUPPLY VOLTAGE BEFORE MAKING ANY RESISTOR OR CAPACITOR MODIFICATIONS!**

3. **THE FOLLOWING ADJUSTMENTS MUST BE MADE WITH THE MOTOR UNCOUPLED FROM THE LOAD! ALSO SECURE THE MOTOR AS SUDDEN MOTOR SHAFT MOVEMENT MAY OCCUR!**

General Procedure

The following steps outline the current loop tuning procedure.

1) Determine if additional current loop tuning is necessary.
2) If available try tuning the amplifier using the Current Loop DIP switches
3) If the current loop cannot be tuned with DIP switches then the current loop components must be changed.
   a) Tune the Proportional gain.
   b) Tune the Integral gain.

1) Determine if Additional Current Loop Tuning is Necessary

The following are indications that the current loop may need to be tuned:

- Motor rapidly overheats even at low current
- Amplifier rapidly overheats even at low current
- Vibration sound comes from the amplifier or motor
- The motor has a high inductance (+10mH)
- The motor has a low inductance (near minimum rating of the amplifier)
- Slow system response times
- Excessive torque ripple
- Difficulty tuning position or velocity loops
- Electrical noise problems
- High power supply voltage (power supply voltage is significantly higher than the motor voltage rating or near the amplifier high voltage rating)
- Low power supply voltage (The power supply voltage is near the low voltage rating of the amplifier)

The above indicators are subjective and suggest that the current loop may need to be tuned. These can also be signs of other problems not related to current loop tuning. If several of the indicators are true then the current loop response should be looked at on an oscilloscope. See Appendix A for the procedure (Viewing Current Loop Response).

2) Tuning the Amplifier with DIP Switches

Some amplifiers have DIP switches that control current loop tuning. If these are available they should be tried first before changing the components on the amplifier board. Appendix B describes how to find the current loop switches in the block diagram.

The two current loop tuning switches are: “Current Loop Gain” and “Current Loop Integrator.” Some amplifiers don’t have these switches, some have one and some have both.

While viewing the current loop response (See Appendix A) try the different switch settings. If acceptable performance cannot be achieved with the switches then the current loop tuning components will need to be changed.

3) Tuning the Amplifier by Changing the Current Loop Tuning Components on the Amplifier Board

The resistors and capacitors shown under the current control block on the functional block diagram for the amplifier control the response of the current loop. It is important to tune the current loop appropriately for the motor inductance and resistance, as well as the power supply voltage to obtain optimum performance.

Appendix B describes how to find the current loop tuning components on the block diagram and on the amplifier board.

Appendix C has some hints to make the tuning process easier.

Appendix D has some examples of real amplifier and motor systems.

ALWAYS REMOVE THE POWER SUPPLY VOLTAGE BEFORE MAKING ANY RESISTOR OR CAPACITOR MODIFICATIONS!

Tune the Proportional Gain

1) Short out the current loop integrator capacitor(s) using the appropriate DIP-switch or a jumper (see functional block diagram and data sheets).

2) Apply power to the amplifier. Approximate application power supply voltage should be used or the current loop compensation will not be correct.

3) View the current loop as described in Appendix A. Small step tuning is different than large step tuning so adjust the function generator square wave amplitude so the amplifier outputs a current step similar to what will be expected when the amplifier is in operation.

4) Increase the value of the gain resistor to the point of overshoot in the current response. If there is a large amount of over shoot or there are oscillations decrease the gain resistor value until there is little or no overshoot.

Tune the Integral gain

1) After the gain resistor has been adjusted, re-enable the integrator capacitor(s).

2) Using a function generator, adjust the square wave amplitude as in the current loop gain adjustment procedure above.

3) Apply power and observe the current loop response with the default current loop capacitor. If necessary adjust the value of the capacitor so the amplifier outputs a critically damped square wave. Be sure to use non-polarized capacitors. The square wave can have a small amount of overshoot but it should settle to a flat top. Use smaller value capacitors to sharpen the corners of the square wave. Use larger value capacitors to reduce oscillations or overshoot.. Approximate application power supply voltage should be used or the current loop compensation will not be correct.

Appendix A
View Current Loop Response

Concept
The amplifier output should follow the input command. To see if your amplifier does this simply use your oscilloscope to display the input command on channel 1 and the amplifier output on channel 2. By comparing the two wave forms you can determine if the current loop needs tuning.

Procedure

Current Mode
Use the DIP switches to set the amplifier in current mode. The switch settings are listed in the amplifier data sheets. Even if the amplifier is intended to run in velocity mode it will need to be in current mode while tuning the current loop.

Function Generator
Use a function generator to produce the input command. Hook it up to the input reference of the amplifier and set it to output a 50 Hz square wave. Set the square wave amplitude so the amplifier outputs a current step similar to what will be expected when the amplifier is in operation. Use channel 1 on your scope to view the square wave. Also use this channel to trigger the scope.

Current Probe
Use a current probe to view the amplifier output to the motor. Clamp the current probe to motor phase A.

Note:
If a current probe is not available use the amplifier current monitor. The signal from this pin is unfiltered and may be difficult to view. Also depending on the amplifier this pin may not be isolated from the amplifier power ground. If this is the case the oscilloscope must have isolated channels to avoid large ground currents.

An alternate method of viewing the current is to use a resistor in series with the motor. The current through the resistor will be proportional to the voltage across the resistor (I=V/R). Make sure the resistance is less than 1/10 of the motor resistance, also make sure the power rating of the resistor is sufficient to handle the current. Be very careful with oscilloscope grounding if using this method.

Set up Details

Different amplifiers need to be set up differently to view the current loop response properly. Use the diagrams and explanations on the following pages to help set up your system properly.

Brush Type Amplifiers

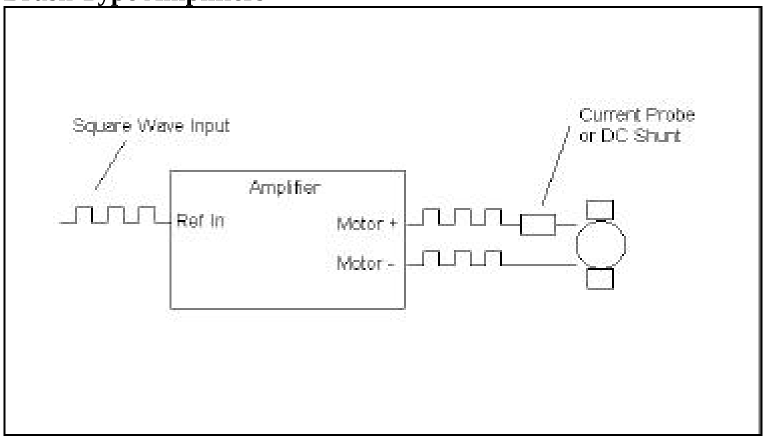


Figure A1. Brush type amplifiers have two motor outputs, Motor + and Motor -. Since the two motor wires are in series the current through the wires is the same. The current probe can be attached to either wire with the same results.

To keep the motor from turning during the tuning process the motor shaft must be locked.

SE amplifiers and
Trapezoidal Brushless Type amplifiers

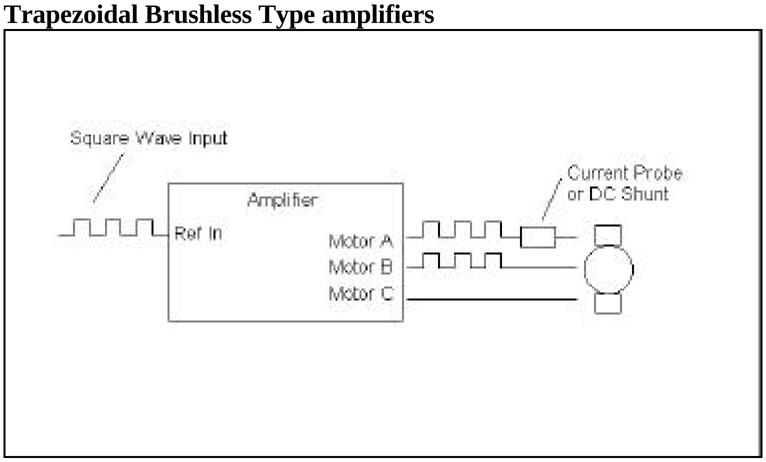


Figure A2. These amplifiers have three motor outputs, Motor A, Motor B and Motor C. The current through the motor outputs changes depending on the signal from the Hall sensors. The current out of the amplifier can be forced to go through Motor A and Motor B by:

1) Disconnecting the Hall wires from the amplifier
2) Setting the 60/120 degree phasing switch to the OFF position.

With this configuration attach the current probe to either Motor A or Motor B.

The motor shaft does not need to be locked since the amplifier will not commutate without the Hall sensors.

S-series

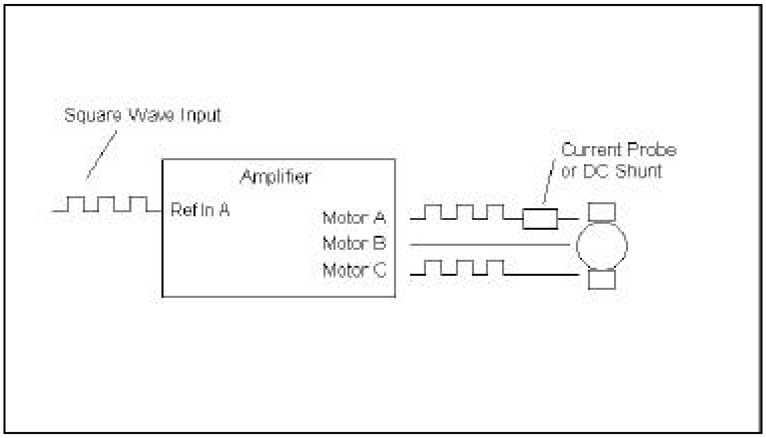


Figure A3. These amplifiers have three motor outputs, Motor A, Motor B and Motor C. The current through the motor outputs changes depending on the relationship between the “Ref In A” signal and “Ref In B” signal. The current out of the amplifier can be forced to go through Motor A and Motor C by applying the square wave command signal to “Ref In A” only.

With this set up attach the current probe to either Motor A or Motor C.

The motor shaft does not need to be locked since the amplifier is not commutating.

SR-Series (Resolver based commutation)

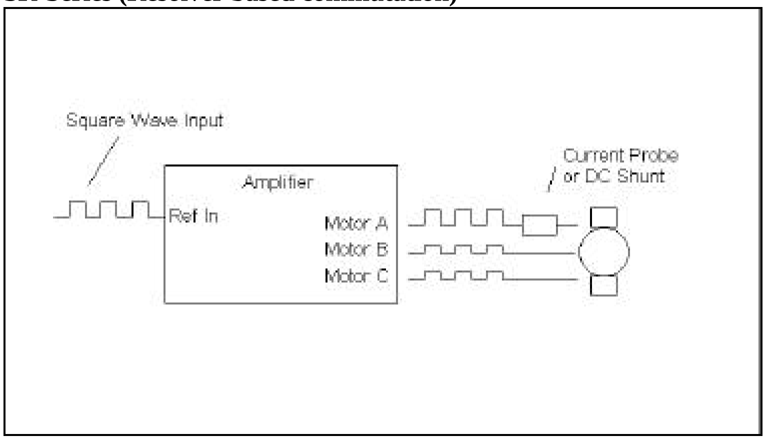


Figure A4. These amplifiers have three motor outputs, Motor A, Motor B and Motor C. The current through the motor outputs changes depending on the position of the motor shaft. There is no direct way to force the current into any specific motor output.

To achieve the best results use the following steps:
1) Go through the auto commutation procedure listed on the amplifier data sheet.
2) Apply a square wave to the reference input.
3) Monitor the current through Motor A.
4) Rotate the shaft until maximum current is observed through phase A.
5) Lock the motor shaft.

Alternate method. If two motors are available hook up the resolver feedback on one motor and the motor wires of the motor you are trying to tune. Apply the square wave to the amplifier and monitor the current into phase A of the second motor. Turn the shaft of the first motor until the square wave amplitude in the second motor is at a maximum. The motor shaft does not need to be locked with this method.

Appendix B
How to find the Current Loop in the Block Diagram

Brushed-type amplifiers and brushless DC (or trapezoidal) amplifiers have a single current loop. Sinusoidal amplifiers have three current loops. In the case of sinusoidal amplifiers all three loops must be tuned the same or the amplifier will not operate properly. The loop gain and the integrator capacitance of the current loop must both be adjusted for the tuning to be complete.

The block diagrams below conceptually show where the current loop is. **Contact Advanced Motion Controls to get the actual locations of the current loop components. Ask for a copy of the PCB silk screen for the amplifier model you are tuning.**

Block diagram for the B15A8 amplifier.

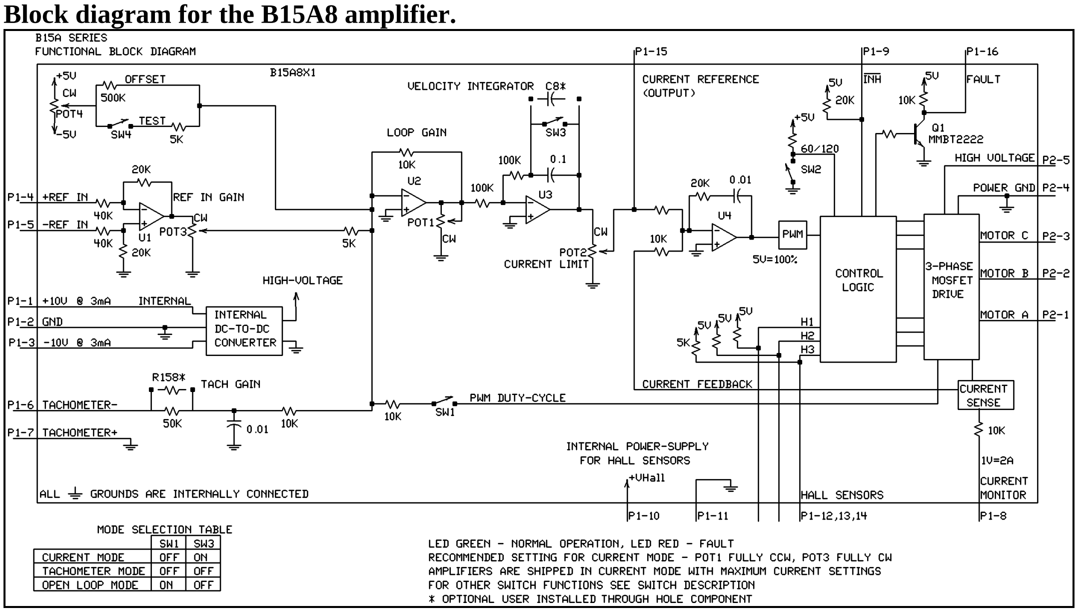


Figure B1. The current loop can be located by following the line labeled “Current Feedback” to the gain stage U4.

The 20k resistor in the current loop adjusts the current loop proportional gain. The 0.01uF capacitor adjusts the current loop integrator. There are no switches that control the current loop for this amplifier.

Block diagram for the 50A20 amplifier.

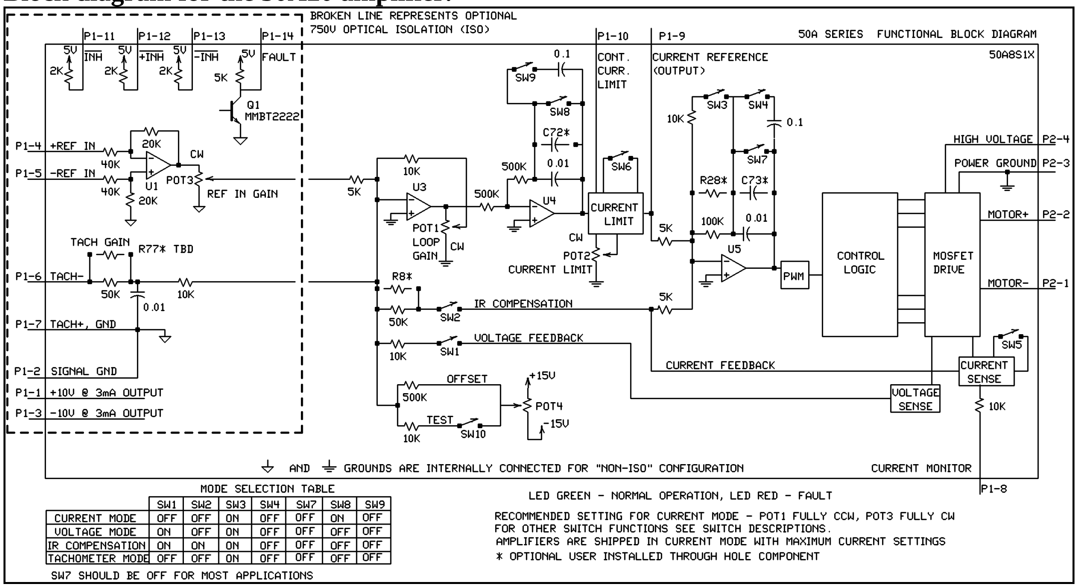
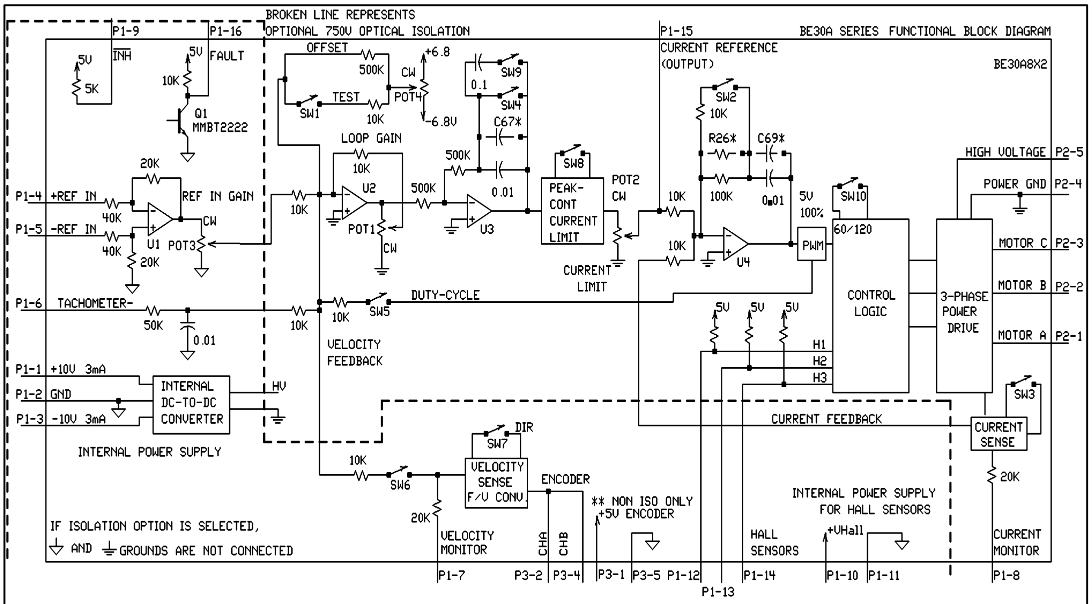


Figure B2. The current loop can be located by following the line labeled “Current Feedback” to the gain stage U5.

This amplifier has several options to tune the current loop with the switches. SW3 increases the current loop gain resistance from 9.1k to 100k. SW4 increases the current loop capacitance from 0.01uF to 0.11uF. SW7 shorts the current loop capacitor.

Through hole locations R28 and C73 can be used to adjust the current loop response if adjusting the switches is not effective.

Block Diagram for the BE25A20 amplifier.



MODE SELECTION TABLE

MODES	SW2	SW4	SW5	SW6	ENC	TACH
CURRENT	ON	ON	OFF	OFF	NC	NC
ENCODER VELOCITY	ON	OFF	OFF	ON	CONN	NC
OPEN LOOP	ON	OFF	ON	OFF	NC	NC
TACHOMETER	ON	OFF	OFF	OFF	NC	CONN

LED GREEN - NORMAL OPERATION, LED RED- FAULT
RECOMMENDED SETTING FOR CURRENT MODE - POT1 FULLY CCW, POT3 FULLY CW
AMPLIFIERS ARE SHIPPED IN CURRENT MODE WITH MAXIMUM CURRENT SETTINGS
FOR OTHER SWITCH FUNCTIONS SEE SWITCH DESCRIPTION
* OPTIONAL USER INSTALLED THROUGH HOLE COMPONENTS
** +5V @ 150mA, NON ISO ONLY

Figure B3. The current loop can be located by following the line labeled "Current Feedback" to the gain stage U4.

The current loop is located at stage U4. Switch SW2 changes the current loop gain resistance from 9.1kΩ to 100kΩ. Capacitor C69* is used to change the current loop integrator.

Block diagram for the SE30A40 amplifier.

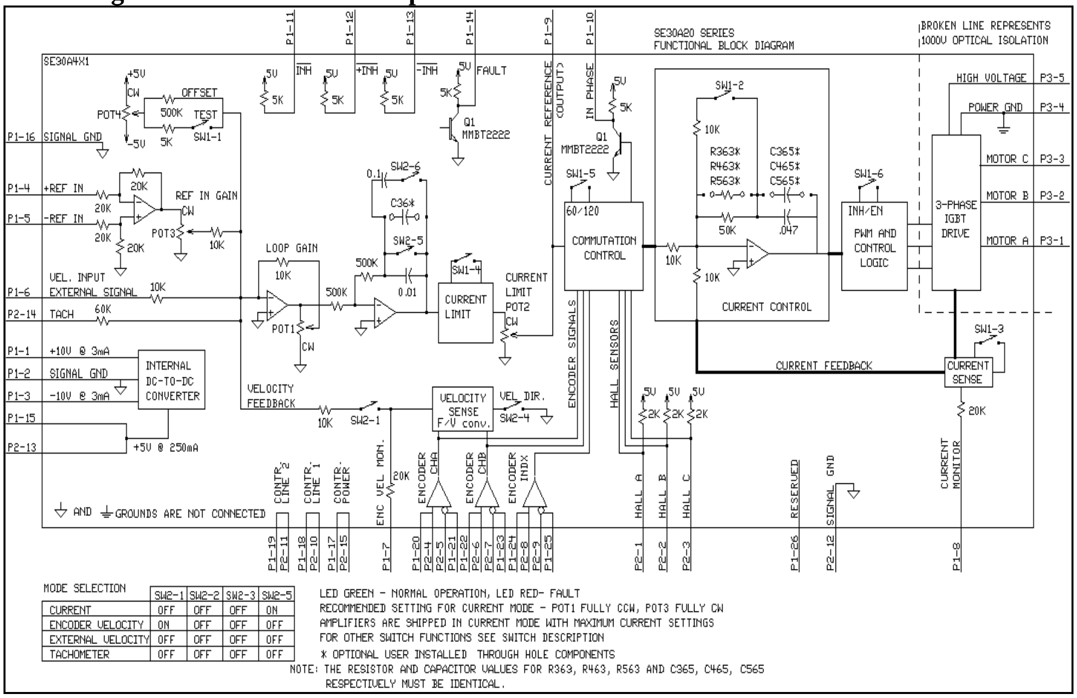


Figure B4. The current loop can be located by following the line labeled “Current Feedback” to the gain stage labeled “Current Control.”

Switch SW1-2 increases the proportional gain resistance from 8.3kΩ to 50kΩ. If neither switch position gives sufficient current loop performance then the resistance can be changed further by removing the 50k resistors at locations R363*, R463*, and R563* and replacing them with other values. The integrator capacitor values can also be changed by replacing the capacitors at C365*, C465* and C565*.

Appendix C
Helpful Hints

The following are some helpful hints to make the current loop tuning process easier.

Pin receptacles to reduce the need for soldering
Some amplifiers have pin receptacles that make it easy to change the tuning resistors and capacitors without the need for soldering. Other amplifiers do not have these receptacles so soldering is required. To avoid the need to solder every time a tuning value needs to be changed a pin receptacle can be soldered into the through hole location of the tuning component. Mill Max P/N 8427 works well for this purpose.

Use a potentiometer to find the correct current loop gain value more quickly
A potentiometer can be used to continuously adjust the gain resistance value during the tuning process. Install a potentiometer in place of the gain resistor. Adjust the potentiometer while viewing the current loop response on an oscilloscope. When the optimal response is achieved turn off the amplifier, remove the potentiometer and measure the resistance. Use the closest resistor value you have available.

Note: This method will not work if the optimal tuning value is beyond the range of the potentiometer. This method also does not work for sine drives since it is difficult to keep the tuning values in the three current loops the same.

Progressively double the resistance value when tuning the current loop gain for faster results
If the gain resistor needs to be increased during the tuning process the fastest results are achieved by doubling the resistance from the last value tried. Use this method until over shoot is observed and then fine tune from there.

Be aware of any components that are in parallel with the values you are trying to tune
For example: when tuning the BE25A20 amplifier in figure B3 there is a 10k, 100k, and R26 in parallel with each other. If you remove the 100k resistor but forget to turn SW2 to the OFF position then the 10k resistor is still in the circuit. With the 10k resistor in the circuit the total resistance will not exceed 10k regardless of what value is used at R26. In this situation you may find yourself using a 500k resistor (or more) at R26 with no change in the current loop response - which would result in a very frustrating experience.

The same can happen when trying to decrease the integrator capacitor value since capacitors in parallel add to each other.

Safety
Always remove power when changing components on the amplifier.
Float the oscilloscope and function generator grounds to avoid large ground currents.
Decouple the motor from the load to avoid being injured by sudden motor movements.

Appendix D
Examples

Example 1: System With Oscillating Current Loop Response

In this example the machine doesn't have the expected bandwidth. The motion seems sluggish and tuning the PID parameters in the controller doesn't seem to help. It is suspected that the current loop is not tuned and is causing the system to have slow response.

Amplifier	Advanced Motion Controls BE25A20
Power Supply Voltage	48VDC
Expected Current Step Command for Application	2A
Motor	CMC BMR4027A
Motor Inductance	9.4mH
Motor Resistance	2.6 Ohms phase to phase

The first step is to take a look at the current loop response:
Appendix A shows how to view the current loop response.
Appendix B shows how to use the block diagram to find the current loop and current loop tuning components and switches.

The following scope images show the commanded signal on channel 1 and the actual output current on channel 2. The command signal scaling is 0.5V per division. The current output scaling is 2A per division. The amplitude of the current step should be adjusted to match the expected current step when the system is in operation. In this case the command signal amplitude was adjusted so the current output was a 2A step.

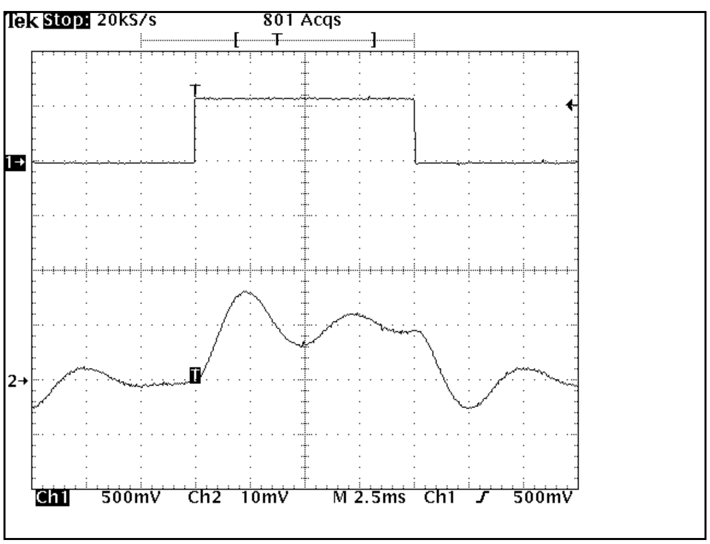


Figure D1-1. Current loop step response with switch 2 ON.

The scope image clearly shows that the amplifier is not tuned to the motor. The rise time is slow, there is excessive overshoot, and there are heavy oscillations. Since the leading edge of the square wave is not very steep, this indicates the gain probably needs to be increased.

The next step is to try switching SW2 OFF to increase the gain resistor from 9.1kΩ to 100kΩ.

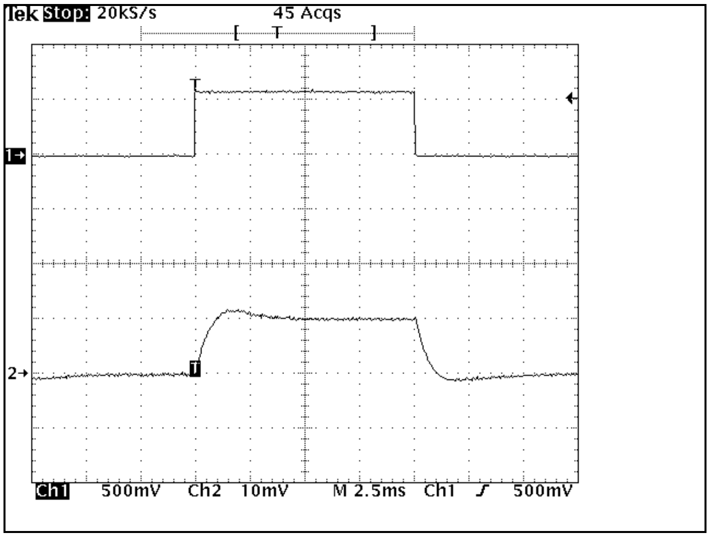


Figure D1-2. Step response with switch 2 OFF.

The response improved greatly with the increased current loop gain. The current response now resembles a square wave. There is still some overshoot and the corners of the square are rounded, but this response will be sufficient for the application.

If desired, the current loop can be further improved by removing the 100k current loop resistor and 0.01uF integrator capacitor and replacing them with different values at locations R26* and C69* (See block diagram). This will be demonstrated in the next example.

Note: Convention says that overshoot is an indication that the gain is too high. However from experience second order responses have also been observed when the gain is too low. To determine if the gain is too high or too low you should look at the step response with the integrator capacitor shorted. If the overshoot persists with no integrator then the gain is too high, if the over shoot goes away then the gain is too low.

Example 2: System With Over Damped Current Loop Response

This system uses a high inductance linear motor with a sinusoidal amplifier. The system bandwidth is much lower than expected.

Amplifier	Advanced Motion Controls SE30A40
Power Supply Voltage	290VDC
Expected Current Step Command for Application	3A
Motor	Linear motor
Motor Inductance	Unknown (high)
Motor Resistance	25.5 Ohms phase to phase

As in the previous example the first step is to look at the current loop step response and try to tune the amplifier using the switches.

Appendix A shows how to view the current loop response.
Appendix B shows how to use the block diagram to find the current loop and current loop tuning components and switches.

Block diagram for the SE30A40 amplifier.

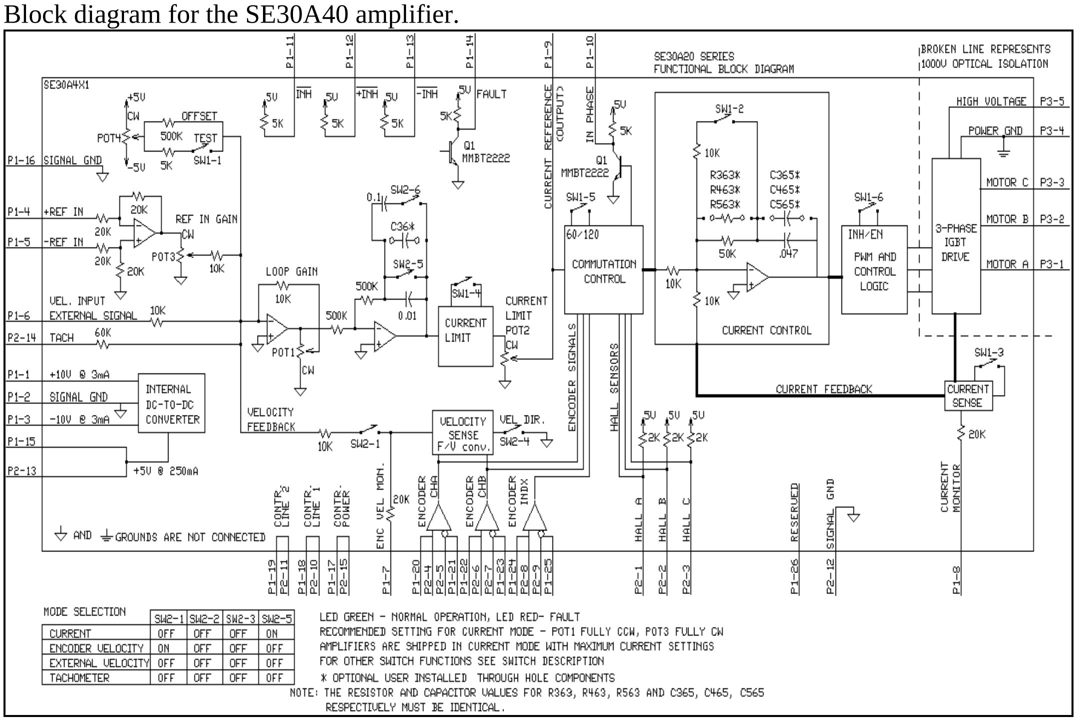


Figure D2-1. The current loop can be located by following the line labeled “Current Feedback” to the gain stage labeled “Current Control.”

Switch SW1-2 increases the proportional gain resistance from 8.3kΩ to 50kΩ. If neither switch position gives sufficient current loop performance then the resistance can be changed further by removing the 50k resistors at locations R363*, R463*, and R563* and replacing them with other values. The integrator capacitor values can also be changed by replacing the capacitors at C365*, C465* and C565*.

The following scope images show the commanded signal on channel 1 and the current output on channel 2. The command signal scaling is 0.5V per division. The current output scaling is 2A per division. The amplitude of the current step should be adjusted to match the expected current step when the system is in operation. In this case the command signal amplitude was adjusted so the current output was a 3A step.

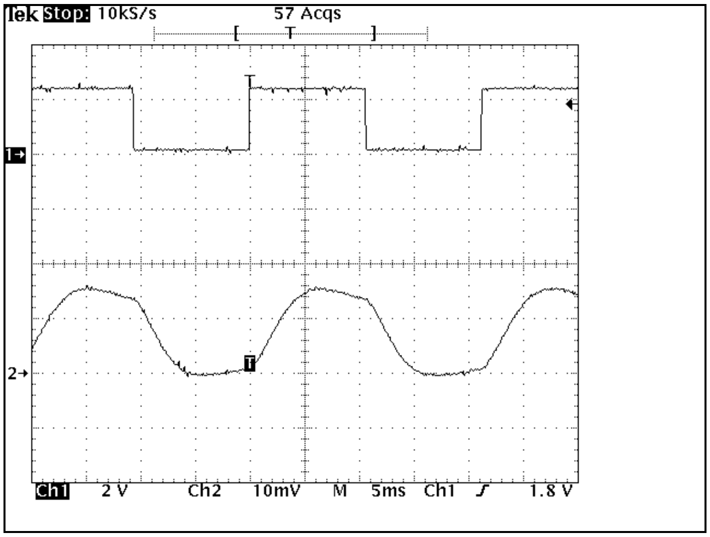


Figure D2-2. Current loop step response with SW1-2 ON.

The figure above shows the current response with the current loop gain switch set to the low setting. The current loop response is very poor with this setting. The output looks more like a sine wave than a square wave. The rise time is very slow and the corners are totally rounded.

The next step is to try turning SW1-2 OFF to increase the gain resistance from 8.3k to 50k.

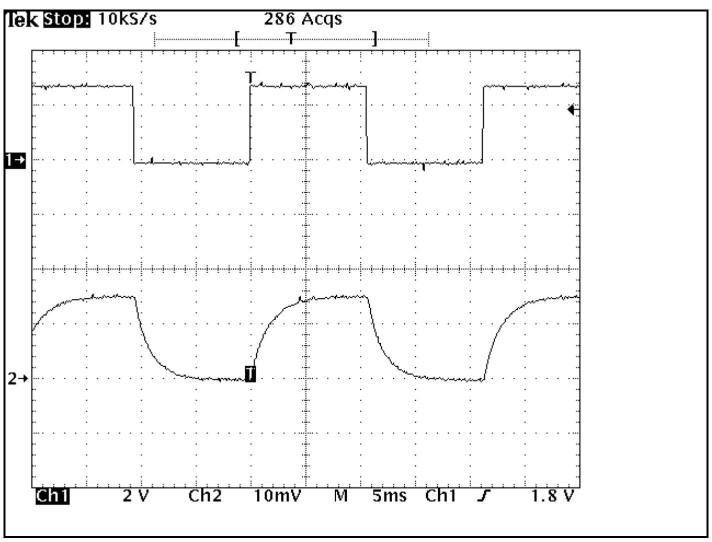


Figure D2-3. Step response with SW1-2 OFF.

The performance is slightly increased with this setting but the rise time is still slow and the leading corner of the square wave is overly rounded. Increasing the gain should square up the leading corner of the square wave. Since it is not possible to increase the current loop gain any further by using the switches, it will be necessary to add and remove resistors on the PC Board.

The SE series amplifiers have three current loops. To keep the three phases balanced it is necessary to always keep the current loop resistors at identical values. This also applies to the current loop capacitors. Trapezoidally commutated amplifiers have one current loop so there is only one resistor and one capacitor to change when tuning these.

Please contact Advanced Motion Controls for the locations of the loop gain resistors and capacitors.

The following steps describe the process of tuning by changing the loop gain resistors and capacitors.

1. Locate the loop gain resistors and capacitors on the PC board.
2. Short the capacitors either by switch (if available) or use jumpers.
3. If there is a Current Loop Gain Switch check the amplifier block diagram and set the switch so there are no other resistors in parallel with the resistors you are changing.
4. Increase the gain resistors incrementally until the response is critically damped with little or no overshoot.
5. Un-short the capacitors.
6. Change the capacitor values until the response is critically damped with little or no overshoot.

For this system the first resistor value will be 100k.

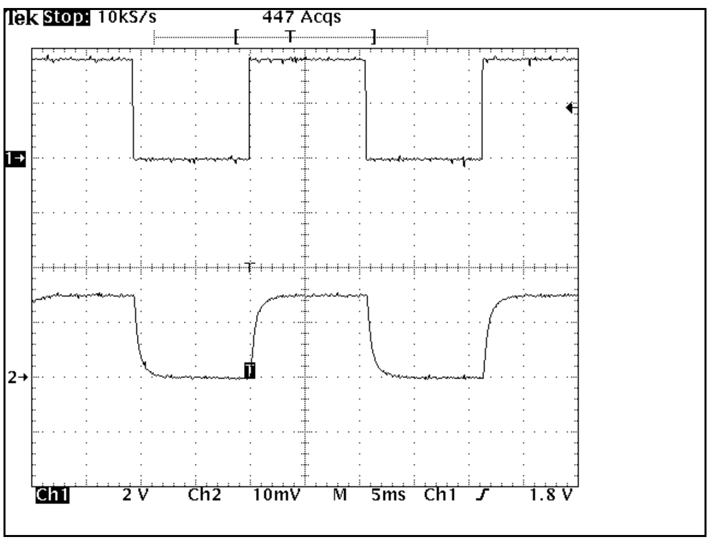


Figure D2-4. Step response with 100k resistors, shorted capacitors.

The response is getting better so a higher resistor value will be tried next.

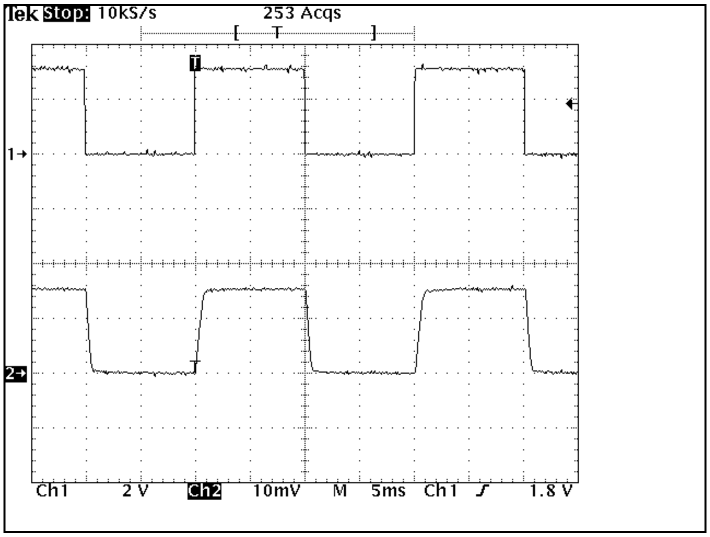


Figure D2-5. Step response with 270k resistors, shorted capacitors.

The response has improved greatly with a 270k resistor. This value may be sufficient but a higher value should be tried to see if performance improves.

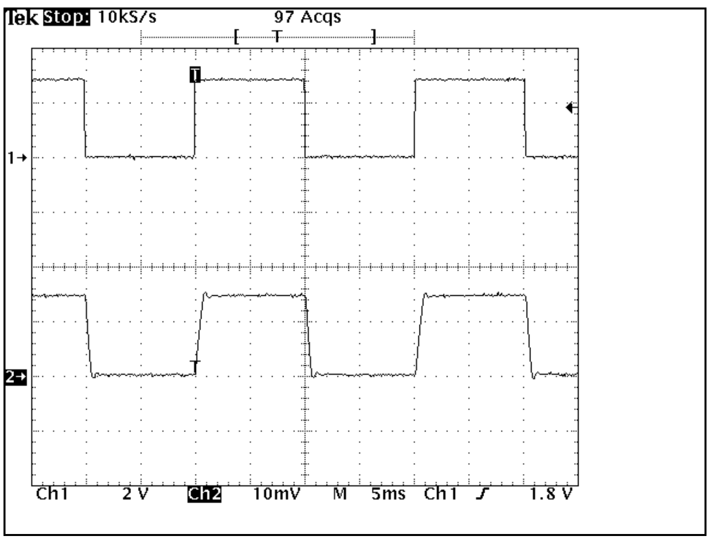


Figure D2-6. Step response with 510k resistors, shorted capacitors.

With a 510k resistor there is some overshoot starting to appear. The rise time is slightly improved and the corners are as sharp as they are going to get. The rise time is now limited more by the power supply voltage and motor inductance and can no longer be significantly improved with loop tuning.

Note: It is up to the system designer to decide how much overshoot is acceptable. As a rule it should be less than 10%.

The next step is to add the capacitors back into the loop. The capacitors eliminate the steady state error in the current loop. The steady state error is proportional to 1/Kp (Kp = proportional gain). With the gain resistors at 50 times the nominal value it is unlikely there is very much steady state error. The capacitors will add little to the performance of this system, and may actually cause the response to be a little slower and more unstable. The next figure shows the response with the standard capacitor values added in.

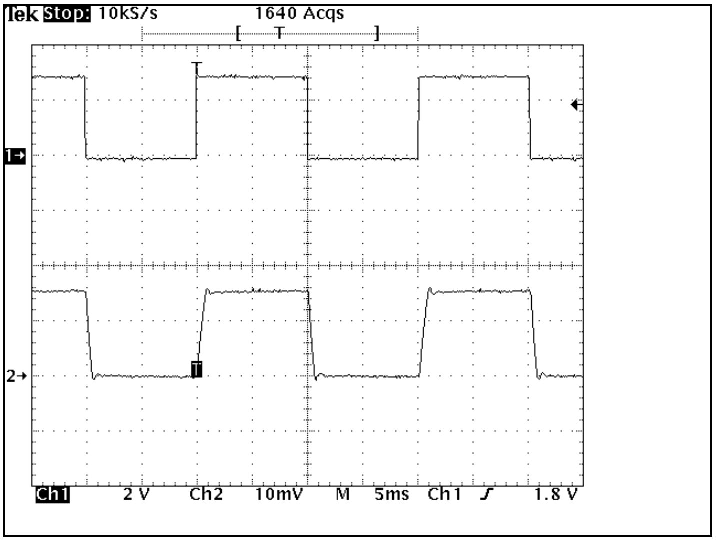


Figure D2-7. Step response with 510k resistors and .047uF capacitors.

The 0.047uF capacitors didn't affect the response significantly. The overshoot is slightly more pronounced and the performance didn't appear to improve. A faster (lower value) capacitor can be tried to see if this will increase performance.

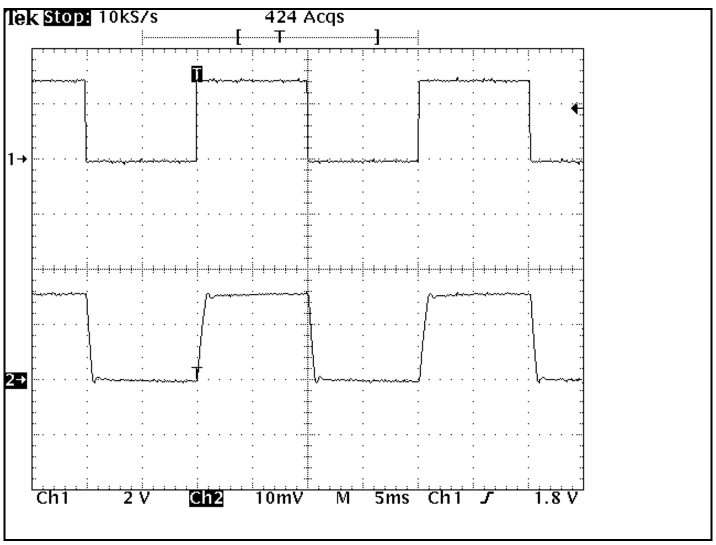


Figure D2-8. Step response with 510k resistors and 0.01uF capacitors.

There is no noticeable improvement in performance. Notice that the flat portion of the square wave has a slight upward slope. This may indicate there was some steady state error that was not being closed off when the capacitor was shorted. A faster capacitor may eliminate this, but at the expense of stability. With the gain so high the contribution of the capacitor to the loop tuning is very small. It is up to the system designer to decide whether to stay with the 0.01uF capacitor or to continue trying capacitors of smaller values or to leave the capacitors shorted as in Figure D2-6.

Example 3: Brushed Motor

This system uses a low inductance brushed motor with a high winding resistance. Tuning the amplifier to this motor required increasing the gain resistor to a relatively high value and decreasing the capacitor value substantially.

Amplifier	Advanced Motion Controls 50A20
Power Supply Voltage	40VDC
Expected Current Step Command for Application	2A
Motor	Brushed
Motor Inductance	1.2mH
Motor Resistance	5.4 Ohms

As in the previous examples the first step is to look at the current loop step response and try to tune the amplifier using the switches.

Appendix A shows how to view the current loop response.
Appendix B shows how to use the block diagram to find the current loop and current loop tuning components and switches.

This amplifier has several options to tune the current loop via switches. SW3 toggles the current loop gain resistance between 9.1k and 100k. SW4 toggles the current loop capacitance between 0.01uF and 0.11uF. SW7 shorts the current loop capacitance.

The following scope images show the commanded signal on channel 1 and the current output on channel 2. The command signal scaling is 0.5V per division. The current output scaling is 1A per division. The amplitude of the current step should be adjusted to match the expected current step when the system is in operation. In this case the command signal amplitude was adjusted so the current output was a 2A step.

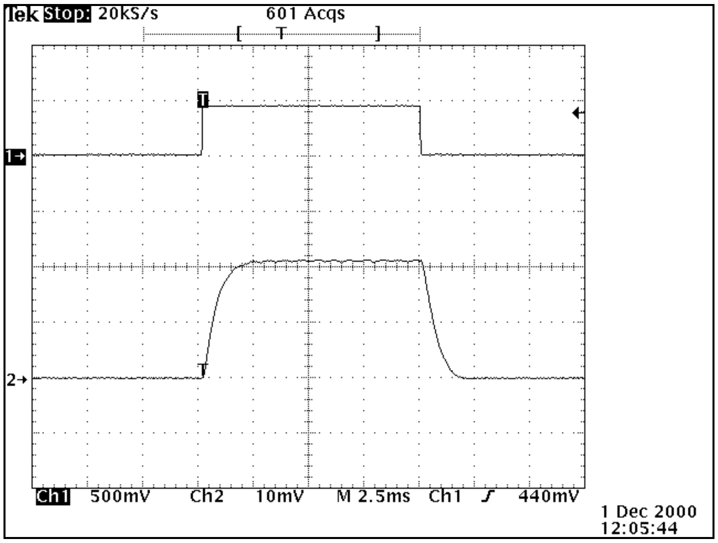


Figure D3-1. Current loop step response with the suggested switch settings.

The switch settings were set to what is suggested in the mode selection table in the block diagram in Figure B2. With SW3 ON the gain resistance is 9.1kΩ and with SW4 OFF the capacitance is 0.01uF. Figure D3-1 shows that with these settings the step response is slow and the leading corner is rounded. In most applications this response would be good, but to increase the performance for high bandwidth applications the amplifier should be tuned.

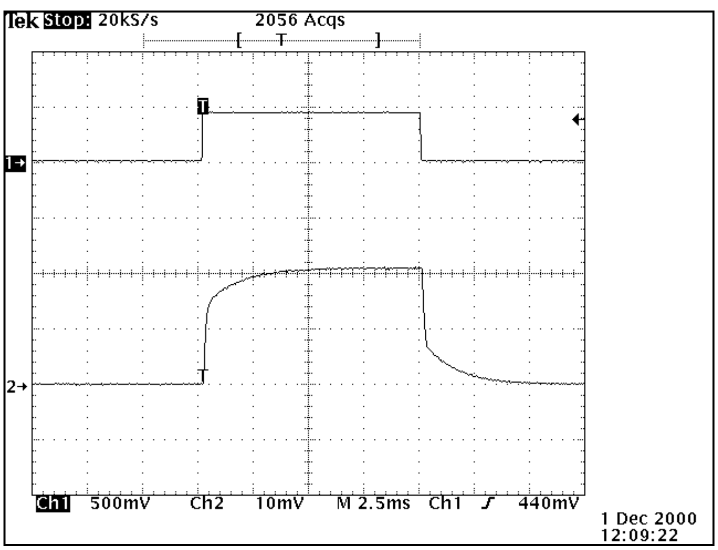


Figure D3-2. Step response with loop gain SW3 OFF.

With SW3 OFF the proportional gain resistor was increased from 9.1kΩ to 100kΩ. This resulted in a faster initial rise but the leading corner is still very rounded.

To further increase performance the standard tuning procedure should be followed. The capacitor should be shorted while the proportional gain resistor value is increased. The resistor value should be increased until a small amount of overshoot starts to appear. Once the resistor value is set the capacitor should be adjusted until the step response has square corners with little or no overshoot.

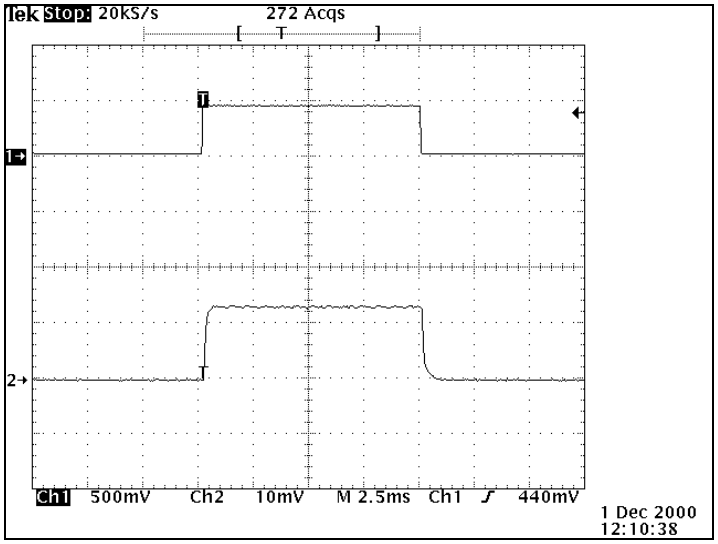


Figure D3-3. Step response with a 100k resistor and shorted capacitor.

With the 100k resistor the response looks very good. The leading corner is slightly rounded so a higher resistor value should be tried to see if the response can be improved.

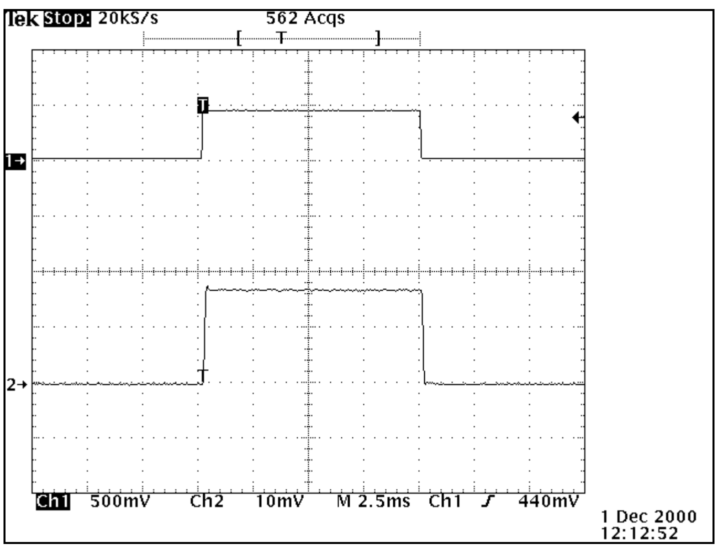


Figure D3-4. Step response with a 240k resistor in the current loop and a shorted capacitor.

With the 240k resistor the corners are very crisp and well defined, however there is some overshoot starting to appear. It is up to the system designer to decide weather to go with this value or with the more conservative 100k resistor (or try an intermediate value). A higher resistor value will be demonstrated next to show the effects of over tuning the amplifier.

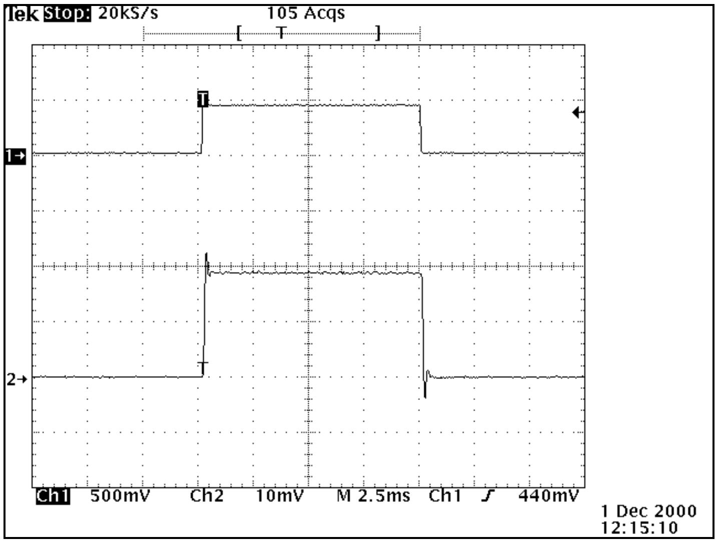


Figure D3-5. Step response with a 510k resistor and shorted capacitor.

The 510k resistor value is much too high and is causing the sharp overshoot on the square wave. Don't tune your system this aggressively.

The next step is to add the capacitor back into the current loop. The onboard 0.01uF capacitor will be tried first by switching SW7 OFF.

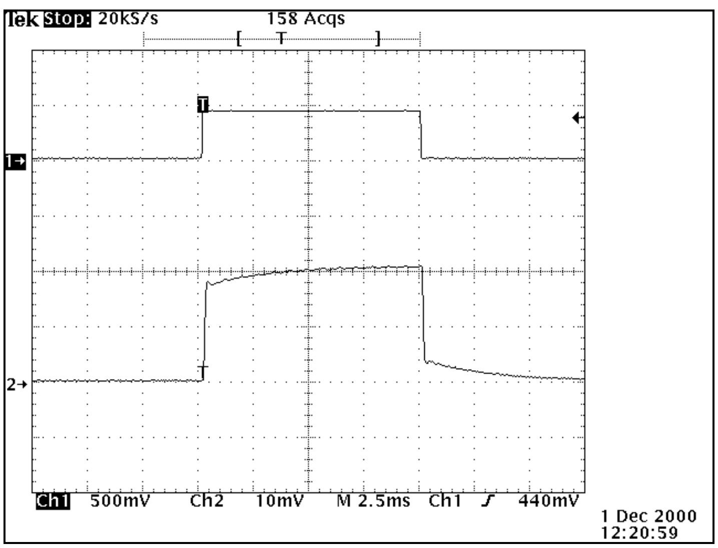


Figure D3-6. Step response with 240k resistor and .01uF capacitor.

With the 0.01uF capacitor added in you can see there was a steady state error that the resistor wasn't able to close off by itself. The current rises quickly to the same value as in Figure D3-4 but the capacitor is slow to close off the error. A faster capacitor will be required to square up the corners on the square wave.

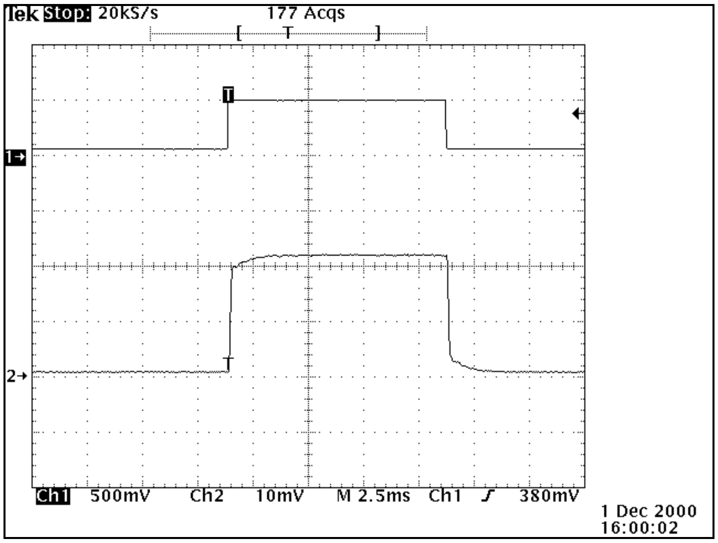


Figure D3-7. Step response with 240k resistor and 0.0025uF capacitor.

The 0.0025uF capacitor does a better job of closing off the steady state error but the leading corners are still rounded. This tuning is sufficient for this application, however if better response is required continue to decrease the capacitor value until the desired response is achieved.

Example 4: Low Torque Ripple Application

This system uses a sinusoidal amplifier to reduce the torque ripple in the application. During operation there is much more torque ripple than was expected.

Amplifier	Advanced Motion Controls SE10A80
Power Supply Voltage	40VDC
Expected Current Step Command for Application	400mA
Motor	Brushless
Motor Inductance	1.8mH
Motor Resistance	1.5 Ohms phase to phase

The first step is to look at the current loop response and try to tune the amplifier using the switches. Appendix A shows how to view the current loop response.

The following scope images show the commanded signal on channel 1 and the current output on channel 2. The command signal scaling is 100mV per division. The current output scaling is 200mA per division. The amplitude of the current step should be adjusted to match the expected current step when the system is in operation. In this case the command signal amplitude was adjusted so the current output was a 400mA step.

During operation the SE amplifiers generate a sinusoidal current in each phase as the motor turns. To verify that the commutation will be smooth the sine wave response should be looked at as well as the step response.

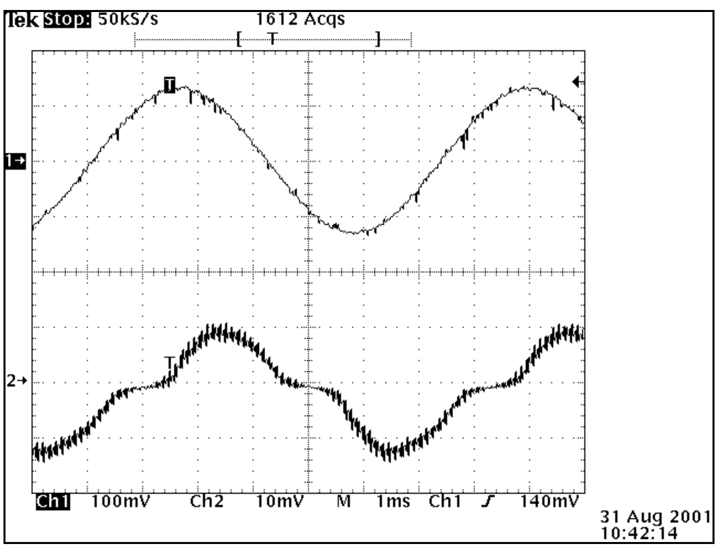


Figure D4-1. Sine wave response with SW1-2 ON and standard capacitor values.

With SW1-2 ON the gain resistance is 8.3k. The standard capacitor value is 0.047uF. It is easy to see where the torque ripple is coming from. Since torque is proportional to the current in the motor the dead band in the sine wave shows up as torque ripple.

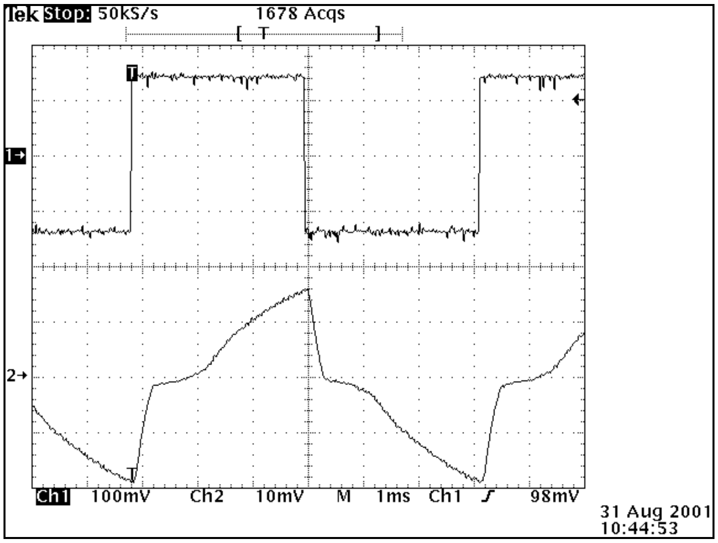


Figure D4-2. Step response with the same tuning values above.

From the square wave response it is easy to see that the amplifier is very mistuned. The next step is to look at the step response with the capacitors shorted.

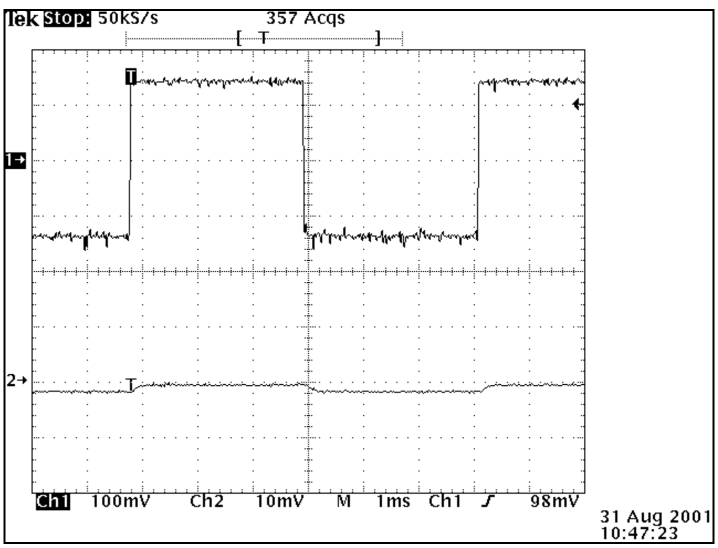


Figure D4-3. Step response with SW1-2 ON and shorted capacitors

It is clear now that the proportional gain is set much too low. Almost all of the current response was driven by the integrator capacitor. Without the capacitor there is almost no response.

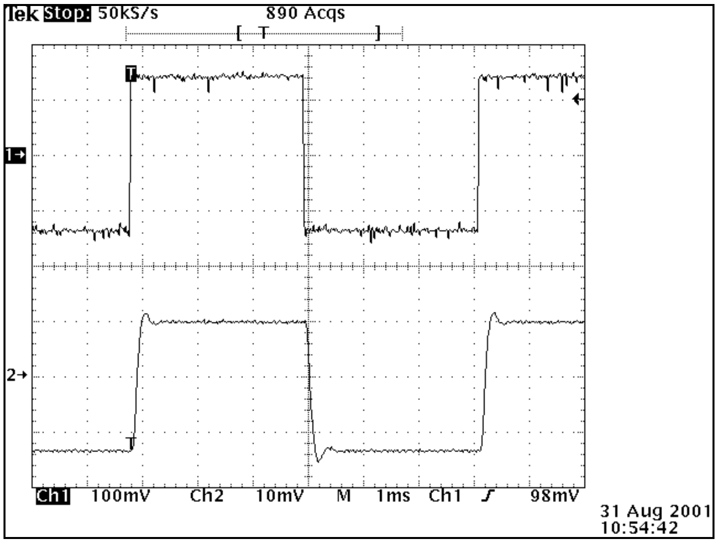


Figure D4-4. Step response with SW1-2 OFF and shorted capacitors.

With SW1-2 OFF the gain resistance is 50k. This gives very good response with some over shoot. The over shoot can be addressed by trying smaller gain resistor values, however in this case we will stay with these values.

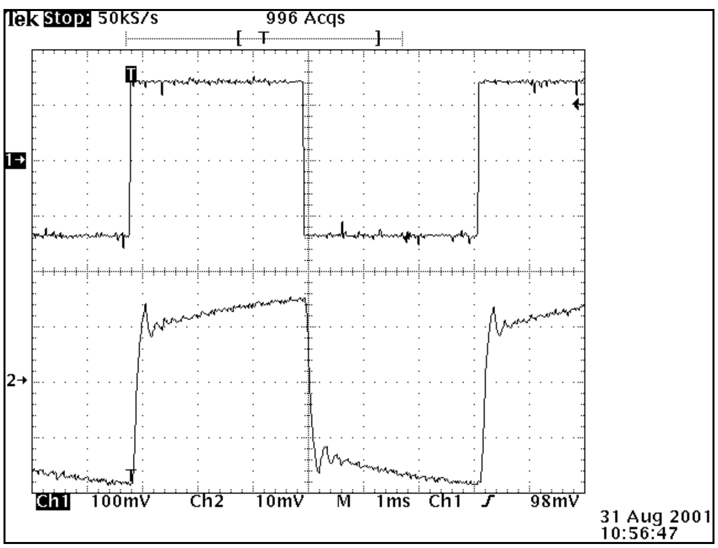


Figure D4-5. Step response with SW1-2 OFF and standard capacitor values.

With the standard capacitor values the steady state error is being closed off but not very quickly. A faster capacitor should be tried. Also the proportional gain value may need to be looked at again since the over shoot is now more pronounced.

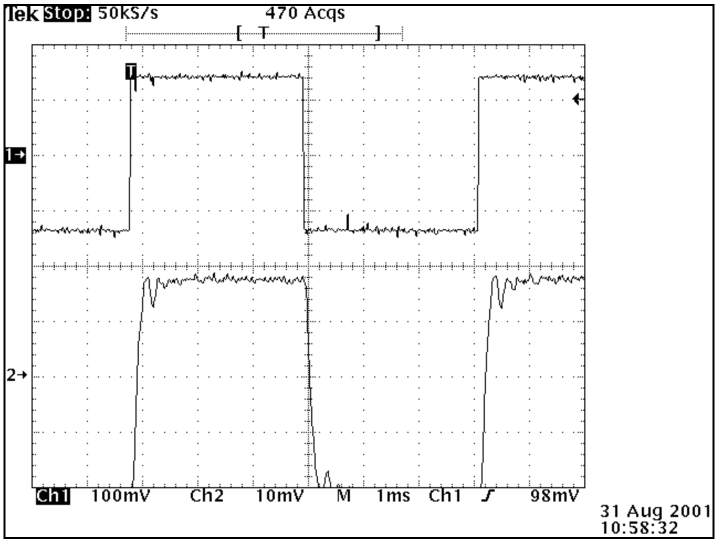


Figure D4-6. Step response with SW1-2 OFF and .0056uF capacitors.

The .0056uF capacitor does a much better job of closing off the steady state error. Everything looks good about this square wave except the initial oscillation at the leading edge of the square wave.

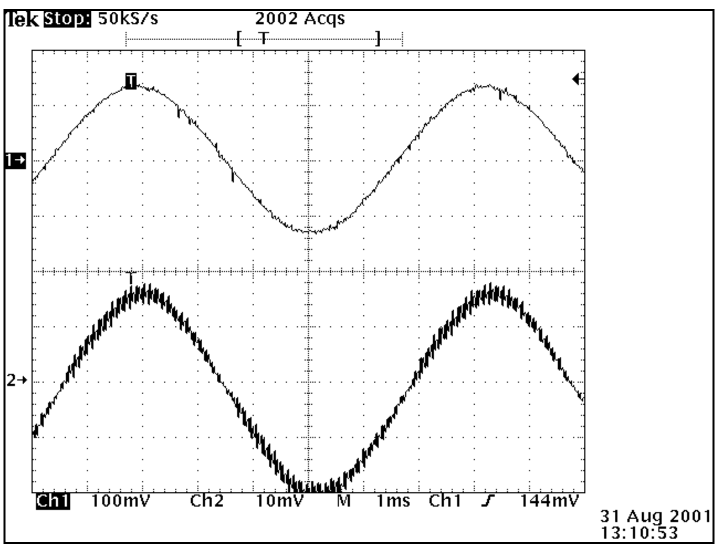


Figure D4-7. Sine wave response with the same tuning values above.

The sine wave response has been greatly improved. There is no longer any dead band so there should be little or no torque ripple caused by the amplifier. The oscillations at the peaks of the sine wave are probably related to the over shoot that was seen in the step response in figure D4-6. It would probably be best at this point to run the amplifier in the system to see if the performance is acceptable. If not the tuning can be refined.