ANALOG DEVICES

Four-Channel, Isolated Thermocouple/mV Conditioners

T-71-11-07

2B54/2B55

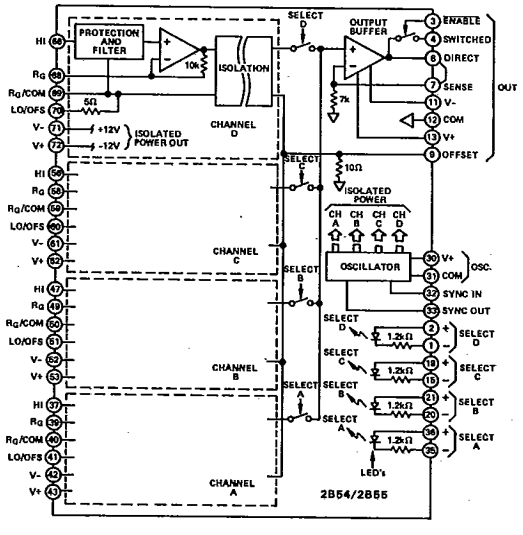
FEATURES

- Low Cost Per Channel
- Wide Input Span Range: ±5mV to ±100mV (2B54)
  ±50mV to ±5V (2B55)
- Pin Compatible with 2B34 RTD Conditioner
- High CMV Isolation: ±1000V dc; CMR = 156dB min @ 60Hz
- Low Input Offset Voltage Drift: ±1μV/°C max (2B54B)
- Low Gain Drift: ±25ppm/°C max (2B54B)
- Low Nonlinearity: ±0.02% max (±0.012% typ)
- Normal Mode Input Protection (130V rms) and Filtering
- Channel Multiplexing: 400 chan/sec Scanning Speed
- Solid State Reliability

APPLICATIONS

- Multichannel Thermocouple Temperature Measurements
- Low and High Level Data Acquisition Systems
- Industrial Measurement and Control Systems

FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

Models 2B54 and 2B55 are low cost, high performance, four-channel signal conditioners. Both models are functionally complete, providing input protection, isolation and common mode rejection, multiplexing, filtering and amplification.

The 2B54 has been designed to condition low level signals (±5mV to ±100mV), like those generated by thermocouples or strain gages, in the presence of high common mode voltages. The 2B55 is optimized to condition ±50mV to ±5V or 4 to 20mA transmitter signals as inputs. The four-channel structure of both models results in significant cost and size reduction.

The high performance of the 2B54 and 2B55 is accomplished by the use of reliable transformer isolation techniques and an amplifier-per-channel architecture. Each of the input channels is galvanically isolated (±1000V dc) from the other input channels and from output ground. The amplifier-per-channel structure is used to obtain low input drift (±1μV/°C max, 2B54B), high common mode rejection (156dB @ 60Hz), and very stable gain (±25ppm/°C max). Other key features include low input noise (1μV p-p), low nonlinearity (±0.02% max) and open-thermocouple detection (2B54).

APPLICATIONS

Models 2B54 and 2B55 were designed to serve as a superior alternative to the relay multiplexing circuits used in multi-channel data acquisition systems, computer interface systems, process signal isolators, and temperature measurement and control instrumentation. Advantages over relay circuits include functional versatility, superior performance, and solid state reliability. Both models are also pin compatible with the 2B34, four-channel RTD/strain gage conditioner.

In thermocouple temperature measurement applications, outstanding low drift, high noise rejection, high throughput and 1000V isolation make the 2B54 a natural choice over flying capacitor multiplexers in conditioning any thermocouple type. When cold junction compensation is required in measurement of temperature with thermocouples, the 2B54 may be used directly with the model 2B56 Universal Cold Junction Compensator.

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DESIGN FEATURES AND USER BENEFITS

High Reliability: To assure high reliability and provide isolation protection to electronic instrumentation, reliable transformer isolation and solid state switching are used. Both models have been conservatively designed to meet the IEEE standard for Transient Voltage Protection (472-1974:SWC) and offer 130V rms normal mode input protection.

High Noise Rejection: To preserve high system accuracy in electrically noisy industrial environments, the 2B54 and 2B55 provide excellent common mode noise rejection, RFI/EMI immunity, and low pass filtering for rejection of series mode noise and 50Hz/60Hz pickup.

Ease of Use: The multichannel, functionally complete design in a compact (2″ × 4″ × 0.4″) module, assures ease of use, conserves board space and eliminates the need for a number of discrete components necessary in relay multiplexing circuits.

Low Cost: The 2B54 and 2B55 offer the lowest cost per channel for isolated, solid state, low level signal conditioners.

2B54/2B55—SPECIFICATIONS (typical @ +25°C and V_S = ±15V and V_{OSC} = +15V, unless otherwise noted)

Model	2B54A	2B54B	2B55A
ANALOG INPUT			
Number of Channels		•	•
Input Span Range	±5mV to ±100mV	•	±50mV to ±5V
Gain Equation	G = 1 + 10kΩ/R_G	•	•
Gain Error	±0.2% max (G = 50 to 300)	•	±0.2% max (G = 1 to 100)
	±1% max (G = 1000)	•	NA
Gain Temperature Coefficient	±35ppm/°C max	±25ppm/°C max	±25ppm/°C max
Gain Nonlinearity[1]	±0.03% max (G = 50 to 300)	±0.02% max(±0.012% typ)	±0.02% max (G = 1 to 100)
	±0.03% (G = 1000)	•	NA
Offset Voltage			
Input Offset, Initial (Adj. to Zero)	±20µV max	•	±50µV max
vs. Temperature	±2.5µV/°C max	±1µV/°C max(±0.5µV/°C typ)	±5µV/°C max
vs. Time	±1.5µV/month	•	•
Output Offset (Adjustable to Zero)	±12mV max	•	•
vs. Temperature	±50µV/°C max	•	•
Total Offset Drift (RTI), max	$\pm\left(2.5+\frac{50}{G}\right)\mu V/^{\circ}C$	$\pm\left(1+\frac{50}{G}\right)\mu V/^{\circ}C$	$\pm\left(5\mu V+\frac{50}{G}\right)\mu V/^{\circ}C$
Input Noise Voltage			
0.01Hz –100Hz, R_S = 1kΩ	1µV p-p	•	•
CMV, Channel-to-Channel or Channel-to-Ground			
Continuous, ac, 60Hz	750V rms	•	•
Continuous, ac or dc	±1000V pk max	•	•
Common Mode Rejection			
R_S ≤ 100Ω, f ≥ 50Hz	156dB min (G = 1000)	•	145dB min (G = 100)
R_S ≤ 100Ω, f ≥ 50Hz	128dB min (G = 50)	•	110dB min (G = 1)
Normal Mode Input, Without Damage	130V rms, 60Hz	•	•
Normal Mode Rejection, @ 60Hz	55dB min (G = 1000)	•	55dB min (G = 100)
Input Resistance, Power On	100MΩ	•	•
Power Off	35kΩ min	•	74kΩ min
Input Bias Current	+8nA max	•	•
ANALOG OUPUT			
Output Voltage Swing[2]	±5V @ ±5mA	•	•
Output Noise, dc – 100kHz	0.8mV p-p	•	•
Output Resistance			
Direct Output	0.1Ω	•	•
Switched Output	35Ω	•	•
CHANNEL SELECTION			
Channel Selection Time to ±0.01% FS	2.5ms max	•	•
Channel Scanning Speed	400 chan/sec min	•	•
Channel Select Input Reverse Voltage Rating	3V max	•	•
POWER SUPPLY			
Voltage			
Output ±V_S (Rated Performance)	±15V dc ±10%	•	•
(Operating)	±12V to ±18V dc max	•	•
Oscillator +V_{OSC} (Rated Performance)	+13.5V to +24V	•	•
Absolute max +V_{OSC}	+26V	•	•
Current			
Output ±V_S = ±15V	±4mA max	•	•
Oscillator +V_{OSC} = +15V	40mA max	•	•
Supply Effect on Offset			
Output ±V_S	100µV/V RTO	•	•
Oscillator +V_{OSC}	1µV/V RTI	•	•
ENVIRONMENTAL			
Temperature			
Rated Performance	0 to +70°C	•	•
Operating	–25°C to +85°C	•	•
Storage	–55°C to +85°C	•	•
Relative Humidity			
Non-Condensing to +40°C	0 to 85%	•	•
CASE SIZE	2" X 4" X 0.4"	•	•

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NOTES

*Specifications same as 2B54A.

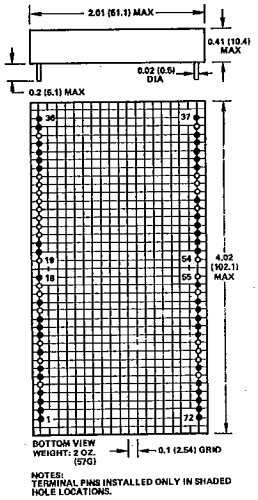
[1] Gain nonlinearity is specified as a percentage of output signal span representing peak deviation from the best straight line; e.g. nonlinearity at an output span of 10V pk-pk (±5V) is ±0.02% or ±2mV.

[2] Protected for shorts to ground and/or either supply voltage.

Specifications subject to change without notice.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



NOTES:
TERMINAL PINS INSTALLED ONLY IN SHADED HOLE LOCATIONS.

PIN DESIGNATIONS

PIN	FUNCTION	PIN	FUNCTION
1	– SELECT CH. D	37	HI
2	+ SELECT CH. D	38	
3	SW/O OUTPUT ENABLE	39	R_G
4	SWITCHED OUTPUT	40	R_G/COM
5		41	LO/OFS
6	DIRECT OUTPUT	42	V- OUT
7	SENSE OUTPUT	43	V+ OUT
8		44	
9	OFS. ADJ.	45	
10		46	
11	$-V_S$	47	HI
12	COM	48	
13	$+V_S$	49	R_G
14		50	R_G/COM
15	– SELECT CH. C	51	LO/OFS
16		52	V- OUT
17		53	V+ OUT
18	+ SELECT CH. C	54	
19		55	
20	– SELECT CH. B	56	HI
21	+ SELECT CH. B	57	
22		58	R_G
23		59	R_G/COM
24		60	LO/OFS
25		61	V- OUT
26		62	V+ OUT
27		63	
28		64	
29		65	
30	$+V_{OSC}$ OSC. POWER	66	HI
31	COM OSC. POWER	67	
32	IN SYNC	68	R_G
33	OUT SYNC	69	R_G/COM
34		70	LO/OFS
35	– SELECT CH. A	71	V- OUT
36	+ SELECT CH. A	72	V+ OUT

CHANNEL A: 37–43
CHANNEL B: 47–53
CHANNEL C: 56–62
CHANNEL D: 66–72

FUNCTIONAL DESCRIPTION

The internal structure of the 2B54/2B55 is shown in Figure 1. Four individually isolated input channels are multiplexed into a single output buffer, with the desired channel selected by control inputs SELECT A through SELECT D. Isolated power and timing signals for the input channels are provided by an internal oscillator.

Each channel contains an input protection and filtering network and a low-drift amplifier whose gain is set by a user-supplied resistor (R_G). Additional filtering is provided in the amplifier circuit. This structure preserves signal integrity by taking all signal gain ahead of the isolation and multiplexing circuits. The isolated power supply for each channel is brought out to permit convenient fine adjustment of the input offset voltage if desired.

Transformer coupling is used to achieve stable, reliable galvanic isolation of each channel from all other channels and from output ground. Although the bandwidth of the input channels is small (<2Hz at high gains) to provide immunity to normal-mode noise, the multiplexing technique allows the channels to be scanned at a high rate (400 channels/sec). Thus a high revisitation rate is maintained even in systems with a large number of input channels.

The output buffer amplifier operates at unity gain with feedback provided by an external connection from the DIRECT output to the SENSE input. The DIRECT output provides a ±5V swing with low source resistance to permit error-free operation with heavy loads. In addition, a separate series-switched output with an active-low enable control is provided so that multiple modules may be combined without the use of external analog multiplexers. An offset trim point which does not affect drift is also provided on the output channel.

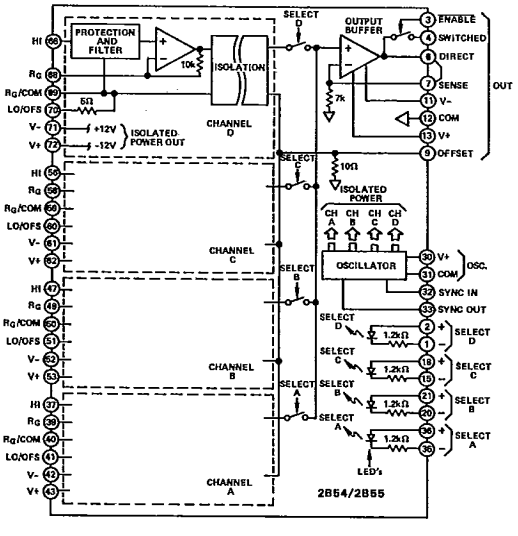


Figure 1. 2B54/2B55 Functional Block Diagram

The internal oscillator has its own power supply pins for enhanced application flexibility, and a sync mechanism is provided to eliminate beat-frequency errors when multiple 2B54/2B55's are used or when a system clock is present.

The 2B54 and 2B55 share the same design, differing only in input specifications and filter characteristics.

OPERATING INSTRUCTIONS

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The connections shown in Figure 2 are common to most applications of the 2B54/2B55, and in many cases will be all that is required. The following sections describe this basic application and also detail some optional connections which enhance the module's utility in more complex applications.

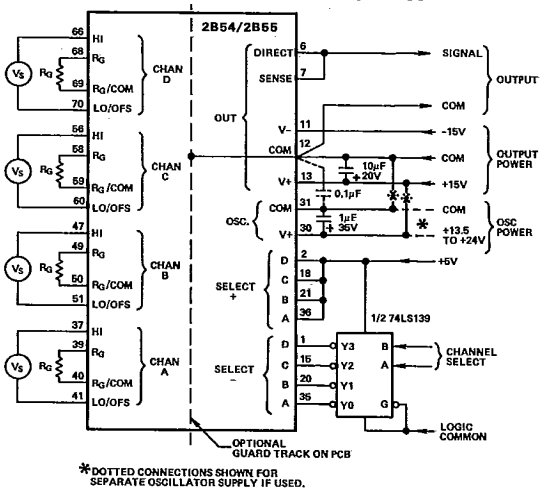

Figure 2. Basic 2B54/2B55 Application

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Interconnection Guidelines

In any high accuracy isolator application it is important to minimize coupling between input and output, and the 2B54/2B55 pinout has been designed to make this easy to do. For best results, keep all leads associated with signals on the input edge as far as possible from signals on the output edge. This will minimize the effects of board leakage and capacitance. The use of a guard track on both sides of the board (Figure 2) can also be helpful.

The power supplies should be decoupled with tantalum capacitors as close to the unit as possible. For lowest noise, the output grounding scheme should be as shown in Figure 2. The output signal common is connected directly to pin 12, with power supply returns brought separately to that pin so that power supply currents do not flow in the low lead of the signal output.

Since most of the power taken by the 2B54/2B55 is supplied to the internal oscillator which requires only a positive supply and can accommodate a wide range of supply voltages, it is sometimes desirable to power the oscillator from a convenient source of unregulated power (such as +24V — Figure 2). A 0.1μF capacitor should be then connected directly from pin 12 to pin 31. Since the output and oscillator circuits are not fully isolated, a dc path must exist between the two power supply commons. A small (one or two volts) potential difference between OUT COM and OSC COM will not affect operation.

Gain Setting

The gain of each channel is independently set by a user-supplied resistor (R_G) connected as shown in Figure 2. Channel gain will normally be selected so that the maximum output of the signal source will result in a plus or minus full scale (±5V) output swing. The resistor value required is $R_G = 10k\Omega/(G-1)$. Thus if $R_G = 101\Omega$, the gain will be 100, and an input signal swing of ±50mV will yield an output span of ±5V.

A parallel trim on the gain-setting resistor can be used to trim out the resistor's tolerance and the module's gain error (Figure 3). Since a parallel trim will always increase the gain, the value of the gain-setting resistor should be chosen to give an untrimmed gain somewhat lower than the desired trimmed gain. Good quality metal-film resistors should be used for R_G since gain accuracy and drift are a direct function of R_G's characteristics. Cermet pots are suitable for the trim.

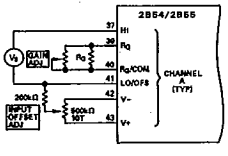

Figure 3. Input Offset and Gain Adjustments

Optional Offset Adjustment

The 2B54/2B55 has provision for fine adjustment of the input offset of each channel and the output offset of the entire module. None of the offset adjustments affect offset drift, and there is no need to make any adjustment unless the application calls for tighter offsets than those specified for the module type.

Connections for input offset adjustment are shown in Figure 3. This is a fine trim with a limited range (±250μV – 2B54 and ±1mV – 2B55, RTI), used to adjust each channel for zero offset while operating at the desired gain. Since the range of the input offset trim is small, it will usually be necessary to adjust output offset first. This can be conveniently done by operating one channel with zero input at unity gain (by disconnecting the gain resistor) and adjusting the output offset control for zero output. Connections for output offset adjustment are shown in Figure 4.

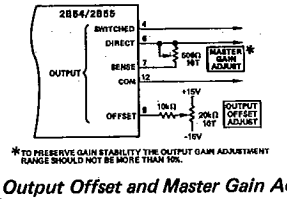

Figure 4. Output Offset and Master Gain Adjustments

An alternative offset adjustment procedure is appropriate in applications where the channel gains are field-selected by switching the gain-setting resistor. Here it is desirable to set the input offset so that there is no zero shift at the output when the gain is changed. To make the adjustment, switch back and forth from low to high gain with zero input and adjust the input offset control until no shift occurs at the output when changing gains. Then adjust the output offset control for zero output at the lower gain.

Stable components (a metal film resistor and a cermet pot) should be used for the input offset adjustment to avoid compromising drift. Output offset adjustment components are not critical and may be omitted altogether when a single 2B54/2B55 is followed by an A to D Converter that has a zero adjustment.

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Channel Selection

Each channel in the 2B54/2B55 is turned on and off by a SELECT input. As indicated in Figure 1, each SELECT input consists of an LED in series with a resistor, and is not connected to any other circuits in the module. Turning the LED on (I≥2.5mA) turns the channel on, and turning the LED off (I≤50μA) turns the channel off. This allows considerable flexibility of connection, but the easiest way to use the SELECT inputs is to tie all four SELECT + pins to +5V and drive the SELECT–inputs from TTL logic (either open-collector or totem-pole outputs can be used), as shown in Figure 2.

It is also possible to use CMOS logic to drive the SELECT inputs (Figure 5). With a +15V logic supply a standard CMOS decoder or gate can supply enough current to drive the SELECT inputs directly, but at lower supply voltages it is advisable to use a buffer such as that shown in Figure 5b. The power taken by the SELECT inputs is small, since only one is on at a time, but at the higher CMOS supply voltages more current than the required 2.5mA will flow. This does not affect operation, but if desired the current can be brought back to the minimum value with series resistors as shown in Figure 5. Use 2kΩ for 10V operation, and 3.9kΩ at 15V.

The maximum reverse voltage applied to any SELECT input must be limited to 3V to avoid damage to the LED. Maximum forward current should be kept below 25mA. Each SELECT input is isolated from all other circuits in the module and may be operated up to ±50V away from output and power ground.

Channels may be selected in any order, and there are no restrictions on rate or duty cycle except the 2.5ms settling time for access to a channel. It should be noted, however, that selecting two or more channels simultaneously for more than a few microseconds will result in a very long settling time when the conflict is resolved. Timing overlaps should therefore be avoided.

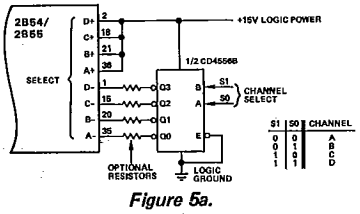

Figure 5a.

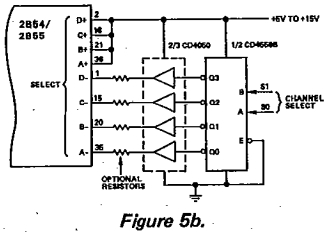

Figure 5b.

Figure 5. CMOS Channel Selection

Channel Expansion

The 2B54/2B55 has provision for directly interconnecting several modules when more than four channels are needed. The series-switched outputs of a group of modules are connected together, the SELECT inputs are driven in parallel, and the output of the desired module is selected using the Output Enable pin. This is shown in Figure 6. A single 74LS139 decoder is used to drive the SELECT inputs of up to four modules, and also provides address expansion so that the binary coded channel address word selects the appropriate module output via the Output Enable pins. The overall operation of the series-switched outputs is analogous to three-state logic, and the output rail is thus an analog bus.

It is possible to operate up to sixteen modules in parallel, for a total of 64 input channels. Note that it will be necessary to break up the SELECT inputs into several groups to avoid overloading the decoder when many modules are used. The settling time of the output switches is <50μs to ±0.01% and is thus negligible in comparison to the channel selection times.

The Output Enable signal is active low, and is compatible with both TTL and CMOS logic. The switching threshold is +1.8V; input current at 0V is typically –0.4mA.

The output resistance of the Switched Output (typically 35Ω +0.5%/°C) is low enough to provide fast switching times but will cause gain errors when driving a heavy load. A single buffer isolating the Switched Outputs from the load will solve this problem in an "analog bus" application (Figure 6). In single-module applications the DIRECT (low impedance) output should be used. Note that in all cases the SENSE pin *must* be connected to the DIRECT output to provide feedback for the output amplifier.

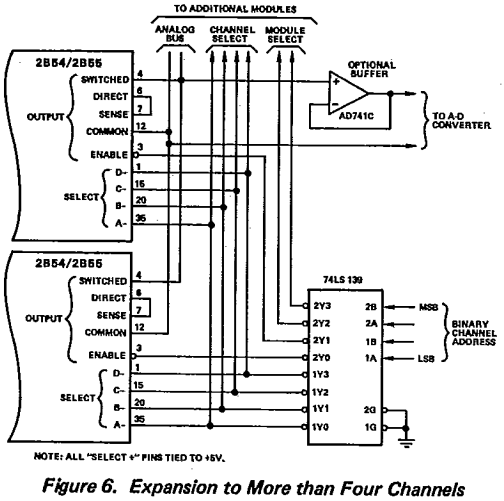

Figure 6. Expansion to More than Four Channels

Synchronization

In applications where multiple 2B54/2B55's are used in close proximity or when system clock signals are present near the isolator, differences in individual oscillator frequencies may cause "beat frequency" related output errors. To eliminate these errors, multiple units may be synchronized by connecting the SYNC OUT (pin 33) terminal to the SYNC IN (pin 32) terminal of the adjacent 2B54/2B55 (Figure 7). The first of a group of modules may be synchronized to an external source via the SYNC IN pin. To minimize noise pickup, sync wiring should be separated from analog signal runs.

The frequency of the external sync source, when used, will have a small effect on the gain and output offset of the 2B54/2B55. Thus any adjustments should be made with the module synchronized.

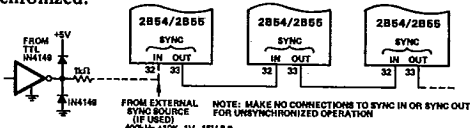

Figure 7. Synchronization

Open Input Detection

The 2B54 can be programmed to respond to an open-circuit condition on a channel input with either an upscale or downscale response when the affected channel is selected. The response time to detect an open input can be in the tens of seconds, since only a few nA of input bias current are available to charge the input filter. The circuits in Figure 8 indicate the selection of either downscale or upscale response and can be used to provide shorter open-circuit response times. Either circuit will produce a bias current of approximately 20nA which can be used to aid or oppose the 3nA typically supplied by the module, as shown. The circuit of Figure 8A has the advantage of simplicity, but the high-value resistor may not be readily available. Figure 8B shows how to solve the problem at the expense of complexity. The values shown may be modified to give an optimum trade of bias current for response time in a given application. A 2 to 5 second response is typical for the values shown.

If a downscale response is desired, a resistor divider circuit like Figure 8B may be desired to prevent a negative overscale. If a negative overscale condition occurs (typically –7V), the output will saturate on all channels.

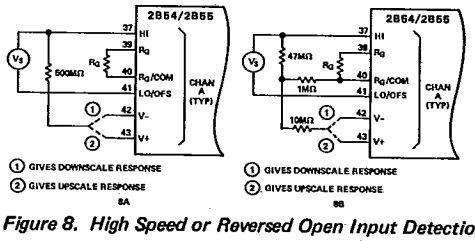

Figure 8. High Speed or Reversed Open Input Detection

Output Filtering

In most applications, no output filtering will be required since the effect of the small carrier-related noise spikes on the output (<1mV p-p, 100kHz B.W.) drops off rapidly as bandwidth decreases and in many cases will be negligible. In some applications (e.g., when driving a successive-approximation A to D) the effective system bandwidth may be large enough to pass the noise. To eliminate the carrier noise (without any effect on switching times), a simple R-C filter may be used at the output (Figure 9A). Only one filter is needed even when multiple modules are used, as shown in Figure 9B. If the load to be driven has an input resistance of less than 10MΩ, a buffer will be needed.

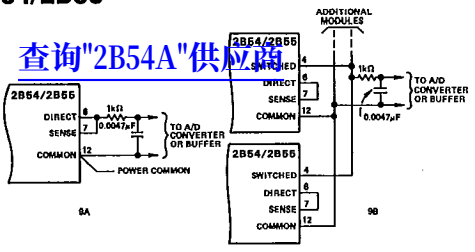

Figure 9. Output Filtering

CMR AND NMR PERFORMANCE

Common mode rejection is a result of both isolation and filtering and indicates ability to reject common mode inputs while amplifying differential signal inputs. CMR is dependent on source impedance imbalance, signal frequency and conditioner gain.

Normal mode rejection is also a function of the 2B54/2B55 gain. Figures 10 and 11 illustrate typical CMR and NMR performance. Note that any additional low pass filtering (e.g., an integrating A to D converter) at the output of the 2B54/2B55 will further improve both CMR and NMR performance.

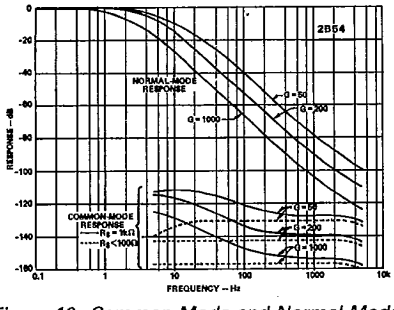

Figure 10. Common Mode and Normal Mode Response – 2B54

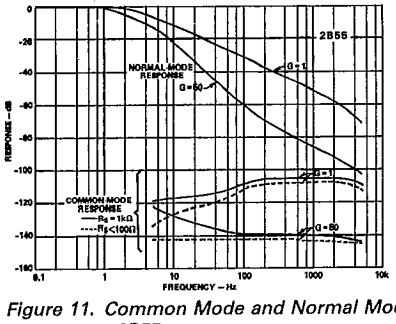

Figure 11. Common Mode and Normal Mode Response – 2B55

APPLICATIONS

Thermocouple Temperature Measurement: Figure 12 shows a four-channel thermocouple input system with isolation, amplification, and multiplexing provided by the 2B54. Several different thermocouple types are used, and the gain-setting resistors on each channel have been chosen to take the standard ANSI range for each type to a 5V output span. Since thermocouples must be compensated for the temperature of the reference junction which is formed where the thermocouple leads are terminated, the 2B56 Universal Cold Junction Compensator is used. The 2B56 monitors the temperature of the reference junction (terminal block) via an external sensor and corrects the signal at the output of the 2B54 for reference temperature. Compensation for several thermocouple types is selectable via digital control inputs. Thermocouple linearization, if needed, would be typically performed in system's software.

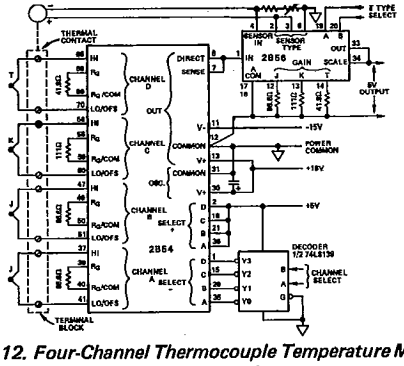

Figure 12. Four-Channel Thermocouple Temperature Measurement with Cold Junction Compensation

Process Signals Interface: In Figure 13, the 2B55 is used to provide floating inputs for four 4-20mA process signal loops. The use of floating inputs in this type of application gives protection from common-mode voltages and greatly simplifies system configuration, since additional loads in series with the loop can be connected on either side of the isolator input.

Each current input is converted into a 1 to 5 volt signal by a 250Ω resistor. The 2B55 is operated at unity gain (no gain-setting resistors) so that a 1 to 5 volt signal appears at the output. Since no gain-setting resistors are used, gain adjustment, if required, is done by connecting trims directly across the input resistors. Other current ranges can be accommodated by changing the value of the input resistors.

When there are several loads on the loop, compliance voltage at the transmitter may be at a premium. In this case it will be advantageous to reduce the voltage swing at the isolator inputs by using smaller resistors (perhaps 25Ω) and scaling the output back to a 5V span by taking an appropriate gain in the isolator.

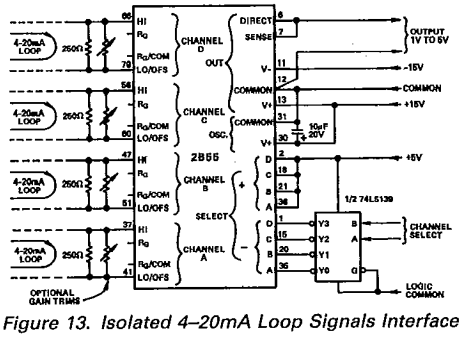

Figure 13. Isolated 4–20mA Loop Signals Interface