Cushman CE-6A
100 Hz Loop Alignment Instructions

Equipment Required:

1. Frequency Counter: 1 part in 10^6 accuracy minimum.
2. Digital Volt Meter
3. Dual Trace Oscilloscope: 100 MHz Bandwidth; Tektronix 465 or equivalent.
   10X probes (two required). All measurements DC coupled.
   Volts and time / div adjusted as convenient for required display.
4. Regulated DC Power Supply: High Stability
5. High-Resolution Voltage Divider (see attached schematic).

Procedure:

Note: The cause of many difficulties that manifest themselves as a failure of the 100 Hz loop to lock can be found in a drift of the resonant frequency of the 100 Hz loop filter (Figure 6-29 on pages 6-127 / 6-128 of the Cushman manual). This drift is usually the result of aging of the carbon composition resistors found in this circuit. Before alignment is attempted, it is suggested that the following resistors be replaced with modern 1% film resistors: R1, R3 R4, R6, R8, R9, R11 and R17. Please also note that many of these parts have different values than those on the schematic owing to an undocumented engineering change. Please refer to the attached spread sheet for a table of current values for these parts.

I. Break the loop.

   A. With the instrument on its side, remove the bottom cover and then remove the 4300 board using the provided board extraction tool.

   B. On the 4300 board, disconnect R55, 13K from the junction with R28, R29 and R37. Connect a short length of wire to this junction point (hereinafter referred to as the summing point) and lead it off the board. This will be connected to the High Resolution Voltage Divider.

   C. Re-install the 4300 board.

II. Loop Filter alignment.

   A. Remove the 4500 board using the provided extraction tool and insert it into the provided extender card. Install the board / extender card combination back into its socket.

   B. Connect the high resolution voltage divider to the regulated power supply and the Cushman chassis (ground) as shown on the schematic. Energize the supply and adjust the output voltage to 4 volts. Then turn off the supply.

C. Connect the high resolution voltage divider output to the wire from the 4300 board.

D. Loosely couple the input of the frequency counter to L5 on the VCO. This can be done with a simple loop at the end of the coaxial input of the frequency counter laid on the 4300 board near L5.

E. Energize the Cushman and then the regulated power supply. With the DVM, confirm that there is 4 volts at the summing point; adjust the center pot on the High Resolution Voltage Divider to set to 4 volts if necessary.

F. Set the four lowest order switches of the Cushman frequency control to .5000 MHz. Allow the entire setup to warm up for at least 20 minutes before proceeding further.

G. Observe the frequency counter. Adjust the coupling loop as necessary to get a reliable reading. Check for 4 volts on the summing point; readjust the High Resolution Voltage Divider if necessary. Adjust L9 for 20.500 MHz on the counter. This reading need not be exact, and will walk around a bit, but should be within a KHz or two.

H. Connect channel one of the dual trace scope to TP4 on the 4500 board. Connect channel 2 of the dual trace scope to TP3 on the 4500 board. Trigger from channel one. Use DC coupling on both channels.

I. Set the High Resolution Voltage Divider for 20.510 MHz on the frequency counter. Adjust R10 on the 4500 board for maximum amplitude of the sine wave on channel one. Observe that there should be very narrow, fast rise time pulses visible on channel two. If not present, adjust R7 on the 4500 board so that the maximum amplitude peaks of the sine wave on TP4 are peaking about 1.5 volts above zero volts.

J. Lower the VCO frequency by adjusting the High Resolution Voltage Divider. Observe the pulses on TP 3. As the frequency is lowered, the output sine wave at TP4 will decrease in amplitude as the frequency falls further and further down the slope of the filter selectivity curve. Eventually this reduction in amplitude will cause the drop-out switch to activate, driving TP3 to a steady logic one (about 4 volts). Note the frequency at which this occurs.

Now, raise the VCO frequency by adjusting the High Resolution Voltage Divider. Note the frequency at which drop-out (TP3 to steady high) occurs. Ideally, the dropout points should be at 20.450 MHz on the low end and 20.550 MHz on the high end.

Adjusting R7 will change the separation between the high and low dropout points. Adjusting R10 will change the center point of the pass range (the frequency range where the pulses are not inhibited). The pass range should be roughly 100 KHz centered on 20.500 MHz. These values are not extremely critical, but it is desirable that they should be within +/- 5 KHz of the ideal figures. You will find them somewhat difficult to set exactly owing to frequency drift of the unlocked VCO.

K. Turn off the DC supply and then the Cushman in that order. Remove the 4500 board from the extender card and return it to its normal position in the instrument. This completes the loop filter alignment.

III. VCO Alignment

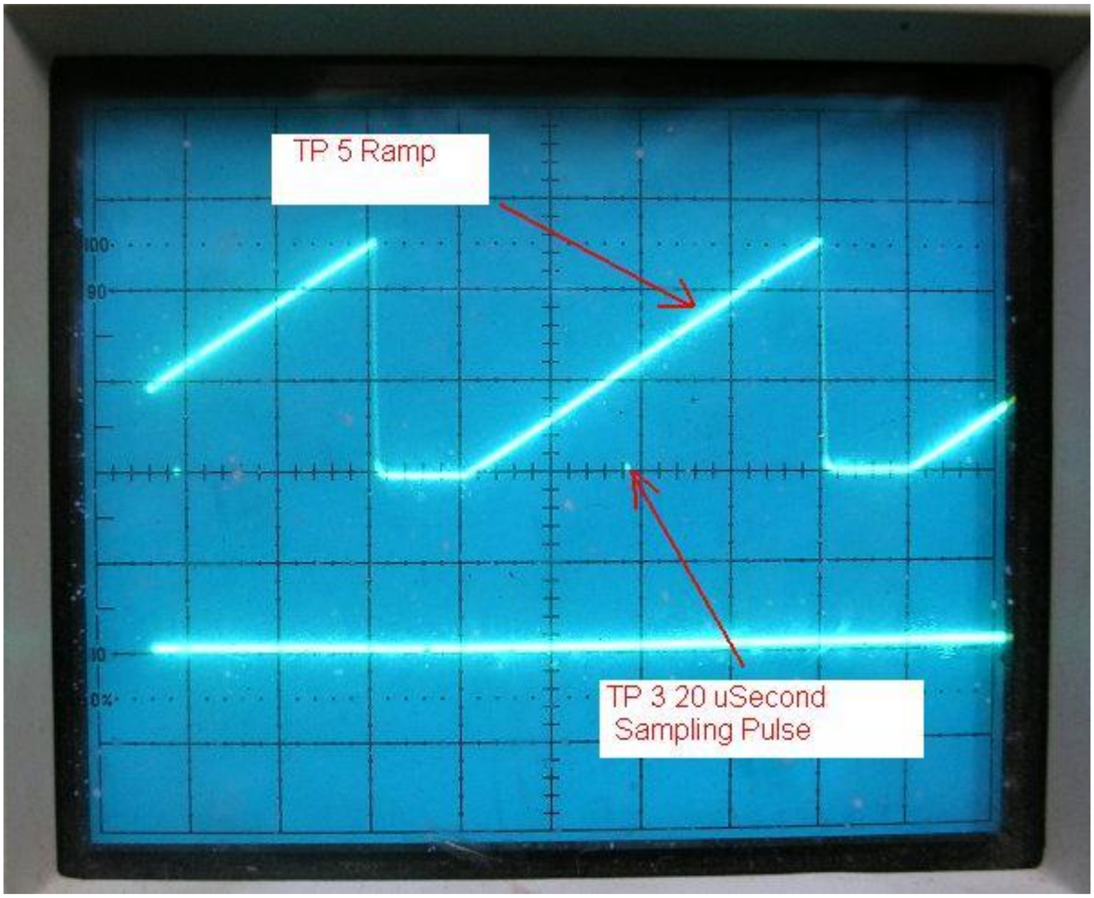
A. Be certain that step II (Loop Filter Alignment) has been performed prior to attempting VCO alignment. Be sure that the instrument is powered off.

B. Remove the 4300 Board from the instrument and extend it on the extender card. Connect the wire soldered to the summing point in step I above to the plus lead of the DVM. Connect the minus lead of the DVM to the Cushman chassis. Couple the frequency counter loop to L9 on the 4300 board as before.

C. Energize the Cushman. Be certain that the four lowest order switches of the Cushman frequency control remain set to .5000 MHz. Allow the instrument to warm up for at least 20 minutes.

D. Adjust R23 for approximately 20.500 MHz on the frequency counter.

E. Power down the instrument and reconnect R55 to the summing point. Connect the dual trace oscilloscope to TP5 (channel one) and TP3 (channel 2). Trigger from channel one. Re-energize the instrument. At this point, the instrument should lock. A stable waveform picture should be presented on the oscilloscope as shown in the example below:



F. Adjust R26 and R52 so that the sampling pulse occurs in the center of the ramp i.e. at a point such that the voltage sampled at that point is midway between the voltages at the ends of the ramp. These adjustments do not appear to be very critical. They most closely resemble go / no-go adjustments. They also interact considerably. When R26 is properly adjusted, there is approximately 1 volt on the base of Q9. This voltage varies from around 890 millivolts to about 1.1 volts depending on the frequency selected on the front panel.

G. Operate the front panel .1 MHz switch to select from 0 to 9. Lock-up should occur within 1 to 2 seconds depending on whether you are going from 0 to 9 or 9 to 0. Be certain that lock occurs at .0000 MHz and 9999 MHz

H. Verify summing point voltages according to the following table. These will vary from instrument to instrument, but the ones given below are representative.

VCO Frequency	Summing Point Volts
20.000 MHz	2.081
20.500 MHz	3.146
20.900 MHz	4.457

I. De-energize the instrument and remove all test leads. Disconnect the wire from the summing point that was added in step I. Remove the 4300 board from the extender card and install it in its socket. Return the extender card and card extraction tool to their storage slot. Replace the bottom cover. This concludes the 100 Hz loop alignment.

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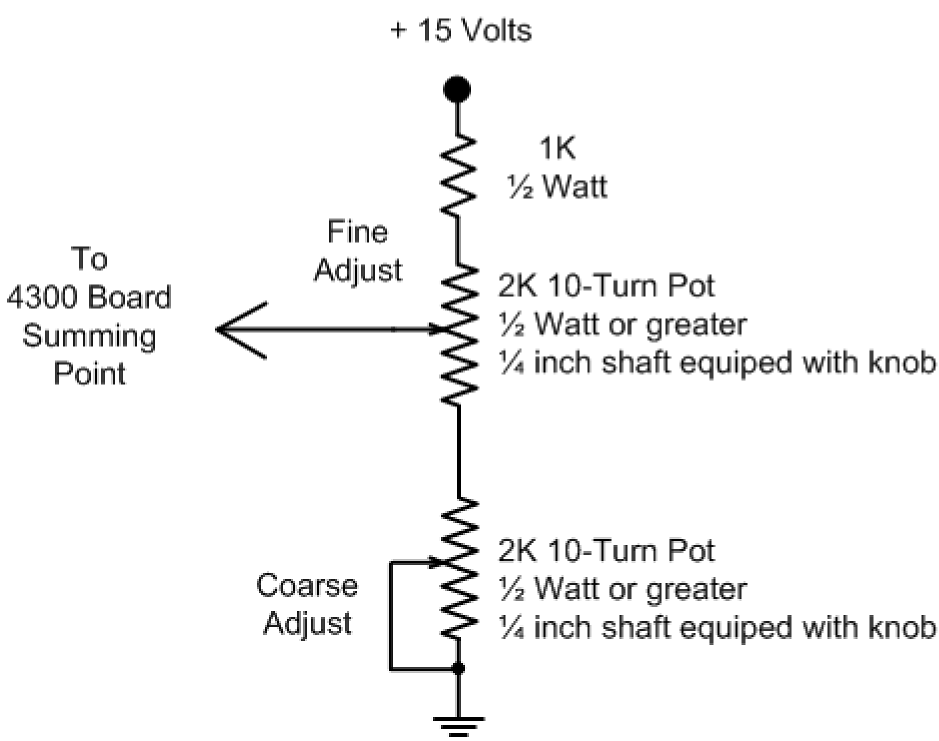
UNDOCUMENTED ENGINEERING CHANGES AND ERRORS IN LOOP FILTER CIRCUITRY ON 4500 BOARD			
CHANGES AND / OR ERRORS ARE NOTED IN RED			
SCHEMATIC	SCHEMATIC	PARTS LIST	AS BUILT
DESIGNATOR	VALUE	VALUE	VALUE
C32	1 uF	10 uF	10 uF
R3	47K	47K	43K
R6	1.5K	1.5K	1.3K
R9	100K	100K	130K
R17	120K	12K	12K



High Resolution
Voltage Divider