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CHOPPER CONTROL BOARD CHECK OUT

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Summary of Chopper Operation

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The chopper can be simplified by comparing its main SCR (or SCR'S) to a switch being easily turned on with the main firing pulse (pulses) from the controller board. The commutator SCR is also a switch which turns on a ringing circuit that can shut off the main SCR and reset itself when given about 80 micro seconds to complete its cycle.

Therefore, by operating the main SCR(s) for a longer or shorter time into a magnet and repeating this cycle many times a second so that the magnet smoothes out the variations in current, a regulated current can be maintained in the magnet. If the commutator firing pulse is delayed further in time the current in the magnet will increase. If the main pulse is followed shortly by the commutator pulse, current in the magnet will decrease. The increments of increase or decrease are very small due to the shortness of the cycle compared to the time constant of the magnet.

The purpose of the pulse controller is then to deliver a main pulse train and a commutator pulse train properly spaced for regulation in the 400A chopper. For the 1400 A chopper the main pulses must also be alternated between two SCR's so they can share the load current. The controller also establishes limits for the pulses to allow safe operation for the magnet and the chopper.

The minimum pulse length to the magnet is 20% of the period at 2,000 hertz. The maximum pulse length is 95% of the period at 2,000 hertz. Some of the choppers run at 360 hertz, for this lower frequency the minimum pulse length is 1.8% of the period (the same number of micro-seconds), and the maximum length is 99% of the period. Note that the lower frequency gives a wider range at a sacrifice of frequency response.

Initial Set Up of Bin and Controller

**1. Install the "MASTER BIN CNTRL" (207-101) in slot 24 and 25 of the CAMAC bin.

**2. Install the "CLOCK MODULE" (207-102) in slot 18 of the bin. Connect the jumper cable from any one of J3 thru J6 on the "CLOCK MODULE" to J5-CLK connector on the "MASTER BIN CNTRL" module.

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**3. Install a "DATAWAY EXTENDER" EB01 in slot 2 of the CAMAC bin, and install a current meter (0-500 ma) in place of the -24V. jumper. An extender for both P1 and P2 are necessary for checkout through the bin connectors.

**4. Set all switches on the "MASTER BIN CNTRL" to the following:

Horizontally mounted (bit) switches numbered 1 thru 16 to the left or low position; "LCL"/"REM" switch to "LCL"; "DAC"/"CNTRL" switch in "DAC"; "SLOT ADDRESS" switch to position 2.

**5. Set the "LINE SYNC"/"NORMAL" to "LINE SYNC" and frequency switch to"24 KHz" on the "CLOCK MODULE".

Chopper Controller Check Out and Adjustment

NOTE: If any condition of any step is not met, do not proceed to the next step without troubleshooting the problem.

**1. On a new chopper controller module adjust R24, 27, 36 and 48 for minimum settings of all regulators (R36 and R48 clockwise, R27 and R24 counter clockwise.) For an operational unit check the respective regulator outputs first. If their voltage outputs are ok proceed to next step.

**2. For the initial alignment of a new module remove U1, U2, and U21 IC's. On an operational unit in for troubleshooting it is only necessary to remove U1 and U2 if there is trouble with the unit missing or having improper output pulses. It should only be necesary to remove U21 if there is an indicated problem with the DAC not functioning properly.

**3. Connect controller board to the extender and turn on power to CAMAC bin. Allow 1 minute for clock to stabilize and monitor it at the end of R113 closet to U8. Adjust the frequency if necessary to 2,160 Hz (463 micro seconds for a high frequency type module or 2777 micro seconds for the 360 Hz low frequency type clock module. +/- 10 micro seconds between pulses) by changing the adjustment pot marked "LINE" on the "CLOCK MODULE").

**4. Monitor current in the -24 V power supply while adjusting R36 until the voltage reaches -15.0V at the output (pin 3) of VR 4, current must not rise above 250 ma and will be about 50 to 100 ma. Turn power off and move the current meter to the +24 V. jumper and reinstall the -24V. jumper.

**5. Monitor the current in the +24V power supply while adjusting R48. The voltage at pin 3 of VR3 should come up to +15.0 without exceeding 260 ma.

**6. Adjust R27 so that pin 3 of VR1 reads +11.75 V +/- 0.25 before the current in the +24 V line reaches 260 ma.

**7. Adjust R24 so that pin 3 of VR2 reads +5.0 V, but do not exceed 260 ma in the +24 V power supply. Shut -off the CAMAC bin power.

**8. Connect or check connection between point A and B near U39, and adjust R110 for a resistance of 5.11 kilohms measured from U39, pin 12 to common, using a Fluke DMM set on the 20K range. Restore power to the board.

**9. Measure voltage at A, it should be about -9 volts, then at E39 it will be about 9V. Also, check pin 12 of U38 to see that it is within 1% of the reading at E39.

**10. Check for clock pulses at pin 12 of U10, they should be positive going 10-14 V peak and about 5 micro-seconds in length, f=2160 Hz for a high frequency type module and f=360 Hz for a low frequency type module.

**11. Check and adjust R19 (Trig. Delay) for an 80 micro second width out of the one shot multivibrator U10 pin 10.

**12. Output of U10 pin 6 should be a 5-8 micro second pulse rising to about 12 V starting when pin 5 goes low. Check pin 7 for the inverse of the pulse and then the output of U13 pin 13 for the original pulse amplitude and duration.

**13. Check U38 pin 1 and adjust R101 for a voltage ramp rising from about 0.2 V to 11 V in a certain time period, which results from C70 being charged with a constant current source. The capacitance value required for C70 is 0.22 micro-farads in the low frequency type module and 0.1 micro-farads in the high frequency type module. The rise time is adjusted to 2777 micro seconds or 463 micro seconds respectively.

**14. Check for unity gain from pin 10 to 8 U39.

**15. Switch the mode switch to "LOC" and check at E27 (near U35) for -10 V +/- 1 VDC when R114 (on front panel) is set in maximum clock-wise position.

**16. At E25 (near U32) check for a pulse which has variable width as R114 ("LOCAL") is changed (pulse will disappear with low setting of "LOCAL"). A commutator pulse is produced when U34 goes low at pin 7 which determines how long the chopper main SCR(s) stay on in a cycle. Current in the magnet is proportional to this duty cycle.

**17. Plug the test cable with the dual banana plug on one end into the "EXTERNAL" jack on the back of the CAMAC crate marked C0S02, J10. This point is available on the Chopper Controller Patch Panel and is labelled J10.

Short the banana plug with a clip lead and apply an AC voltage (of 60-10,000 Hz, no offset) between the clip lead and the shield wire of no more than 5 VRMS. Observe the output of U36 at pin 14 (or E32) and adjust R92 for minimum AC voltage.

> In a "Slaved" controller this amplifier is used as a buffer on the signal from the "Master" controller to generate the main pulse trigger from the ramp in the slave controller.

Turn on power to the Chopper Controller Module Test Chassis.

**18. Remove jumper and AC voltage. Connect the dual banana plug to a 0-10 V. positive DC supply ,ground on plug is low. Output of U36 at E32 should now track the input voltage but with opposite polarity. Switching the mode switch to "EXT ERR" should now cause the output of U34 (E25) to change pulse width as voltage changes positive on E30. Remove connector from C0S02, J10.

Set all bit switches on the Master Bin Controller Module (1-16) to their low position.

Remove power. Install U21, and restore power. Put "LCL"/"REM" switch in "LCL" and push "SEND" button. Monitor voltage at U25 pin 6 and adjust "OFFSET", control, R43, for 0.00000 V.

Move probe to E17 and see that it is also 0.000 V. Switch bit switches to high position and press "SEND", an output of 10.0 V should be read. Monitor pin 6 of U25 again and adjust this point to 10.0000 V with R45 ("GAIN"). Repeat until both readings are correct.

**20. Switch 16 to low position and push "SEND".

Monitor pin 6 of U25 again (it will be 5.00 V) and then change each bit switch in order down to the bit 1 switch, each time pressing "SEND" and observing the 50% decrease in voltage at U25 or E17, for each bit.

**21. Connect the cable used to test "EXTERNAL" input to the "XDCTR" connector C0S02, J9. This point is available on the Chopper Controller Patch Panel and is labelled J9. Put a clip lead between the pins of the banana plug and check the output of U31 for 0.00v. Connect the AC source (0-10000 Hz) used in step **17 to the clip lead and shield of the test cable and observe the output of U31 with a scope while minimizing the output with the adjustment of R75.

> This procedure tests the common mode rejection of Amp U31 used to buffer the transductor signal into the differential amplifier. There should be less than 100 micro-volts peak to peak at E20 for an input of 1 volt peak to peak of any frequency from DC to 10,000 hertz. Any loss of common mode rejection introduces noise (sometimes 60 or 120 hertz) in the output of the chopper that can not be taken out by the regulator. There is a large common mode signal on the transductor output with respect to the rack frames.

**22. Remove the clip lead and AC supply and connect the dual banana plug to the 0-10 volts positive DC power supply. Set the supply for 10 volts Check E20 for a -10 V output and reduce the DC to 5 V to see that the output tracks the input within +/- 1%.

**23. With input of 5 V to U31 set bit 15 to high and press

"SEND". Set mode switch to "ERR". Connect a scope to E27 (near U35) and set it to observe a +/- 15 V swing as bit 16 is toggled high and low (each change must be followed by a "SEND" command).

**24. Monitor E19 (near U30) with a volt meter as the input to U31 is changed. R112 should cause about a 14% change in gain from stop to stop. Set R112 to read the same as E20 (it will be opposite polarity) and change the input to U31 to see that input and output track, then return to 5 V.

**25. Set all bit switches high and press "SEND", then change "DAC"/ "CNTRL" switch to "CNTRL". Set all bit switches low, now while monitoring the output of U24 at E15 with a voltmeter, toggle bit 13 high and low, followed each time by a "SEND" command. When bit 13 is high, voltage at E15 will be the same as at E19 (5V). E15 will be the same as E17 or E16 (10V) when bit 13 is low. Now connect an isolated voltmeter to pins A and B of COSC2 J5; the reading will be the same as at E15, pin A will be positive.

**26. Push the chopper controller "RESET" button,the "GL" LED should be out. Momentarily, remove the input to U31 to verify that the glitch detector circuit lights the "GL" light, then push "RESET" again to extinguish it.

**27. Adjust R87 to maximum counter-clockwise position, and set the input to U31 at 9.20V. Reset the controller board ("OC" over current light should be out) and slowly adjust R87 clockwise until the "OC" light comes on. Lower the input voltage and reset again, then raise input voltage until the "OC" light comes on. Read this voltage and if it is not 9.2V adjust R87 until it is within 0.1 volts. Lower input of U31 to 7V and push "RESET" to extinguish all lights.

**28. Turn off power to the board, then connect the KRP 11 24 VDC relay and test connector assembly to the "OC RELAY" recepticle, COS02, J6. This has already been done via the patch panel and is labelled accordingly. Restore power, then as the input to the circuit is raised to 9.2 v the relay will release and when the voltage falls to approximately 7 volts it will pull in. The status of the relay is indicated on the patch panel by two LEDs labelled "OC RELAY". Check between pins A and C with an ohmmeter for the relay blocking diode as indicated on the schematic. Restore power to the bin only and push "RESET", all lights will now be off.

**29. With Bin Controller "DAC"/CNTRL" switch in "CNTRL" position enable the controller board by switching only bit 15 to high and pushing "SEND".

The "EN" light will come on and remain on.

**30. Switch bit 16 to high, all others low, and push "SEND", this will extinguish the "EN" light.

**31. Repeat step 29.

**32. Short pins 11 and 12 together on U5, all lights will now be on except the "OC" light. Set the input voltage to U31 to +10 volts to trip the overcurrent protection circuit and light the "OC" light. When the "OC" light comes on the "EN" light will go out.

**33. Switch bit 14 to high and press "SENI", the "OC" and MP" lights will go out; "EN" will come on if bit 15 has been left high.

**34. Switch bit 12 to high and press "SENI", the "GL",light should go out.

NOTE: The "OC", "MP", and "EN" circuits are very similar because the led's have built in current limitation which allows them to be driven by simple emitter followers in a CA3082 I.C. The 4043, quad R-S latch, toggles output at Q either high if S is high or low if R is high. If both are high, output at Q goes high; if none are low, no change of output state occurs. The 6N139 is an optically coupled isolator which repeats the input signal at its output.

**35. Set up a scope to chop two inputs and with one channel check for a pulse with no offset rising to +12V at socket for U2 pins 9 thru 12. Period of pulse will be 463 (2,777 for low frequency controller) micro second and pulse width will be 5 to 8 micro-seconds. This is the single chopper main pulse.

**36. Enable the module. Move the probe to the socket of U1, pins 9 thru 12 and sync the scope to that channel It will be a similar pulse to that in 35 but with a period of approximately 926 micro-seconds for the high frequency controller and approximately 5,555 micro-seconds for the low frequency controller. Connect the channel 2 probe to U1 socket, pins 2 thru 5, the two traces now will show the pulses appearing on alternate channels at 463 micro second intervals for the high frequency controllers and 2,777 micro-second interval intervals for the low frequency controllers. This is to allow the 1400 A choppers two main SCR's to be fired on alternate main pulses and divide the average load current equally between them. U5 is the JK flip-flop that provides this alternation by keeping one of the U3's one shot multivibrators from firing on alternate "TRIG" pulses (which are delayed clock pulses). See Chopper Controller Schematic.

**37. Repeat step 30 while monitoring the main pulses at U1 and U2, all should disappear when "EN" light goes off.

**38. Disconnect the clock input to the chopper controller by switching the "12KHz/EXT/24 KHz" switch on the clock module to "EXT" and check pins 4 and 11 on both U1 and U2 sockets for a DC voltage, none of these should be more than 10 milli-volts.

**39. Shut off power to the controller board install U1 and U2 and return clock module switch to orginal position. Restore power to the board, turn "LOCAL" pot fully c.c.w., and switch mode to "LOC".

**40. Move channel 1 scope probe to "TRIG" output at U10, pin 6, SYNC on this channel and connect 2 probe to U9, pin 6, then adjust "EARLY" control (R15) so that the channel 2 pulse is 30 micro second +/- 5 micro second wide. Both pulses will be 12 V peak with no offset.

**41. Move the channel 2 probe to the end of R8 closest to U2 (the pulse will be 12v, 5 to 8 micro-seconds in duration), now rotate the local pot fully clockwise and see that the pulse moves (measured from the leading edge) from a point 30 micro-seconds +/- 5 micro-seconds to 373 micro-seconds +/- 10 micro-seconds for a low frequency type module. For the high frequency type module the pulse should range fron 30 micro-seconds +/- 5 micro-seconds tho 2,333 micro-seconds +/- 50 micro-seconds.

**42. Move the channel 1 probe to pin 6 of U9 and turn "LOCAL" pot fully clockwise. Reconnect the 10 VDC supply to the input of U31 to trip the "OC" light. Both the main firing pulse and the commutation pulse will disappear due to the enable modification which takes away all pulses if the enable of the module is lost.

**43. Push the "RESET" button and enable the unit. The "MP" light will come on when pin 10 of U4 socket is grounded momentarily with a jumper. Push "RESET" on the controller front panel and the light will go out. Remove power from board and disconnect the 10 V supply.

The commutator pulse control circuit is composed of U10, 1/4 of U13 (pins 9-12, and 13), U38, U35, U39 (excluding "ERROR BUFFER"), U34, U9 (Early Limit) U8, U6, 1/4 U7 (pins 4,5,and 6) and U4 (output pin 10).

U10 supplies a pulse 5-8 micro second wide, delayed behind the clock by the setting of R19. This pulse, called "TRIG" on the Chopper Controller Schematic, is used to set the "Q" output of U8 high and is then lengthened by the setting of R15 and applied to pins 9 and 12 of U6. Both OR gates of U6 will now have high outputs which cause U7 pin 4 to be high. When the output of U9 goes low after the ("EARLY LIMIT") delay the output one or both U6 "OR" gates (and consequently the output of U7) may go low if the error input from the comparator, U34, is low (U6 pin 13 is still set high from the "TRIG" pulse applied to U8). This will fire the one shot multivibrator (U4) for the commutator circuit since it is set to respond to a negative going waveform.

If the comparator, U34, has not gone to a low output, U6 pin 8 will be high and its output will not change state, so there can be no change of state at U7 pin 4 or U4, pin 10.

If an over current fault happens after this point in time, U8 gets reset by a high on pin 12, which brings pin 15 low along with the outputs of U6 (pin11) and U7 (pin 4), which fires the commutator one shot multivibrator. Through the succeeding cycles if the over current remains neither the main pulse nor the commutation pulse will appear due to the enable modification.

If there is no change of state of the comparator (U34) or no over current fault, the commutator pulse is supplied when the next clock pulse acts on U8 to transfer the low at pin 10 to pin 15, which will make the output of U6 (pin 11) and U7 (pin 4) go low to fire the commutator one shot multi-vibrator (M.V.)

During normal regulation cycles the commutator pulse is placed between the early and late limits by comparing an error or reference signal (some DC level between 0 and -10 V, with a positively ramping voltage of between about .2 and + 11V. At the point in the time that the absolute value of the two are equal at U34, pin 3's output goes low and causes U6, pin 10, to go low. Since U6 pin 11 was high from the action of TRIG setting U8 pin 15 high, the resulting negative going waveform changes the state of U7 pin 4 and fires the commutator one shot m.v. The voltage ramp for the comparator input is initiated by an inverted "TRIG" signal driving the pin 1, 2, and 3 transistors of U38 to saturation and discharging C70, which is then allowed to recharge with a constant current source composed of U39 and the remaining transistors of U30 and U39. This ramp is linear when points A and B are connected but may be (by connecting A to C) instantaneously changed with an input (FEED FWD) from the chopper power supply voltage. This change pre-compensated the commutator pulse so that the feed-back loop does not have to respond to the resulting change of magnet current caused by power supply voltage variation.

**44. Disconnect P2 and connect test plug A. Connect yellow lead of the test plug to pin 23 of P1. Connect the black lead of the test plug to the board ground. This is the lead referred to as "Clip Lead" in the following text. Restore power to board.

**45. Monitor pin 1 of U 18, it should be low when the "Clip lead" is attached and high when not. Now monitor pin 11 of U18, it will be high with the clip connected and low when not.

**46. Switch mode to "DAC REF" and monitor pin 60 of P1,U18 pin 16, connect the "Clip Lead" to the resistor as in step 45, pin 60 will be low. Switch the mode to "ERR" while monitoring pin 60, it will remain low until the "Clip Lead" is momentarily removed, and when reconnected will go high.

Data is shifted to the output of U18 when U14 is clocked high on pin 10 or 11, data is held and accessible while those pins are low.

**47. Monitor pin 59 of P1,U18 pin 9, it will be low. Switch mode to "EXT ERR" and momentarily disconnect "Clip Lead" as in step 46, pin 59 will now be high.

**48. Monitor pin 61,U18 pin 15, it will be low. Switch mode to "LOC" and momentarily disconnect the "Clip Lead", pin 61 will now be high.

**49. Monitor pin 62, U18 pin 12, it will be low. Switch mode to "EXT ERR" and momentarily disconnect the "Clip Lead", pin 62 will now be high.

**50. Monitor pins 57 and 58,U18 pin 5 and pin 6 respectively, push "RESET" and confirm that the "OC" and "GL" lights are out.

Momentarily disconnect the "Clip Lead" and both pins will now be high.

**51. Connect the 10 volt power supply to the gray leads on test plug A (Black is positive) to momentarily trip the "CC" and "GL" lights on. Now momentarily disconnect the Black "Clip Lead" while monitoring pins 57 and 58,U18 pin 5 and pin 6, the pins will now both be low.

Disconnect power to the board, then install or check for a wire from E46 to P2-16.

**52. Remove test plug A completely. Reconnect P2. Jumper point F to point D (both near U35) check to see if E is already wired to D and if so, remove wire at E and move to F. Restore power to board, then switch the mode switch to "LOC" and check U39 "ERROR BUF" for unity gain and inversion with the "LOCAL" pot. Check pins A and B of the "BUFF ERROR" receptacle (COS02, J7) for the same positive output as monitored at the output of U39 (E36), use an isolated voltmeter; pin A will be positive.

**53. Move the plug from the "XDUCTR" receptical,(COS02, J9), and connect it to the "FEED FWD" receptical,(COS02, J8). With the supply connected and set to +10V, check with an isolated voltmeter at E40 and E41 for the same voltage; E40 will be positive.

**54. Remove the extender. Install the controller board in position 2 of the bin and restore power.

**55. Enable the board by repeating step 29, also push reset.

**56. Run a 20' or longer RG58 (or equivalent impedance) cable to COS02 J1 and terminate the line with a 50 ohm load teeing off to the scope input. Observe each of the outputs J1 thru J4 to be a minimum of 35 V Peak 10 +/- 1.5 micro second wide at the 40 V level, with a rise time of 200 nano-seconds.