FEATURES

- OutSmarts™ technology tames clipping behavior into single-ended loads
- Pin-compatible with SSM2142
- Balanced, floating output delivers transformer-like behavior
- Stable when driving long cables and capacitive loads
- THAT 1430 delivers low output offset voltage using single capacitor

APPLICATIONS

- Differential Line Driver
- Audio Mix Consoles
- Distribution Amplifiers
- Audio Equalizers
- Dynamic Range Processors
- Digital Effects Processors
- Telecommunications Systems
- Instrumentation
- Hi-Fi Equipment

Description

The THAT 1420 and 1430 are a new generation of audio differential line drivers with improved performance over conventional cross-coupled monolithic designs. Both models exhibit low noise and distortion, high slew rate, stability under difficult loads, wide output swing, and have outputs which are short-circuit protected.

In addition both models incorporate patented OutSmarts™ technology, a dual feedback-loop design that prevents the excessive ground currents typical of cross-coupled output stages (CCOS) when clipping into single-ended loads[1].

To overcome this problem, the THAT 1420 and 1430 use two individual negative-feedback loops to separately control the differential output voltage and common mode output currents, making the design inherently more stable and less sensitive to component tolerances than the CCOS. Most importantly, the dual-feedback design prevents the loss of common-mode feedback that plagues the CCOS designs, avoiding the excessive ground currents and overly-distorted output waveform that can result when driving single-ended loads.

Where minimum output offset voltage with minimum parts count is desired, the THAT 1430 further improves over existing designs. In conventional CCOS circuits, two relatively high-value electrolytic capacitors are required to reduce the offset voltage. By contrast, the THAT 1430 topology requires only a resistor and a single film or ceramic capacitor to achieve the same effect at lower parts count and price.

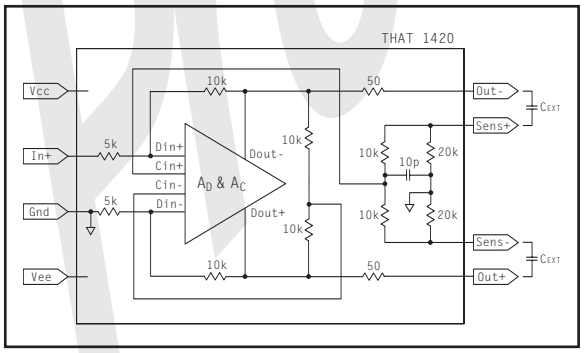


Figure 1. THAT 1420 Equivalent Circuit Diagram

DIP Pin Number	SO Pin Number	1420 Pin Name	1430 Pin Name
1	3	Out-	Out-
2	4	Sens-	Cap2
3	5	Gnd	Gnd
4	6	In	In
5	11	Vee	Vee
6	12	Vcc	Vcc
7	13	Sens+	Cap1
8	14	Out+	Out+

Table 1. THAT 1420/1430 pin assignments

1. See Gary Hebert's paper, An Improved Balanced, Floating Output Driver IC, presented at the 108th AES Convention, Feb. 2000

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SPECIFICATIONS[2]

Absolute Maximum Ratings (T_A = 25°C)

Positive Supply Voltage (Vcc)	+18 V	Operating Temperature Range (T_{OP})	-40 to +85°C
Negative Supply Voltage (Vee)	-18 V	Storage Temperature (T_{ST})	-40 to +150°C
Output Short Circuit Duration	Continuous	Junction Temperature (T_J)	150°C
Power Dissipation (P_D)	TBD mW	Lead Temperature (T_{LEAD})(Soldering 60 sec)	300°C

Electrical Characteristics[3]

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
Input Impedance	Z_{IN}		4	5		kΩ
Gain	G1	R_L=600Ω				
		Balanced	4.35	4.65	4.95	dB
		Single Ended	4.4	4.6	4.8	dB
Gain	G2	R_L=100kΩ				
		Balanced	5.8	6	6.2	dB
		Single Ended	5.8	6	6.2	dB
DC Power Supply Rejection Ratio	PSRR	±4V to ±18V	80	105		dB
Output Common-Mode Rejection Ratio	OCMRR	f=1kHz, BBC Method	50	68		dB
Output Signal Balance Ratio	SBR	f=1kHz, BBC Method	28	40		dB
THD+N (Balanced)	$THD+N_1$	20Hz-20kHz 1kHz		0.001 0.0005		% %
THD+N (Single Ended)	$THD+N_2$	V_O=10 V_{RMS}, R_L=600Ω, 20Hz-20kHz		0.0018		%
Output Noise	SNR	Bal. Mode, 20 kHz BW		-104		dBV
Headroom	HR	0.1% THD+N		25		dBV
Slew Rate	SR			16		V/µS
Output Common Mode Voltage Offset	V_{OCM}	R_L=600Ω, w/o Sense capacitors	-300	±60	300	mV
THAT1420	V_{OCM}	R_L=600Ω, w/ Sense capacitors	-6	±4	6	mV
Output Common Mode Voltage Offset	V_{OCM}	R_L=600Ω, w/o Sense capacitor	-400	±80	400	mV
THAT1430	V_{OCM}	R_L=600Ω, w/ Sense capacitor	-20	±10	20	mV

2. All specifications are subject to change without notice.
3. All measurements taken with V_S=±18, T=25°C, unless otherwise noted

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Electrical Characteristics (cont'd.)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
Differential Output Offset	V_{OOD}	R_L=600Ω	-10	±4	10	mV
Differential Output Voltage Swing,Pos		V_{IN} = ±18V		V_{CC}-2		V
Differential Output Voltage Swing,Neg		V_{IN} = ±18V		V_{EE}+2		V
Output Impedance	Z_O		40	50	60	Ω
Quiescent Supply Current	I_S	Unloaded, V_{IN} = 0		4	5.2	mA
Short Circuit Output Current	I_{SC}		60	70		mA
Voltage Supply Range			±4		±18	V

Theory of Operation

OutSmarts™ technology

The THAT 1420 and 1430 are similar devices, both employing the OutSmarts topology, a variation of circuitry originally developed at Audio Toys, Inc. OutSmarts topology employs two negative-feedback loops -- one to control the differential signal, and a separate loop to control the common mode output levels.

Figures 2 and 3 show the gain core common to both the THAT 1420 and 1430. The gain core is a single amplifier that includes two differential input pairs, $C_{in+/-}$ and $D_{in+/-}$, and complementary outputs, V_{out+} and V_{out-}, related to each other by two gain expressions, $A_D(s)$ and $A_C(s)$. The first pair of differential inputs, $D_{in+/-}$, are connected to the differential feedback network between the outputs and the input signal. The second differential input pair, $C_{in+/-}$, is connected to a bridge circuit which generates an error signal that is used to servo the common-mode behavior of the outputs. The loop equations are then,

$$D_{OUT+} - D_{OUT-} = \Delta D_{OUT} = A_D(D_{IN+} - D_{IN-})$$

where A_D is the differential open-loop gain, and

$$D_{OUT+} + D_{OUT-} = \sum D_{OUT} = A_C(C_{IN+} - C_{IN-})$$

where A_C is the common-mode open-loop gain.

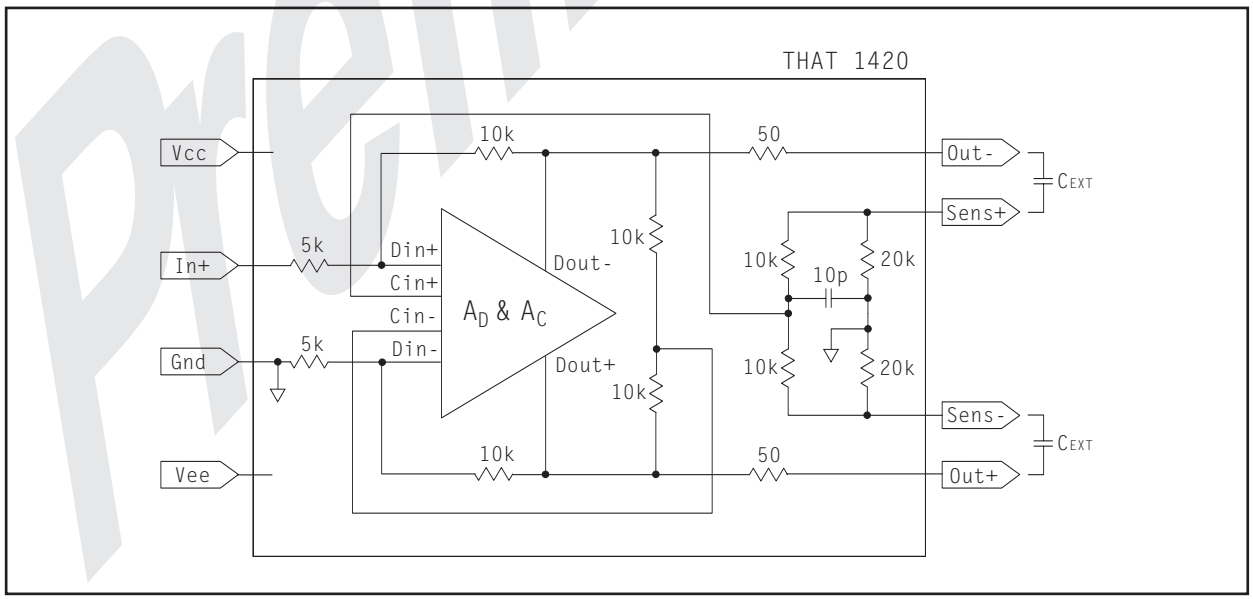


Figure 2. THAT 1420 Equivalent Circuit Diagram

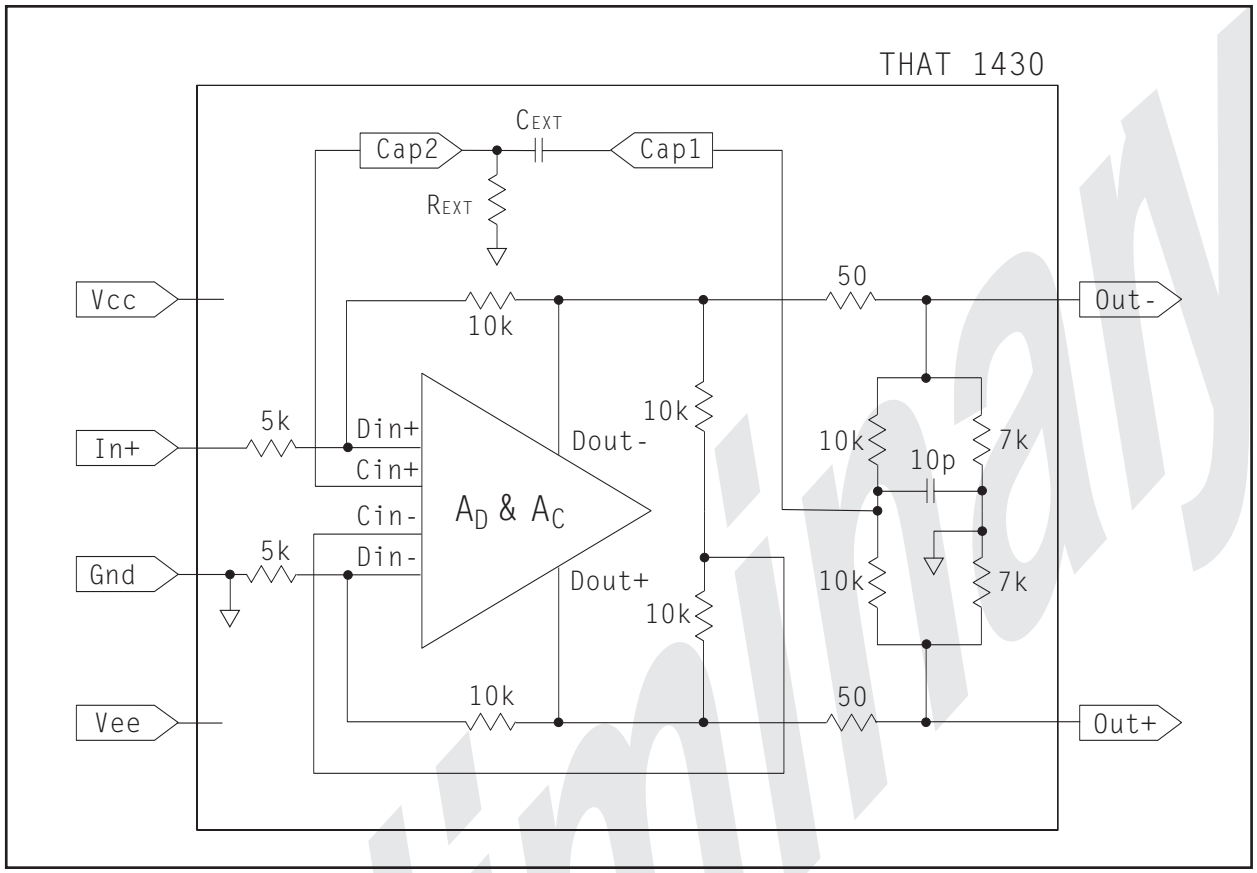


Figure 3. THAT 1430 Equivalent Circuit Diagram

These equations can be solved much like standard op-amp loop equations, and for the differential case, we can see that (using superposition) resistor feedback results in

$$D_{IN+} = (\tfrac{1}{3} D_{OUT-} + \tfrac{2}{3} In_{+}) \text{ and}$$

$$D_{IN-} = \tfrac{1}{3} D_{OUT+}$$

Substituting and simplifying into the equation that defines differential operation yields

$$\Delta D_{OUT} = A_D(\frac{-\Delta D_{OUT}}{3} + \frac{2}{3} In_{+})$$

Dividing through by A_D (assuming that $A_D >> 3$) and simplifying yields

$$\Delta D_{OUT} = 2(In_{+})$$

as one would expect for a +6dB line driver.

The derivation for the common mode equation is more complicated[1] in that it is dependent on the attached load, and in any event doesn't yield much insight into the device's operation.

In op-amp analysis or in the above derivation, the combination of negative feedback and high open-loop gain results in the open-loop gain "dropping out" of the equation, and the differential inputs being forced to the same potential. If we start with that assumption, we can intuitively discern the operation of the common-mode feedback loop as follows:

Referring again to Figures 2 and 3, the common-mode input actually senses the sum of the IC's output currents by way of two 50 ohm resistors and the bridge network (the 10pF capacitor simply limits the maximum frequency at which this action occurs). The resulting error signal is amplified and then summed into both outputs, with the net effect being to force the sum of the currents to be zero, and thus the common mode output current to zero. Since this is negative feedback, the common-mode loop can raise the effective output impedance at audio frequencies without the side effects of circuits that use positive feedback to implement this function.

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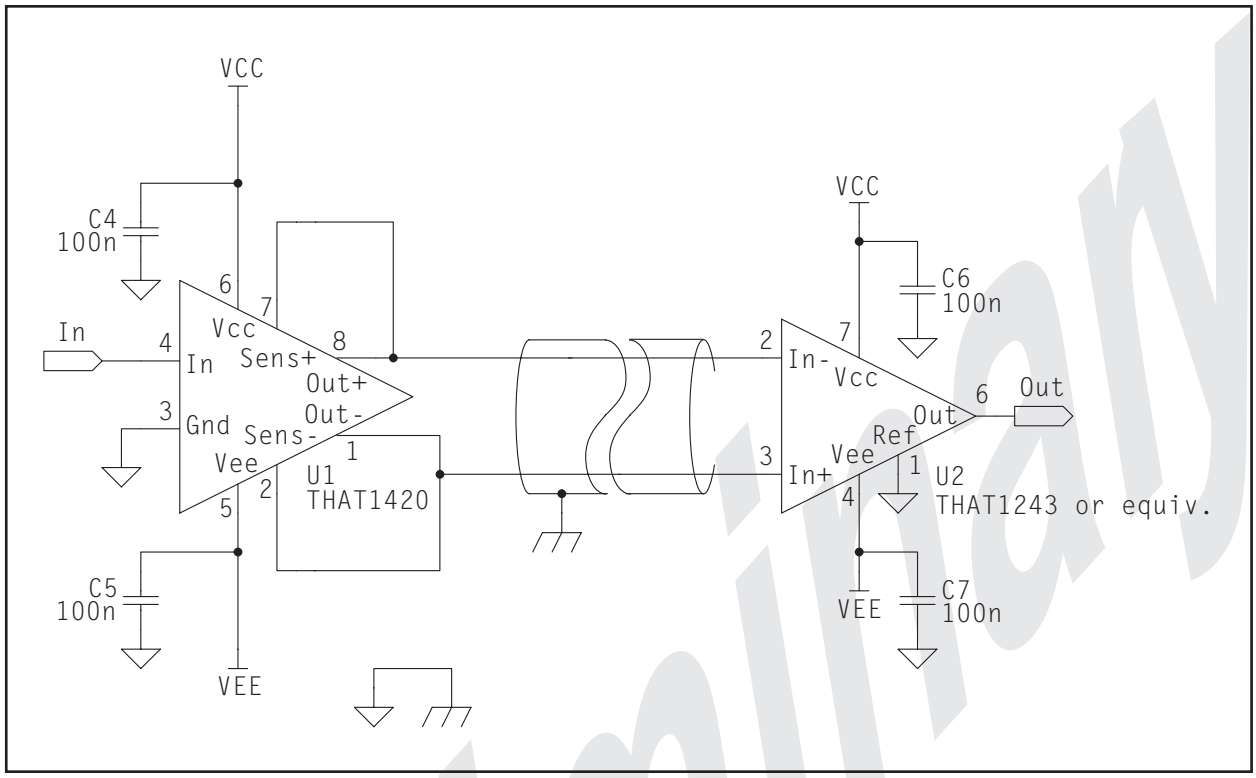


Figure 4. Basic THAT 1420 applications circuit

Applications

Circuit implementations using the THAT 1420/1430 are relatively straightforward. A quiet, solid ground reference, stiff voltage supplies, and adequate supply bypassing are all that is required to achieve excellent performance out of both ICs. Both devices are stable into any capacitive load, and the maximum capacitance is limited only by slew rate and frequency response considerations.

For the purposes of the frequency response calculation, the line driver's 50Ω sense resistors can be lumped into a single 100Ω resistor. The correct cable capacitance to use is the sum of the inter-conductor capacitance and the two conductor-to-shield capacitances. Unfortunately, some manufacturers only specify the inter-conductor capacitance and the capacitance of one conductor to the other while connected to the shield, and some extraction may be required.

As an example, one manufacturer supplies a shielded, twisted pair with 30pF/ft of inter-conductor capacitance and 25pF/ft of conductor to shield capacitance. The corner frequency of the THAT 1420/1430 driving 500 ft of this cable will be

$$f_C = \frac{1}{2\times\pi\times100\Omega\times500\left(30^{pF}/_{ft}+25^{pF}/_{ft}+25^{pF}/_{ft}\right)} \approx 40kHz$$

One must also consider the slew rate limitations posed by excessive cable and other capacitances. We know that

$$i = C\frac{dV}{dt}$$

and that

$$\frac{dV}{dt} = V_{Peak}\times 2\pi \times f$$

Rane Corporation has published a document titled RaneNote 126[4], which specifies some of the requirements for a balanced line driver, including a) stablility into reactive loads, b) output voltage swing of at least ±11 volts peak (+20dBu), and c) reliability. This document also suggests a reasonable rule by which to calculate the output current requirements at 20kHz. The author concludes that the ac-

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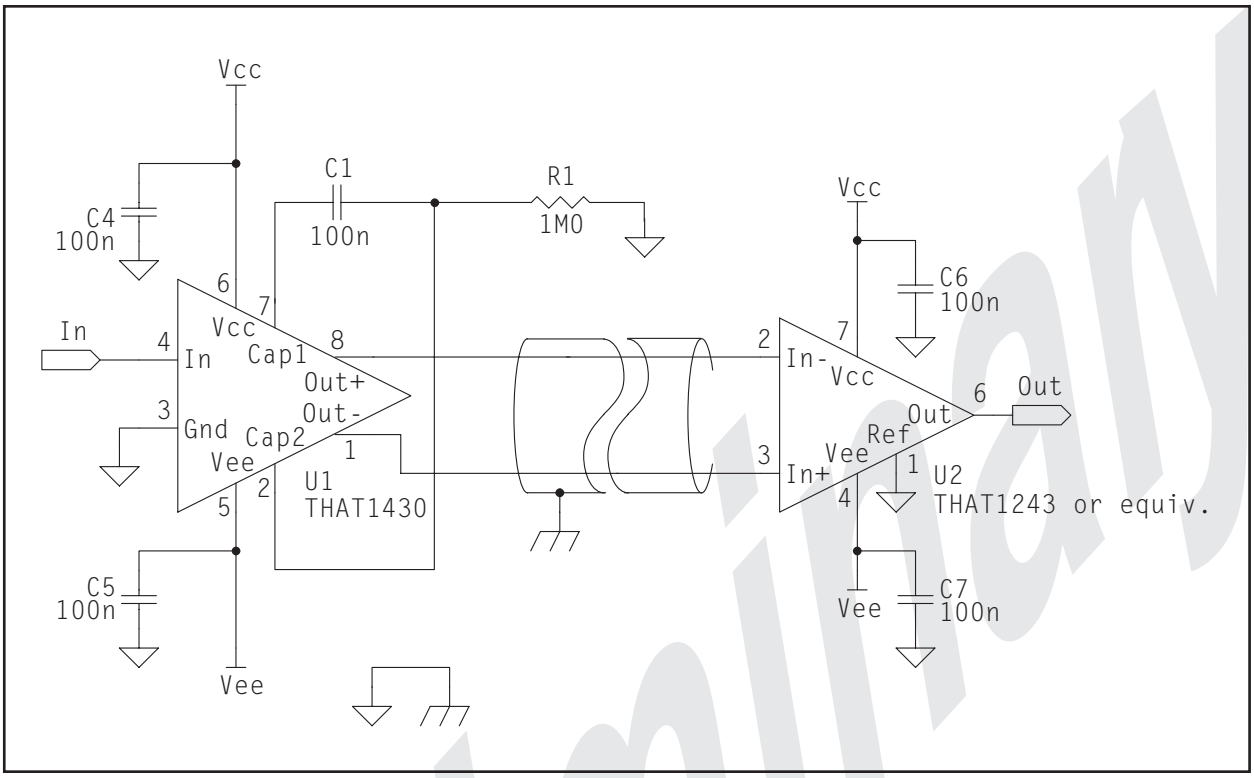


Figure 5. Basic THAT 1430 application circuit with output common mode offset reduction

tual worst case peak level for various types of music and speech will be flat out to 5kHz, and roll off at 6dB/octave above this frequency. Thus the peak levels at 20kHz will be 12dB below those at 5kHz.

Using these, we can calculate the required slew rate and current drive. Since both outputs can swing ±11V, the V_{Peak} is actually 22V (below 5kHz), and at 20kHz, V_{Peak} is 5.5V. Therefore,

$$\frac{dV}{dt} = 2\pi \times 5.5V \times 20kHz = 0.69\frac{V}{\mu s}$$

As a consequence,

$$i = 500ft \times (30\frac{pF}{ft} + 25\frac{pF}{ft} + 25\frac{pF}{ft}) \times 0.69\frac{V}{\mu s} \approx 28mA$$

Thus, driving this 40nF cable requires $28mA_{Peak}$ (well within the 1420/1403's capabilities). Figure 4 shows the most basic connection between the THAT 1420 and a typical line receiver (like the THAT 1243). The only external components that are absolutely required are the local 100nF bypass capacitors, and these could, in fact, be shared with another nearby component. There are no common mode output offset reduction capacitors, and the line driver's outputs are connected directly to their respective sense inputs. The outputs are also DC coupled to the line receiver. If large common mode voltages are expected, the designer may choose to incorporate large, non-polarized capacitors to isolate the THAT 1420's outputs.

Figure 5 shows the basic THAT 1430 applications circuit. This circuit includes external components for common mode offset reduction. This IC is specially designed to allow common mode offset reduction with only a small resistor and capacitor, and is ideal for new designs where space is at a premium. Other considerations that apply to the THAT 1420 apply to the THAT 1430.

Figure 6 shows a THAT 1420 with common mode offset reduction, RFI protection and surge protection, but these last two additions could be added to the THAT 1430 as well. One should also note that the THAT 1420 is pin-for-pin compatible with industry standard line drivers.

These line drivers can easily drive cables hundreds of feet in length without becoming unstable, but attaching such a long cable can act as an antenna (even for AM stations) which can pick up RFI and direct it into the circuit. C3 and C8 are 100pF capaci-

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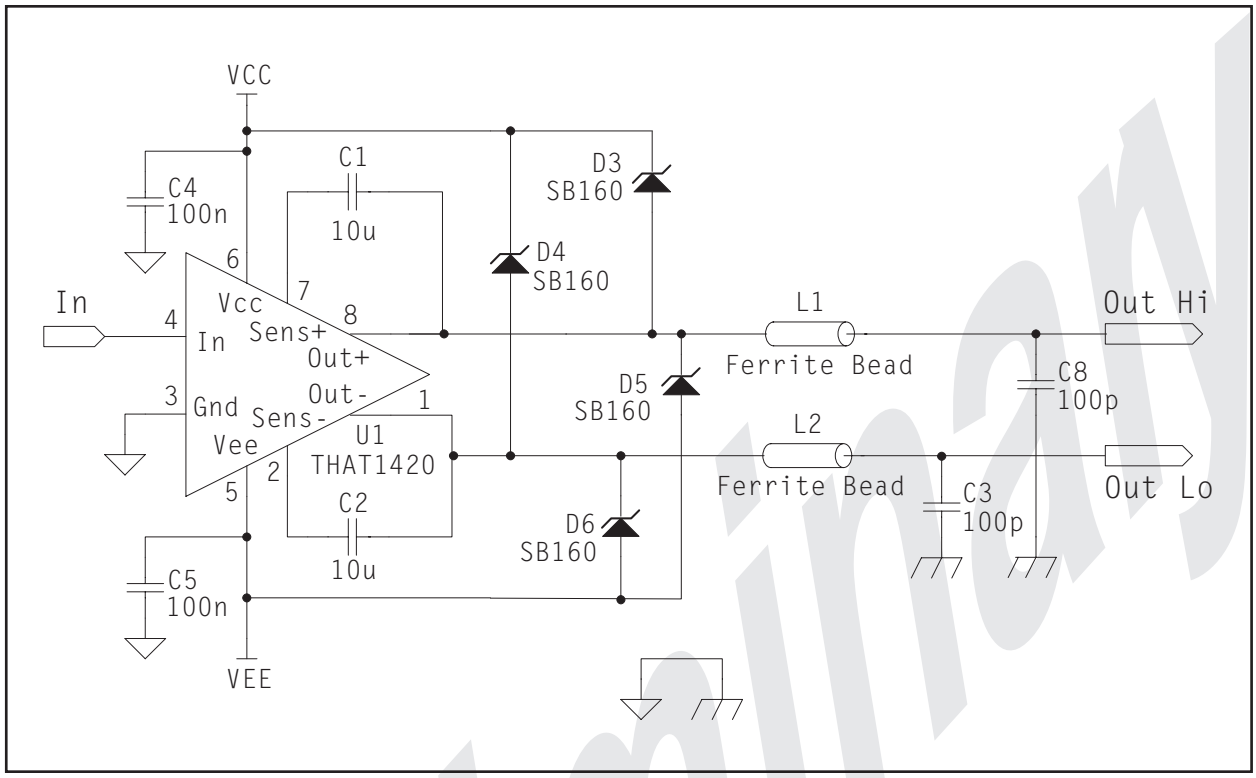


Figure 6. 1420 with output common mode offset protection, RFI protection, and surge protection

tors whose purpose is to redirect this RF energy to the chassis before it can circulate and effectively form a single loop transformer that magnetically couples RF into the remainder of the circuit. Ferrite beads are also included to ensure that RFI current is directed to the chassis and not through the relatively low impedance (at RF frequencies) output of the THAT 1420/1430. The devices will have no effect on the gain error of these line drivers at audio frequencies.

While both of these chips have diode protection to the rails, this protection might not be adequate for some conditions seen in the field. The most obvious problem that one might foresee would be having the line driver's output plugged directly into a microphone preamplifier input that has +48V phantom power applied. This situation can result in surge currents of several amps, which can cause open circuits in the metal traces or failure of the protection diodes on the IC.

This circuit uses a discrete diode bridge composed of SB160's to clamp potentially damaging surges to the IC's supply rails.

Closing thoughts

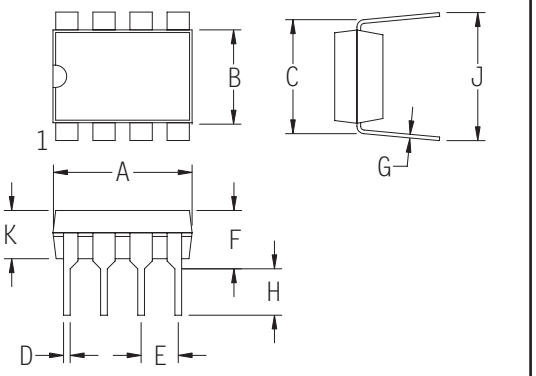
The integrated balanced line driver is one of those highly useful, cost-effective functional blocks that can provide significant improvement over discrete designs. The THAT 1420 and 1430 go a step or two further by improving over existing components. Both incorporate OutSmarts™ technology to tame the aberrant single-ended clipping behavior of conventional cross-coupled output stages. The THAT 1430's design gives reasonably low output offset voltage with only a resistor and a single film or ceramic capacitor, though it is not pin-compatible with existing IC output stages.

For more information on these or other THAT Corporation integrated circuits, please contact us directly, or through one of our international distributors.

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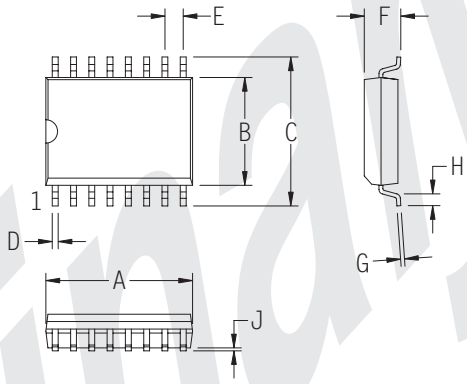
Package Information

The THAT1420/1430 are available in both 8-pin mini-DIP and 16-pin SOIC packages. The package dimensions are shown in Figures 7 and 8, while pinouts are given in Table 1.



ITEM	MILLIMETERS	INCHES
A	9.52±0.10	0.375±0.004
B	6.35±0.10	0.250±0.004
C	7.49/8.13	0.295/0.320
D	0.46	0.018
E	2.54	0.100
F	3.68/4.32	0.145/0.170
G	0.25	0.010
H	3.18±0.10	0.125±0.004
J	8.13/9.40	0.320/0.370
K	3.30±0.10	0.130±0.004

Figure 7. -P (DIP) version package outline drawing



ITEM	MILLIMETERS	INCHES
A	10.11/10.31	0.398/0.406
B	7.40/7.60	0.291/0.299
C	10.11/10.51	0.398/0.414
D	0.36/0.46	0.014/0.018
E	1.27	0.050
F	2.44/2.64	0.096/0.104
G	0.23/0.32	0.009/0.013
H	0.51/1.01	0.020/0.040
J	0.10/0.30	0.004/0.012

Figure 8. -S (SO) version package outline drawing

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