advanced computer controls, inc.

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(408) 749-8330

April 11, 1984

Dear Signal Conditioning Board Customer,

By now you have received your signal conditioning board kit. We opted to ship the board "short" a few parts so you could start reviewing the information packet and begin building the board.

We noted the parts that are missing on a "backorder slip" that was enclosed with your white invoice copy in an envelope on the outside of the original shipping box. In general, the parts that are missing are:

2 - 26 pin right angle headers
1 - 10 pf disc cap
9 - 1 uf 50V ele cap
1 - 4532
1 - MC3403
1 - 78L05

We've sent some of the parts listed above in the envelope accompanying this letter. Your new backorder slip is enclosed and should show the parts still due. If you were originally short a part that is not noted above, this too, should appear on the new B/O slip.

Also enclosed is a "bill of materials" list. Hopefully, this may be easier to read than the parts list that was originally included with the information packet.

Some people have called to ask about the .1 ohm sense resistors that are not included in the kit. We note the suggested value but this really depends on your application. They are generally available in retail electronics stores. You will probably be able to obtain them locally faster than we could by ordering them through a "high order quantity" distributor. (We have to deal with minimum order quantities, long lead times, etc.). As a matter of fact, if anyone has a good source of them maybe they could let me know so I can give the word to customers that have trouble finding them.

Please also note that one of the 14 pin header plugs and one of the 14 pin IC sockets will need to be cut in order to fit into the twelve pin space provided. (Ever wonder how we get a "six pin socket for the RC-850?)

I think this may answer some of your questions I apologize for not being more clear originally. Please be assured that just as soon as the backordered parts become available you will receive them. If there is anything else I can do, please call me or Tim Malm (our new customer service representitive).

73,

CATHERINE

Hello:

Just in case you didn't notice (yet), the silk screen designations for the voltage regulators Q1 and Q2 are backwards. Simply install them turned around from what you would expect. If you've already blown something up, let us know and we'll replace it for you.

73
Ed

Signal Conditioning Board Documentation

Introduction

The Advanced Computer Controls Signal Conditioning board is a general purpose accessory board for use with the RC-850 repeater controller. It provides the following functions:

- Various analog signal conditioning circuits to provide input to the fourteen undedicated "talking meters" on the RC-850 Voice Response Telemetry board.
- Priority encoder to allow automatic selection of courtesy tones based on signal strength, frequency error and supply voltage source.
- Dial tone detector for use with the autopatch.
- VOX comparator for VOX access.

The analog signal conditioning circuits include a noise filter and rectifier to measure quieting, filters and amplifiers to measure frequency error, three high accuracy temperature sensors, two current sensors, four voltage divider/buffer circuits to scale signals down, five amplifier/buffer circuits to scale signals up, and two accurate voltage dividers for direct voltage measurement.

Because of the versatility and generality of this board and its "add-on" nature, quite a bit of configuring is required to set up a fully functioning measurement system. However, a minimum set-up is quite simple. Note that the board provides twenty signal conditioning circuits for the fourteen analog input channels to allow flexibility in the types of signals and meters used.

Installation

The signal conditioning board should be assembled by refering to the parts list, schematic diagram and component numbering on the board itself. Electrically, it is connected in-line in the analog input cable between the Voice Response Telemetry board and the analog input connector. It may be mounted either in the cabinet on top of the VRT board or outside of the cabinet for easier configuration changes. Note that several of the signals on the analog connector have been redefined as shown in Table I. In addition, any of the analog channel pins on the connector may be configured, through the jumper sets H1 and H2, to connect to any of the analog channels and may be reassigned very easily.

The only necessary modification to the existing repeater controller is to get +12 volts to the board via pin 1 of J2.

This can be done most easily by connecting a jumper between pin 1 of J2 on the VRT board (which connects to pin 1 of J2 on the signal conditioning board) and the +12 volt supply at the positive side of C20 on the VRT board.

For VOX operation, pin 1 of J3 (the pin closest to the connectors) must be connected to pin 1 of U17 on the main controller board. For operation of the dial tone detector, pin 2 of J3 must be connected to pin 7 of U5 on the phone board. These connections may be made with thin pieces of wire tack-soldered in place. With the board installed, the autopatch will wait for a dial tone before dialing, thus if this connection is not made the autopatch will never dial the telephone. This can be circumvented by not installing U1 and R4 on the signal conditioning board.

For the courtesy tone selection to work on power supply failure, pin 3 of J3 must be connected to the normal power supply (as oppposed to the backup supply) before the diode, i.e. at the banana jack on the back panel of the RC-850. For the courtesy tone selection to work at all, the UT outputs of the signal conditioning board (pins 5, 7 and 11 of J2) must be connected to the UT inputs on the digital connector of the main controller board (pins 2, 1 and 14).

Configuration

The main configuration required for the signal conditioning board to function is the connection of the appropriate jumpers in the jumper sets H1 and H2. The jumper connections can be made with wire-wrap or with jumpers made from any connectors which will fit over standard wire-wrap pins.

Using Tables I and II, a pin to pin jumper list can be created. For example, to connect a high accuracy temperature meter to channel 13 and the sensor for the meter to analog connector pin 3, we would connect a jumper from H1 pin 3 to pin 32 and another from H2 pin 7 to pin 34. Note that, at most, there will be fourteen jumpers in each set so some pins will be left empty.

Some of the connections to the sensors require special considerations. Note that the noise and frequency error circuits have the same input. This input should be connected directly to the discriminator output of the repeater receiver (or any other receiver for that matter, however the input must be taken before any filtering). The temperature sensor transistors are connected between the circuit input and ground as shown in Figure 1. The current sensor resistors are connected in line with with the positive side of any power supply as shown in Figure 2. The lower voltage side of the resistors are connected to one or the other of the current return lines (pins 9 and 13). The board relies on DC signal strength and DC deviation signals from the receiver and the general scaling circuits can be used to implement these meters by connecting the signals appropriately. Note that a deviation signal may be created from the discriminator output signal by means of the circuit shown in Figure 3.

The selectable resistors (R80-92) are chosen to provide the appropriate gain adjustment range for the various amplifier circuits. Their functions are tabulated in Table 3. Refer to the operational amplifier tutorial section for information on setting the gain of op amps. Jumper JU1 is set according to the discriminator output of the repeater receiver. If the DC level of the discriminator increases for a frequency above the center frequency, the jumper should be between the two pins closest to the connectors (pins A and B). If the output is inverted, the jumper should be between pins B and C (closest to the potentiometers).

After the board is configured, it is suggested that it be tested as fully as possible before it is installed at the repeater site, by simulating input signals and observing the outputs.

Adjustment

Table IV lists the functions of each of the potentionmeters. The general scaling pots should be adjusted until the meter reads correctly. This includes the pots in the temperature and current sensor circuits. All of these adjustments are really just calibrations of the meters. Note that R102 and 103 in the current sensor circuits are zero-adjustment pots, while R100 and 101 are the scale calibration pots. R117 adjusts the dial tone detector and should be set so that pin 8 of U1 is low when a dial tone is present. A middle range setting should be found to ensure reliable detection. R93 and 94 set the allowable frequency error window for the courtesy tone selection and R95 and 96 set the signal strength levels for the courtesy tone selection. These pots should be adjusted so that a strong, centered signal selects tone number one. A scope or voltmeter should be used to adjust the threshold levels relative to the signals available from the receiver. The exact levels for selection is up to the operator and will depend on the environment in which the repeater is used and the variety of equipment of its users.

Many of the specific metering applications have been discussed in the **Metering Notes** sections of past issues of **ACC Notes.** These notes are reproduced here for easy reference along with a tutorial on opertational amplifiers.

<u>METERING NOTES: TEMPERATURE SENSORS</u>. The RC-850 controller allows placing temperature sensors at various places at the site to allow remote synthesized speech readback of temperature. Points of interest might be outside temp, temp inside the building, PA heatsink temp, temp inside the cabinet, etc.

Temperature metering is based on the National LM335 Precision Temperature Sensor. The LM335 is electrically like a zener diode, with a precision temperature/voltage characteristic. The simplest hookup is with a resistor to a voltage source, to provide current flow through the sensor. The voltage developed across the sensor represents the temperature, with a change of about 5 mV per degree F.

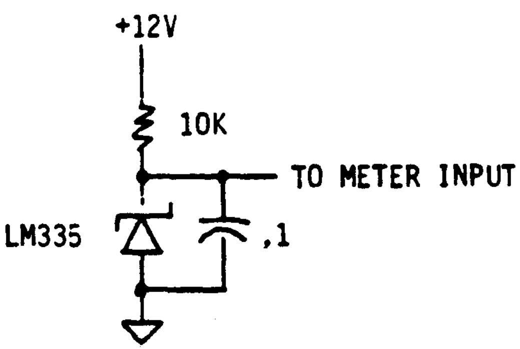
Addition of an op amp circuit can increase the level of signal available, making possible a higher accuracy reading with less resolution required in the measurement circuitry.

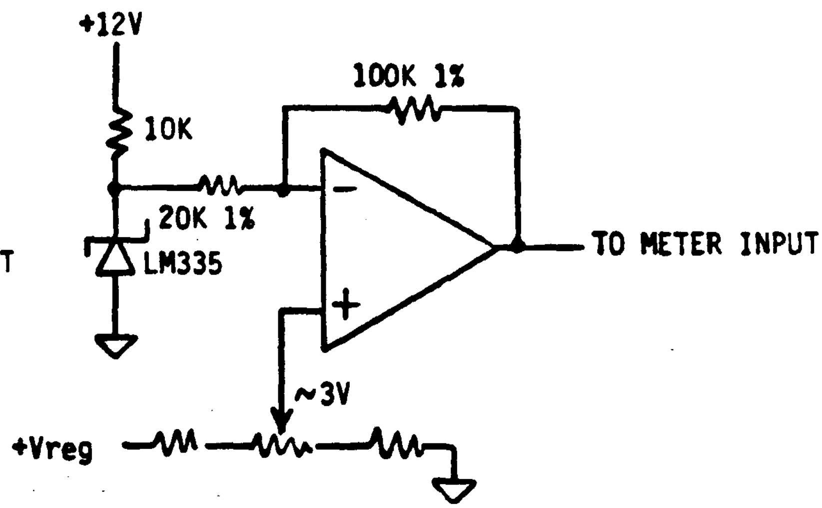
The RC-850 controller includes two temperature meter faces, which match the two circuits below. Either of the meter faces can be assigned to any or all of the analog input channels. Assign the Temperature or High Accuracy Temperature meter faces to the appropriate channels using the Meter Face Assignment configuration commands. Temperature can then be read back with user commands (VRT prefix)(channel#). If the VRT prefix is 8, and temperature sensors are on channels 8, 9, and 10, then commands 88, 89, and 810 read back the temperature in degrees F with synthesized speech.

A built-in sensor on the VRT board in the simple circuit configuration allows readback of internal temperature on channel 15.

The LM335 is available in a plastic (LM335Z) and metal (LM335H) transistor package. If sensing the temperature of a heat sink, the metal package is better because it is easier to thermally couple.

The LM335Z is available from Jameco (415)592-8097, and Digikey (800)346-5144 for about $1.50.



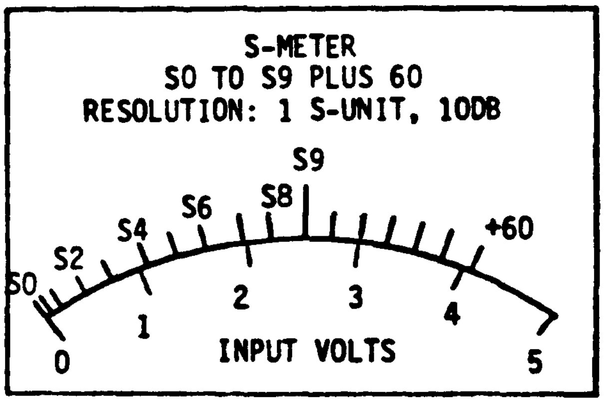


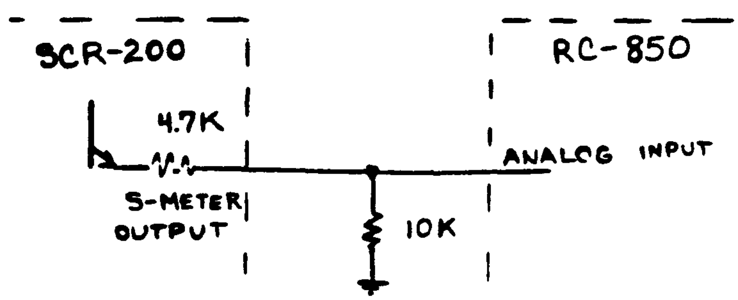
METERING NOTES: S-METER. The RC-850 controller allows users to read back meter readings in synthesized speech. One of the meters which can be read is the receiver's S-meter, allowing users to check their signal strength into the repeater.

An S-meter signal voltage from the receiver can be applied to one of the controller's 16 analog inputs. The S-meter meter face can be assigned to the input selected, so that readback of that channel is in S-units. The S-meter signal is measured by the controller approximately one second into each user transmission. The measured value is stored in memory, and if the user requests an S-meter reading, the stored value is read back in S-units.

The meter voltage should be scaled to match the 0-5 volt input range of the controller. If the voltage is too high, it can be scaled down with two resistors as a voltage divider. If it is too low, it can be amplified with a simple op amp circuit.

The controller's analog inputs should be driven by an impedance of less than about 10K. As an example, the Spectrum SCR200 receiver S-meter output (which has a resistor in series) can connect directly to the controller's input, with a 10K resistor to ground.





METERING NOTES - POWER. The RC-850 Repeater Controller is available with synthesized speech "Talking Meters". Up to 16 meters can be read remotely, over the air or over the phone, in response to Touch-Tone commands. "Meter Faces" defined in the software for different types of measurements may be assigned to each analog input, so readback is in appropriate measurement units.

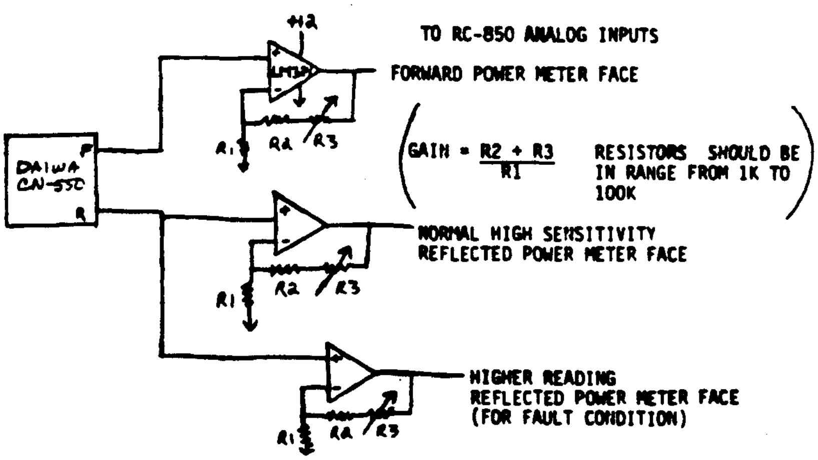
Five meter faces are available for power, with full scale values of 8, 16, 32, 64, and 128 watts. Resolution of readback is one watt. Remote readback of RF power from the repeater site helps diagnose system problems, such as transmitter, power amp, feedline, or antenna difficulties before going to the site, so that you can go prepared. It also permits you to evaluate SWR during different weather conditions, and so on. You can monitor the repeater's transmitter, link transmitters, and other RF equipment at the site.

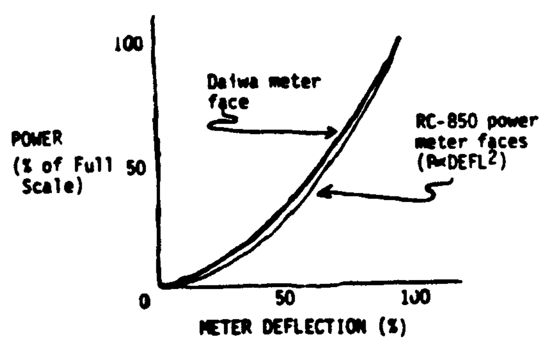
Power is different than other types of measurements in that meter deflection is not linearly proportional to power level. The scale is expanded out at the low end, and crowded in at the high end. This is largely due to the fact that power is proportional to voltage or current squared. There are other non-linearities in the meter's sensing circuits which contribute additional non-linearities in the scale.

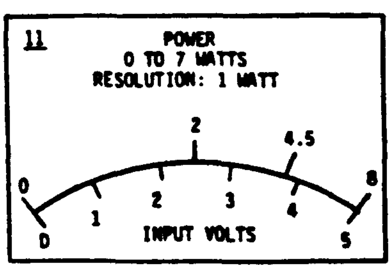
The power meter faces in the RC-850 Controller are based on a power proportional to voltage squared relationship. The figure below shows the curve of power versus meter deflection with the 850's meter face, and a Daiwa CN-550 wattmeter as an example. The match is sufficient to allow valuable power readings, accurate to a few percent, allowing monitoring of system performance. Remember that 1 db error is 26%.

As an actual interface example, we'll show how to interface the CN-550 140-250 MHz dual needle meter to the RC-850 Controller. The CN-550 has its sensor mounted in a shielded enclosure, with rectified dc output for forward and reflected power available at two feedthrough capacitors, which drive the meter movements through adjustable resistors. The dc voltages at the feedthroughs can be tapped to drive op amp circuits to increase the levels to match one or more of the power meter faces.

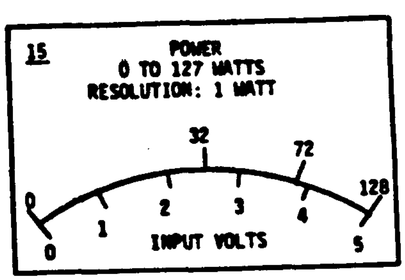
Resistors are selected based on the power level of your system to provide 0-5 volt dc levels to the controller's analog inputs, and should be adjusted for accurate reading at the normal power level. You might want to drive two different meter inputs for reflected power, to allow accurate readback of both normal (small) reflected power, and a higher full scale face in case of antenna problem, without causing the reflected power meter face to "pin".







APPLICATIONS:
REPEATER FORWARD AND REFL. POWER
LINK FORWARD AND REFL. POWER



APPLICATIONS:
REPEATER FORWARD AND REFL. POWER
LINK FORWARD AND REFL. POWER

METERING NOTES- QUIETING. The RC-850 Repeater Controller has the ability to read back in synthesized speech various meter readings from the repeater site. Readback is in response to Touch-Tone commands entered by users over the air or over the phone. Sixteen analog inputs may be measured, with readback in actual units appropriate for the measurement type.

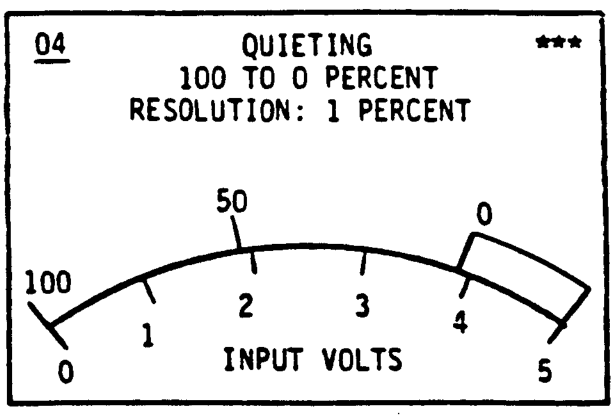
One of the controller's "meter faces" is for quieting, with readback as 0 to 100 percent, with a 1 percent resolution. Readback of quieting to users is valuable for checking how well one is getting into the repeater before making a patch, for comparing antennas, etc. Since quieting resolution is much greater than S-meter readback, particularly when it really matters, it can provide very sensitive readings for equipment comparisons.

When no signal is present, the FM receiver discriminator contains broad band audio noise. As a carrier present increases in strength, the level of the noise decreases until the receiver is fully "quieted". Measuring the level of noise present on a signal gives the degree of quieting.

Since the discriminator contains the intended base band audio signal as well as some level of broad band noise when a signal is present, a quieting measurement circuit should filter only relatively high frequency noise so it isn't fooled by voice audio. The filtered noise can then be rectified to form a dc voltage which may be measured by the RC-850 controller to read back quieting. Since a noise filter/rectifier is a fundamental part of all noise operated squelch circuits, most of the circuitry may already be present in your receiver. It may only be necessary to boost the dc voltage to match the controller's 0-5 volt input range. Otherwise, the discriminator may directly drive a circuit [redacted] which provides band pass noise filtering, an "ideal" rectifier, and scaling circuit.

The controller's meter face, shown below, reads in inverse percent from 100 to 0. The actual measurement is made by the controller at one second into each new user transmission, so it's necessary to key down at least one second when requesting a quieting measurement readback.

Readback of quieting, as well as S-meter, frequency error, and deviation provide user signal diagnostics. Other meter readback provided by the RC-850 controller, such as voltage, current, power, wind speed/direction, and temperature permit remote monitoring of equipment and conditions at the repeater site.



APPLICATIONS:
REPEATER RECEIVER QUIETING
LINK RECEIVER QUIETING

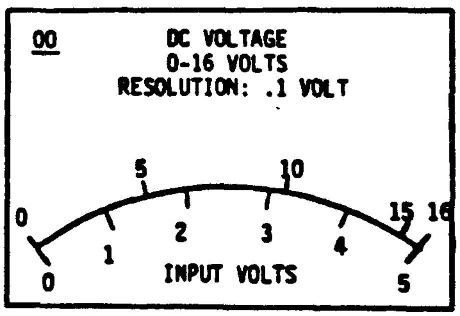
9/83

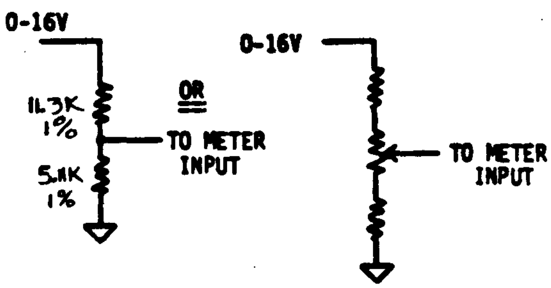
METERING NOTES - VOLTAGE AND CURRENT. The RC-850 controller allows its users to read back various meter readings from the repeater site. Readback is requested by Touch-Tone commands and is provided in synthesized speech. Two of the many meter types supported in Version 2 software are voltage and current.

The 850 controller's 16 analog input channels are capable of measuring 0-5 volt signals. The measurement is layed against the "template" assigned to that channel, and the readback is made in appropriate measurement units. A meter face for 0-16 volts, and 0-16 amps are provided for voltage and current measurement.

Scaling of voltage levels to match the 0-5 volt measurement range is easy - just a voltage divider composed of two resistors. Current is a little trickier, but still only involves an op amp and a few resistors. To provide a voltage proportional to current, a sensing resistor with a true differential, or instrumentation, amplifier is used. The output of the op amp is equal to the current times the sensing resistor, times the voltage gain of the amplifier. The value of the sense resistor that should be used depends on the maximum load current, since the voltage drop across the resistor reduces the voltage to the load. (Ideally, a power supply with remote sensing capability would be used, with the sense return after the sensing resistor. That way the voltage to the load would be independant of current.)

The four resistors around the op amp should be 1 or 2 % metal film types (these are available from RCA in bubble pack). Be sure that the common mode input voltage range of the op amp will accomodate the operating voltages that result from resistor/gain selection. For example, an LM324 or LM358 operating at +12 volts and ground will operate properly with input voltages between 0 and 10 volts (Input Common-Mode Voltage Range from data sheet). An example is shown below for measuring current drain from a repeater power supply.





APPLICATIONS:
SUPPLY VOLTAGE
BATTERY VOLTAGE
INTERNAL REGULATED VOLTAGES

10 WATT REPEATER

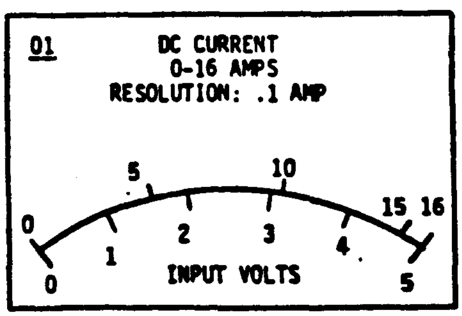
MAX CURRENT DRAW ≈ 3 AMPS

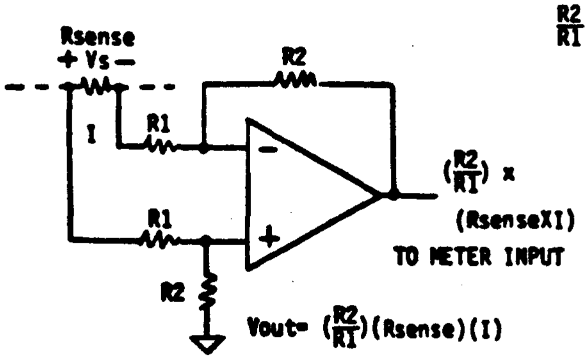
SELECT RSENSE = .1Ω, 5W

$V_{S\,MAX} = .3V$

GAIN NEEDED = $3.125 = \left(\frac{5}{16} \times \frac{1}{RSENSE}\right)$

$\frac{R2}{R1} = 3.125$ R2= 31.6K R1= 10.0K





APPLICATIONS:
REPEATER CURRENT DRAIN
XMTR/PA CURRENT DRAIN
BATTERY CHARGING CURRENT

Signal Conditioning Parts List

Resistors

#	Value	Notes	#	Value	Notes
R 1	10 K		R 59	100 K	1%
R 2	0	*	R 60	100 K	1%
R 3	None	*	R 61	10 K	
R 4	10 K		R 62	100 K	1%
R 5	10 K		R 63	100 K	1%
R 6	100 K		R 64	10 K	
R 7	10 K		R 65	20 K	1%
R 8	0 K	*	R 66	20 K	1%
R 9	10 K		R 67	10 K	1%
R 10	100 K		R 68	51 K	1%
R 11	10 K		R 69	10 K	1%
R 12	5.11 K	1%	R 70	100 K	
R 13	5.11 K	1%	R 71	10 K	1%
R 14	5.11 K	1%	R 72	100	
R 15	11.32 K	1%	R 73	10 K	1%
R 16	5.11 K	1%	R 74	22 K	1%
R 17	5.11 K	1%	R 75	25.5 K	1%
R 18	11.32 K	1%	R 76	100 K	
R 19	0 K	*	R 77	10 K	1%
R 20	100 K		R 78	821	1%
R 21	2.7 K		R 79	4.7 K	
R 22	0 K	*	R 80	Header	
R 23	100 K	1%	R 81	Header	
R 24	20 K	1%	R 82	Header	
R 25	0 K	*	R 83	Header	
R 26	100 K	1%	R 84	Header	
R 27	20 K	1%	R 85	Header	
R 28	0	*	R 86	Header	
R 29	10 K		R 87	Header	
R 30	0	*	R 88	Header	
R 31	10 K		R 89	Header	
R 32	95 K	1%	R 90	Header	
R 33	95 K	1%	R 91	Header	
R 34	10 K		R 92	Header	
R 35	20 K	1%	R 93	10 K	Pot.
R 36	50 K	1%	R 94	10 K	Pot.
R 37	100 K	1%	R 95	10 K	Pot.
R 38	50 K	1%	R 96	10 K	Pot.
R 39	100 K	1%	R 97	10 K	Pot.
R 40	50 K	1%	R 98	10 K	Pot.
R 41	100 K	1%	R 99	10 K	Pot.
R 42	50 K	1%	R100	10 K	Pot.
R 43	0	*	R101	10 K	Pot.
R 44	0	*	R102	10 K	Pot.
R 45	100		R103	10 K	Pot.
R 46	100		R104	10 K	Pot.
R 47	0	*	R105	10 K	Pot.
R 48	100		R106	10 K	Pot.
R 49	0	*	R107	10 K	Pot.
R 50	100		R108	10 K	Pot.
R 51	100		R109	10 K	Pot.
R 52	0	*	R110	10 K	Pot.
R 53	100		R111	10 K	Pot.
R 54	0	*	R112	10 K	Pot.
R 55	100		R113	10 K	Pot.
R 56	100		R114	10 K	Pot.
R 57	10 K		R115	10 K	Pot.
R 58	100		R116	10 K	Pot.
			R117	10 K	Pot.

Signal Conditioning Parts List

Capacitors

#	Value	Notes
C 1	0.1 mF	mono
C 2	1 mF	elec
C 3	1 mF	elec
C 4	2.2 mF	tant
C 5	0.47 mF	mylar
C 6	0.1 mF	mono
C 7	1 mF	elec
C 8	1 mF	elec
C 9	1 mF	elec
C10	0.1 mF	mono
C11	0.001 mF	disc
C12	0.001 mF	disc
C13	0.1 mF	mono
C14	0.01 mF	disc
C15	0.01 mF	disc
C16	0.01 mF	disc
C17	0.001 mF	disc
C18	0.1 mF	mono
C19	0.001 mF	disc
C20	0.001 mF	disc
C21	0.001 mF	disc
C22	0.001 mF	disc
C23	0.001 mF	disc
C24	0.001 mF	disc
C25	0.001 mF	disc
C26	0.1 mF	mono
C27	0.001 mF	disc
C28	0.001 mF	disc
C29	0.001 mF	disc
C30	1 mF	elec
C31	0.001 mF	disc
C32	0.001 mF	disc
C33	0.002 mF	mylar
C34	5 mF	elec
C35	10 pF	disc
C36	0.001 mF	disc
C37	0.1 mF	mono
C38	1 mF	elec
C39	1 mF	elec
C40	0.001 mF	*** 5%
C41	0.001 mF	*** 5%
C42	1 mF	elec
C43	0.01 mF	disc

IC's

#	Value	Notes
U 1	567	
U 2	LM339	
U 3	LM339	
U 4	4532	
U 5	LM324	
U 6	LM324	
U 7	LM324	
U 8	LM324	
U 9	MC3403	
U 10	LM324	

Miscellaneous

#	Value	Notes
Q 1	78L05	Regulator
Q 2	78L08	Regulator
CR 1	1N914	Diode
CR 2	1N914	Diode
JU 1	3 pin	Jumper
J 1	26 pin	Connector
J 2	26 pin	Connector
J 3	3 pin	Connector
H 1	34 pin	Jumper Block
H 2	36 pin	Jumper Block
2	.1 Ohm	Current Sense Res.
2	LM 335	Temperature Sensors

Notes:

- All 1% res. are metal film
- "0" resistance is a jumper
- * is a suggested value only
- Current sense resistors are precision, high wattage
- Metal film resistors should be used for all op amp gain circuit
- *** Any type of precision capacitor is fine

Table 1

Nominal Meter Face*	VRI Input Signal	VRI Conn or J2 Pin #	H2 Pin No.	H1 Pin No.	J1 Pin No.	Analog Conn Pin #	SC Board Input Signal+
S-Meter	Ana Ch # 1	14	11	7	14	7	Ana Chan
Discr.	Ana Ch # 2	18	13	9	18	9	Ana Chan
Devia.	Ana Ch # 3	22	15	11	22	11	Ana Chan
	Ana Ch # 4	26	18	14	26	13	Ana Chan
Pwr Fwd	Ana Ch # 5	16	12	8	16	8	Ana Chan
Pwr Rev	Ana Ch # 6	20	14	10	20	10	Ana Chan
Quieting	Ana Ch # 7	24	16	12	24	12	Ana Chan
Rel Pwr	Ana Ch # 8	25	17	13	25	25	Ana Chan
	Ana Ch # 9	2	5	1	2	1	Ana Chan
Rec Volts	Ana Ch # 10	4	6	2	4	2	Ana Chan
	Ana Ch # 11	8	8	4	8	4	Ana Chan
	Ana Ch # 12	12	10	6	12	6	Ana Chan
Temp.	Ana Ch # 13	6	7	3	6	3	Ana Chan
Temp.	Ana Ch # 14	10	9	5	10	5	Ana Chan
	Ana Ch # 15	(VRI internal)			–	–	Ana Chan
	Ana Ch # 16	(VRI internal)			–	–	Ana Chan
	A Ground	3			3	14	A Ground
	A Ground	5			5	15	UI 1
	DID	9			9	17	Cur Ret 1
	VOX	13			13	19	Cur Ret 2
	Alarm 1	15			15	20	Alarm 1
	Alarm 2	17			17	21	Alarm 2
	D Ground	7			7	16	UI 2
	+12 Volts	1			1	–	–
	Dig Input	11			11	18	UI 3
	Dig Input	19			19	22	Dig Input
	Dig Input	23			23	23	Dig Input
	Dig Input	21			21	24	Dig Input

* Note that these meter faces may be reassigned with configuration commands.

\+ These channel numbers may be assigned via jumper blocks H1 and H2.

Table II

Input H1 Pin #	Function	Output H2 Pin #
18	Freq Error	19
18	Quieting	20
19	Scale Down	27
20	Scale Up	24
21	Scale Up	22
22	Scale Up	29
23	Scale Down	26
24	Scale Down	23
25	Scale Down	21
26	Scale Up	28
27	Scale Up	25
28	Current 2	31
29	Current 1	30
30	Temperature	32
31	Temperature	33
32	Temperature	34
33	Voltage	35
34	Voltage	36

Table III

Selectable Resistor	Function
R 80	Current sensor 2 range select
R 81	Current sensor 1 range select
R 82	Scale down range select
R 83	Scale down range select
R 84	Scale down range select
R 85	Scale down range select
R 86	Scale up gain range select
R 87	Scale up gain range select
R 88	Scale up gain range select
R 89	Scale up gain range select
R 90	Scale up gain range select
R 91	Quieting range select
R 92	Frequency error range select

Table IV

Pot.	Function
R 93	Frequency error CT select upper window
R 94	Frequency error CT select lower window
R 95	Sigmal strength CT select upper threshold
R 96	Sigmal strength CT select lower threshold
R 97	Temperature sensor calibration
R 98	Temperature sensor calibration
R 99	Temperature sensor calibration
R 100	Current sensor 1 calibration
R 101	Current sensor 2 calibration
R 102	Current sensor 1 zero adjust
R 103	Current sensor 2 zero adjust
R 104	Scale down adjust
R 105	Scale down adjust
R 106	Scale down adjust
R 107	Scale down adjust
R 108	Scale up adjust
R 109	Scale up adjust
R 110	Scale up adjust
R 111	Scale up adjust
R 112	Scale up adjust
R 113	Quieting scale adjust
R 114	Quieting input adjust
R 115	Frequency error zero adjust
R 116	Frequency error scale adjust
R 117	Dial tone detector adjust

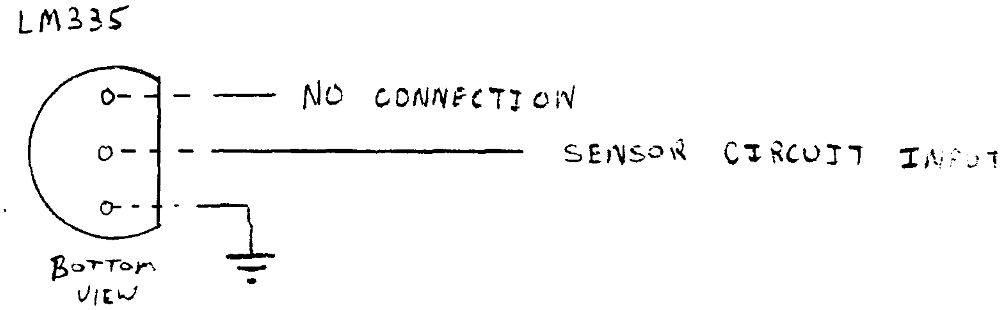


FIGURE 1

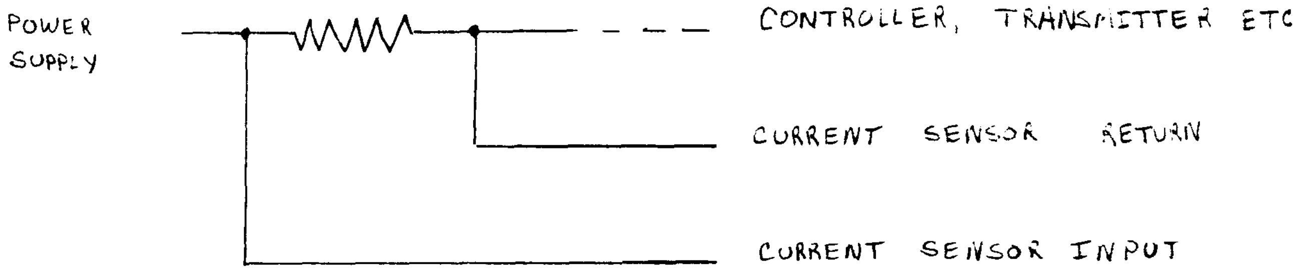


FIGURE 2

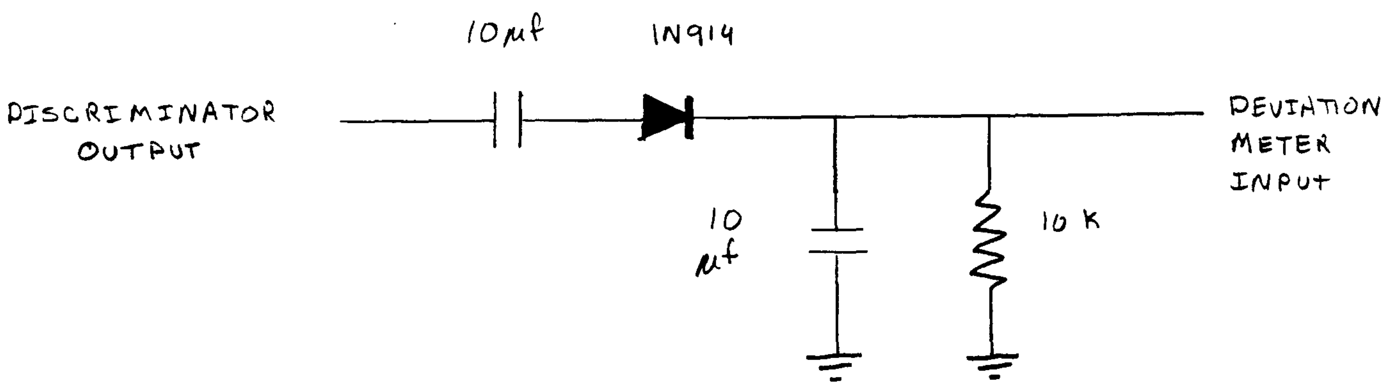


FIGURE 3

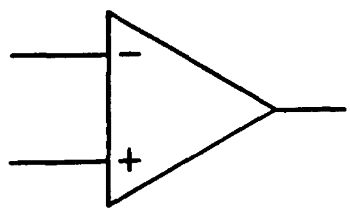
EVERYTHING YOU NEED TO KNOW ABOUT OP AMPS
(AT LEAST TO GET STARTED!)

Although op amps are the most common analog function block, they may seem like black magic until you understand a few simple principles. We'll try to summarize the basics of op amps here, and you should be an expert when you leave the page!

The important characteristics of op amps are:

1) Op amps have infinite gain
2) Op amps have infinite input impedance and draw no input current
3) Op amps have two inputs - inverting and non-inverting
4) Like everyone, op amps like to be happy - <u>not saturated</u>
5) To stay happy, the op amp would like the voltages at its inputs to be equal, and as circuit designers, we're willing to help (through feedback)

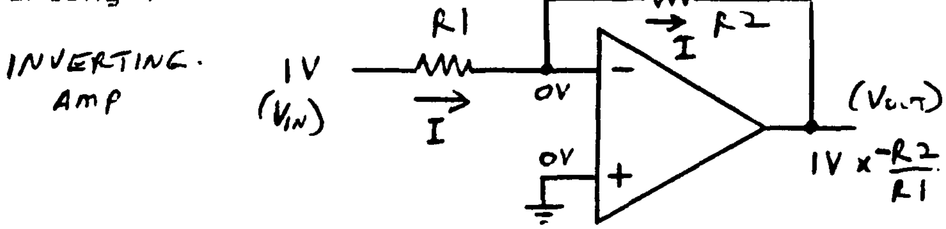
The basic op amp symbol is a triangle, with the inverting (-) and non-inverting (+) inputs on the left, and the output on the right. The op amp's basic goal in life is to be happy - to stay out of saturation. If the op amp saturates, or bangs its head against the the supply rails, it becomes useless in linear applications. Since it has (almost) infinite gain, the only way the output voltage won't be infinite is if the two inputs are at exactly the same voltage (almost infinity times zero is zero!).



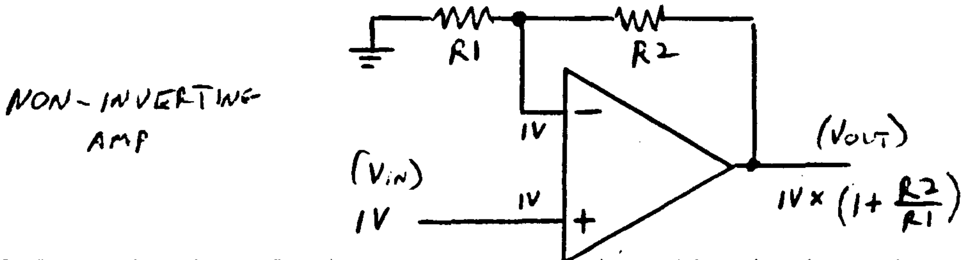
An op amp with feedback (output signal routed back around to the inverting input) keeps out of saturation through a concept called the "virtual ground". This simply means that negative feedback from the output to the inverting input forces the inverting input voltage to equal the non-inverting input voltage. In many applications, the non-inverting input is taken to ground, thus the name "virtual ground" for the inverting input.

If the inverting input voltage happens to be higher than ground, the output voltage drops, pulling the inverting input voltage back down towards ground. If it happened to be below ground, the output would rise, pulling the input up to ground. The point to remember is that if the op amp is happy (i.e. not in saturation and useful in a linear application), both inputs are held at exactly the same voltage by the negative feedback.

Now if we remember that no current flows into the op amp inputs, it's easy to understand how to calculate the gain of simple inverting and non-inverting amplifier circuits. If one volt is applied to R1 of the inverting amplifier, we know the current flowing through R1, since the other side of the resistor is at "virtual" ground - I = 1V/R1. Since no current flows into the op amp, it all must flow through R2, creating a voltage across R2 of R2 x 1V/R1. The gain, or Vout/Vin, is then -R2/R1. See why its negative, or "inverting"?

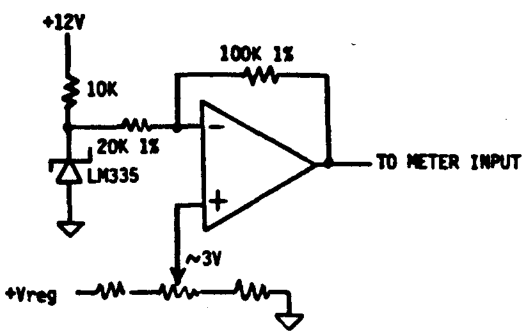


In the case of the non-inverting amplifier circuit, we apply the input signal directly to the non-inverting input of the op amp. Again, negative feedback forces the inverting input to be at the same voltage (although it's not ground), so we know the current through R1 - I = 1V/R1. Since no current flows into the op amp input, it all flows through R2, creating a voltage of 1V/R1 x R2. The output voltage is the voltage across R1 <u>plus</u> the voltage across R2. The gain, or Vout/Vin is therefore R1/R1+R2/R1, or 1+R2/R1. See why?



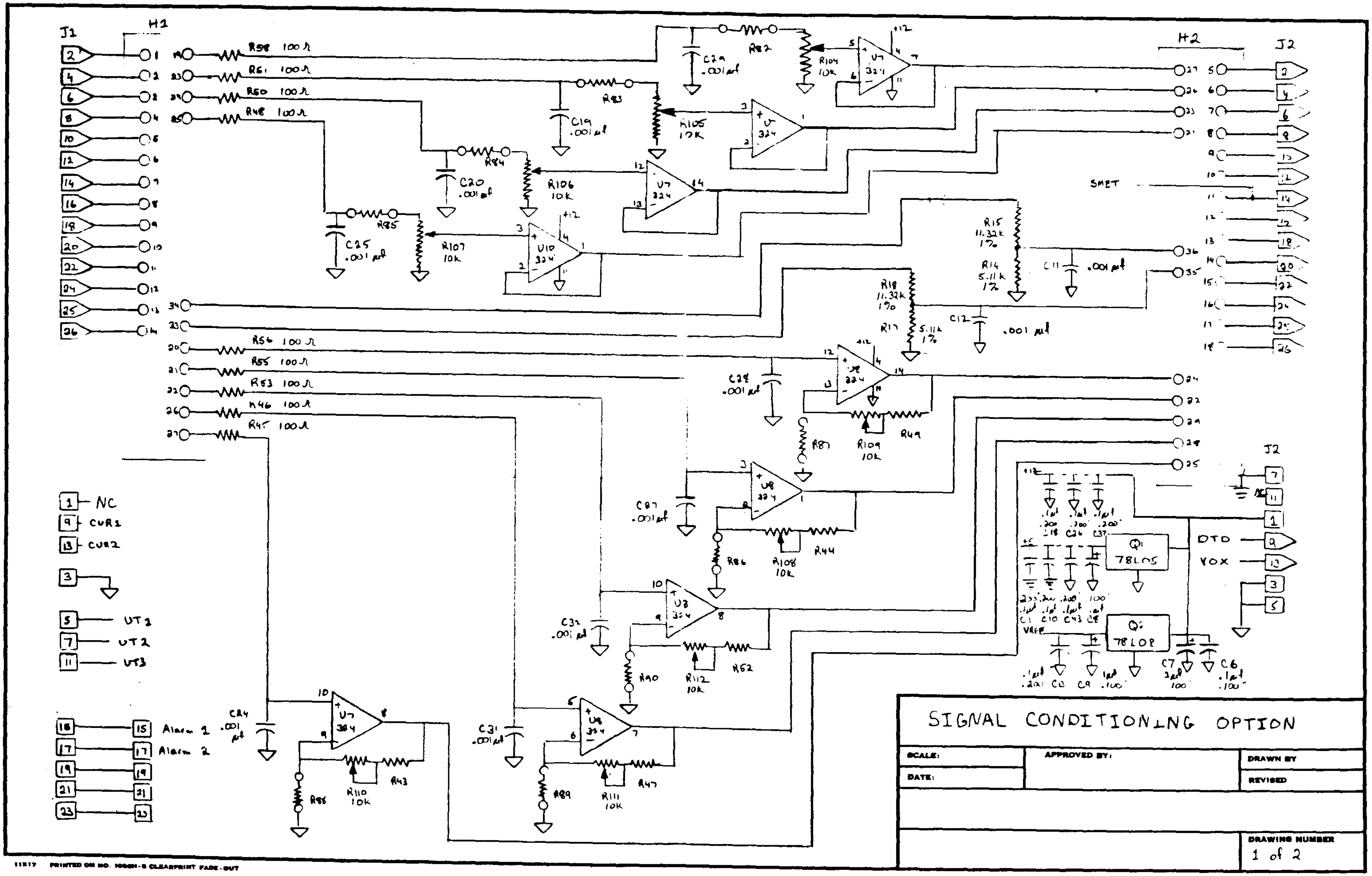
All analysis of linear op amp circuits is based on these principles. Feedback keeps the input voltages equal because of the op amp's infinite gain, and because no current flows into the op amp inputs.

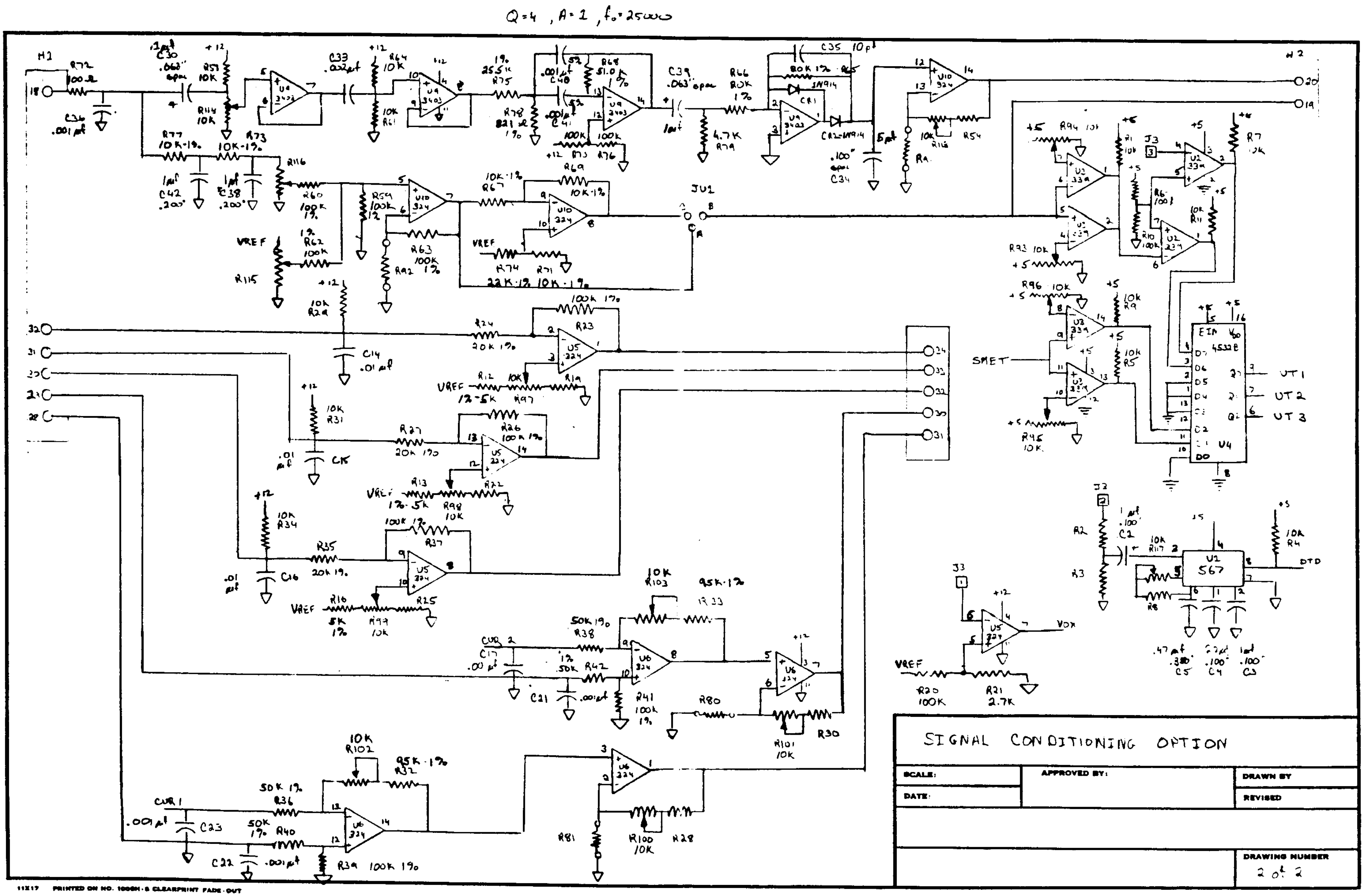
As one more example, we'll analyze the High Accuracy Temperature Sensor circuit. The LM335 temperature sensor and its 10K pullup resistor form a low impedance voltage source - the voltage at the junction is (relatively) independant of the load current drawn from the node. We know easily that the gain of the circuit is -5 (-100K/20K). The op amp inverting input (-) is not at ground, however - it's kept at the same voltage as the non-inverting (+) input by feedback. The effect is to offset the signal voltage from the LM335, as well as to invert and amplify it, in this application to match the High Accuracy Temperature Meter Face. Stable metal film, 1% resistors are recommended (except the 10K pullup) to keep the <u>circuit</u> stable over temperature.



Of course in the real world, nothing is perfect. The op amp's gain isn't really infinite but is very high - typically about a hundred thousand. And its inputs don't try to be exactly the same, but may be offset by a few millivolts. And the input current isn't really zero either, but might be a few microamps or so.

And inputs to the op amp must be within a certain voltage range. If a voltage at either input is outside the op amp's common mode input range, in other words too close to the supply rails, the op amp won't function properly.


J1
H1
H2
J2
R58 100 Ω
R61 100 Ω
R60 100 Ω
R48 100 Ω
R56 100 Ω
R55 100 Ω
R53 100 Ω
R46 100 Ω
R45 100 Ω
C29 .001 µf
R82
R104 10K
U7 324
C19 .001 µf
R83
R105 10K
C20 .001 µf
R84
R106 10K
C25 .001 µf
R85
R107 10K
U10 324
SMET
R15 11.32k 1%
R14 5.11k 1%
C11 .001 µf
R18 11.32k 1%
R17 5.11k 1%
C12 .001 µf
C28 .001 µf
R87
R109 10K
R49
C27 .001 µf
U8 324
R86
R108 10K
R44
C32 .001 µf
R90
R112 10K
R52
C31 .001 µf
R89
R111 10K
R47
C24 .001 µf
R88
R110 10K
R43
Q1 78L05
Q2 78L08
DTD
VOX
VREF
C7 3µf 100
C6 .1µf .100
NC
CUR1
CUR2
UT1
UT2
UT3
Alarm 1
Alarm 2
SIGNAL CONDITIONING OPTION
SCALE:
APPROVED BY:
DRAWN BY
DATE:
REVISED
DRAWING NUMBER
1 of 2


Q=4, A=1, f0=2500
SIGNAL CONDITIONING OPTION
SCALE:
DATE:
APPROVED BY:
DRAWN BY
REVISED
DRAWING NUMBER
2 of 2
VREF
SMET
UT1
UT2
UT3
VOX
DTD
JU1
U4 4532B
U1 567
11X17 PRINTED ON NO. 1000H-8 CLEARPRINT FADE-OUT

acc advanced computer controls, inc.

SIGNAL CONDITIONING BOARD

CORRECTED =COPY=

3/14/84

PAGE 1 OF 2

BILL OF MATERIAL

P/N ______________ REV ___

ITEM	DESCRIPTION	REF. DES.	PART NO.	QUANTITY PER OPTION 0	1	2	3	4	5	6	7	CODE IDENT.
1	10K 10TURN POT	R93, R94, R95, R96, R97	PT-10K 10TURN									
2		R98, R99, R100, R101, R102										
3		R103, R104, R105, R106, R107										
4		R108, R109, R110, R111, R112										
5		R113, R114, R115, R116, R117		25								
6												
7	100Ω 1/4W 5% RES	R45, R46, R48, R50, R51,	RS-100Ω 1/4W 5%									
8		R53, R55, R56, R58, R72		10								
9	2.7K 1/4W 5% RES	R21	RS-2.7K 1/4W 5%	1								
10	4.7K 1/4W 5% "	R79	RS-4.7K 1/4W 5%	1								
11	10K 1/4W 5% "	R1, R4, R5, R7, R9, R11	RS-10K 1/4W 5%	—								
12		R29, R31, R34, R57, R61		—								
13		R64,		12								
14	100K 1/4W 5% RES	R6, R10, R20, R70, R76	RS-100K 1/4W 5%	5								
15				—								
16	5.11K 1/8W 1% RES	R12, R13, R14, R16, R17	RS-5.1K 1/8W 1%	5								
17	11.32K 1/8W 1% "	R15, R18,	RS-11K 1/8W 1%	2								
18	20K 1/8W 1% "	R24, R27, R35, R65, R66	RS-20K 1/8W 1%	5								
19	22.1K 1/8W 1% "	R74	RS-22K 1/8W 1%	1								
20	25.5K 1/8W 1% "	R75	RS-25K 1/8W 1%	1								
21	51.1K 1/8W 1% "	R36, R38, R40, R42, R68	RS-51K 1/8W 1%	5								
22	95.3K 1/8W 1% "	R32, R33	RS-95K 1/8W 1%	2								
23	100K 1/8W 1% "	R23, R26, R37, R39, R41	RS-100K 1/8W 1%	—								
24		R59, R60, R62, R63		9								
25	825Ω 1/8W 1% RES	R78	RS-825Ω 1/8W 1%	1								
26	10K 1/8W 1% "	R67, R69, R71, R73, R77	RS-10K 1/8W 1%	5								
27												
28	JUMPER (CUSTOMER	R2, R8, R19, R22, R25,	NON-STOCK									
29	PROVIDED)	R28, R30, R43, R44,										
30		R47, R49, R52, R54										
31		R3 - BLANK										
32												
33	14 PIN CARRIERS	R80 to R86, R87 to R92	IS-14 PIN HP	2	cut one to fit / see also 14 pin socket							
34												
35	IN-LINE PINS (36 pins in a set)	H1, H2	AP PRODUCTS 929834-01	2 sets of 36 pins								
36	TIN		CN-SHRT/TIN/BLK									
37	26 pin R/A HEADER	J1, J2 mount on	ANSLEY-609-2602M	2								
38		component side	CN-26PIN HDR-R									
39	26 pin jumper cable	exterior of board	CA-PD037	1								
40												

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SIGNAL CONDITIONING BOARD

Corrected copy

BILL OF MATERIAL P/N ______________ REV ___

ITEM	DESCRIPTION	REF. DES.	PART NO.	QUANTITY PER OPTION 0	1	2	3	4	5	6	7	CODE IDENT.
1	10pf DISC CAP	C35	CP-10pf DSC	1								
2	.001uf DISC "	C11, C12, C17, C19, C20,	CP-.001uf DSC	—								
3		C21, C22, C23, C24, C25,		—								
4		C27, C28, C29, C31, C32,		—								
5		C36		16								
6	.0022uf MYL CAP	C33	CP-.0022uf MYL	1								
7		okay alternate	CP-.0027uf MYL	—								
8	.001uf 5% CAP	C40, C41	CP-.001uf 5%	2								
9	.01uf DISC CAP	C14, C15, C16, C43	CP-.01uf DSC	4								
10	.1uf MONO "	C1, C6, C10, C13, C18, C26,	CP-.1uf MNO	—								
11		C37		7								
12	.47uf MYL CAP	C5	CP-.47uf MYL	1								
13	1uf ELE CAP	C2, C3, C7, C8, C9, C30,	CP-1uf ELE	—								
14		C38, C39, C42	tant's okay cross	9								
15	2.2uf TAN CAP	C4	CP-2.2uf TAN	1								
16	4.7uf ELE "	C34	CP-4.7uf ELE	1								
17												
18	14 PIN IC SOCKET	U2, U3, U5, U6, U7, U8, U9,	IS-14 PIN									
19		U10, REF-R80-R86 & R87-R92	*	10	cut one to fit							
20	8 PIN IC SOCKET	U1	IS-08 PIN	1								
21	16 PIN IC SOCKET	U4	IS-16 PIN	1								
22												
23	NE567	U1	IC-NE567	1								
24	LM339	U2, U3	IC-LM339	2								
25	4532	U4	IC-4532	1								
26	LM324	U5, U6, U7, U8, U10	IC-LM324	5								
27	MC3403	U9	IC-MC3403	1								
28												
29	78L05 REGULATOR	Q1	IC-78L05	1								
30	78L08 REGULATOR	Q2	IC-78L08	1								
31												
32	1N914 DIODE	CR1, CR2	DD-1N914	2								
33												
34	LM335	external of board	IC-LM335	3								
35	.1 Ω SENSE RES.	external of board -	NON-STOCK									
36		customer supplied										
37												
38	PCB		PC-R43011-A	1								
39	IN-LINE PINS (set of 3)	J3, JU1	CN-LONG/GLD/RD	2 sets of 3								
40												