

# Audio current conveyor

A recently introduced integrated circuit could be the answer to the harshness in sound that has been a common criticism of compact disc players. The device uses a current conveyor configuration to give low-distortion and wide-bandwidth functions such as gain blocks, inverters and virtual ground inputs without the global negative feedback required by most other circuits such as operational amplifiers. It is therefore inherently free of dynamically induced distortion.

Global feedback techniques can introduce dynamic distortion such as transient intermodulation (TIM) and slewing induced distortion (SID). Many audio signals are band limited and therefore may not contain the fast edges needed to generate this type of distortion but there are notable exceptions. For example, the dynamic characteristics of op-amps in the D-to-A stages of digital recording and compact disc equipment must be considered carefully to eliminate distortion.

The new IC could be the answer. It comes in two versions, PA630 and PA630A, and each has two unity gain buffer amplifiers, a current mirror, and a current conveyor block. The PA630 is a 16-pin device and the PA630A has two extra pins to give more flexibility in interfacing.

Each unity gain buffer amplifier (Fig. 1) consists of four emitter followers and two current sources. The quiescent operating point of each can be set independently with an external resistor. This arrangement produces a fast unity gain buffer that uses only the local feedback inherent in the emitter follower configuration.

The current conveyor consists of two complementary cross-coupled current mirrors and an output transistor. This arrangement produces a virtual ground without the global negative feedback needed in op-amp type circuits. One mirror can set up an opposing reference current to define a net output current of zero at one of the pins for any desired input current. This combination of a current conveyor and opposing current mirror lets many useful function blocks be realised.

The on-chip circuitry consists of a connection of Wilson current mirrors, an emitter degeneration compensation

scheme to optimise the transient response and stability of these mirrors, and an output mirror arrangement to improve output impedance.

The nature of the high impedance current output allows for some interesting applications. Since the input reference (ground) and output

reference (cold end of the load) can be independent, signals can be level shifted between any two voltages in the common mode range. This could be used to isolate two grounds in a system while still retaining DC coupling. In audio systems this could help eliminate noise caused by ground loop circulating currents.

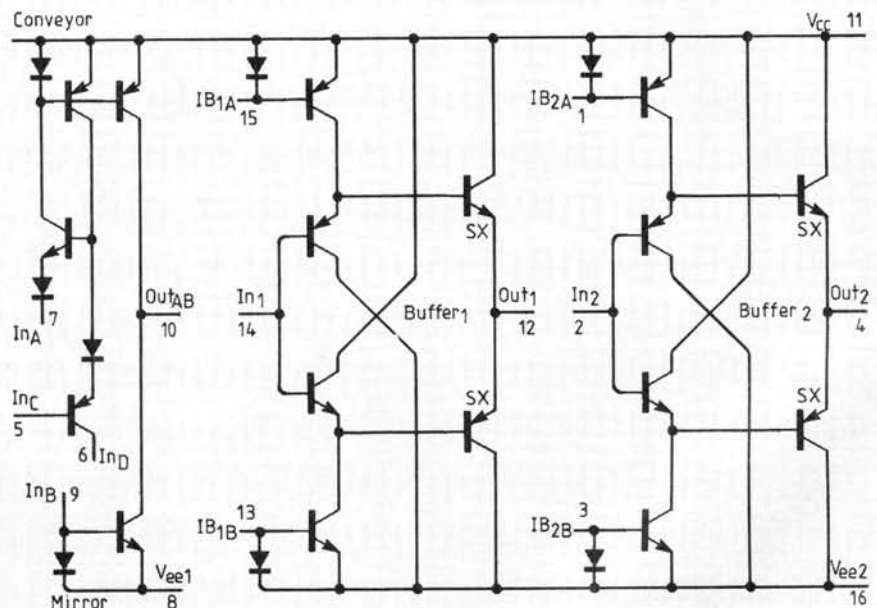


Fig. 1. Functional schematic of the PA630

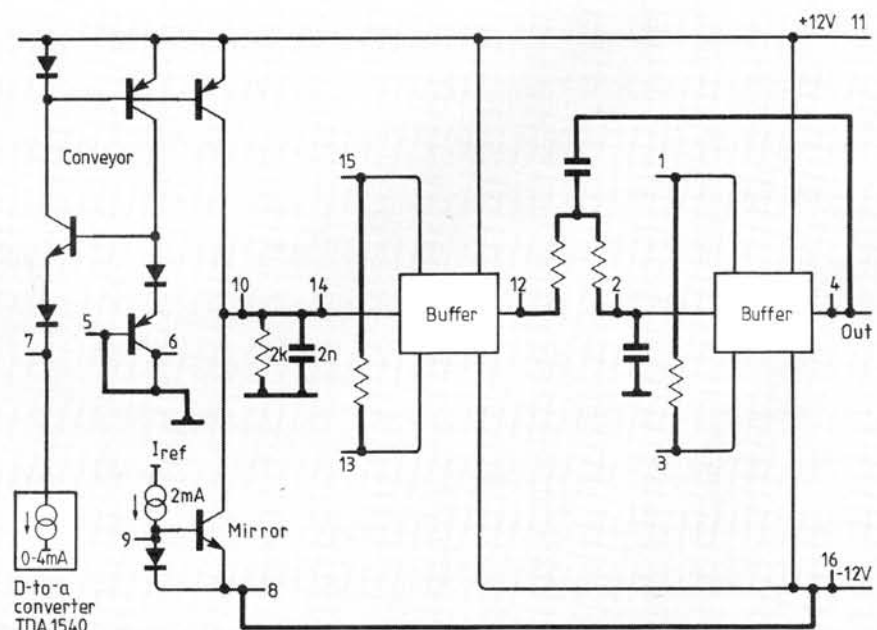


Fig. 2. The output from the CD player

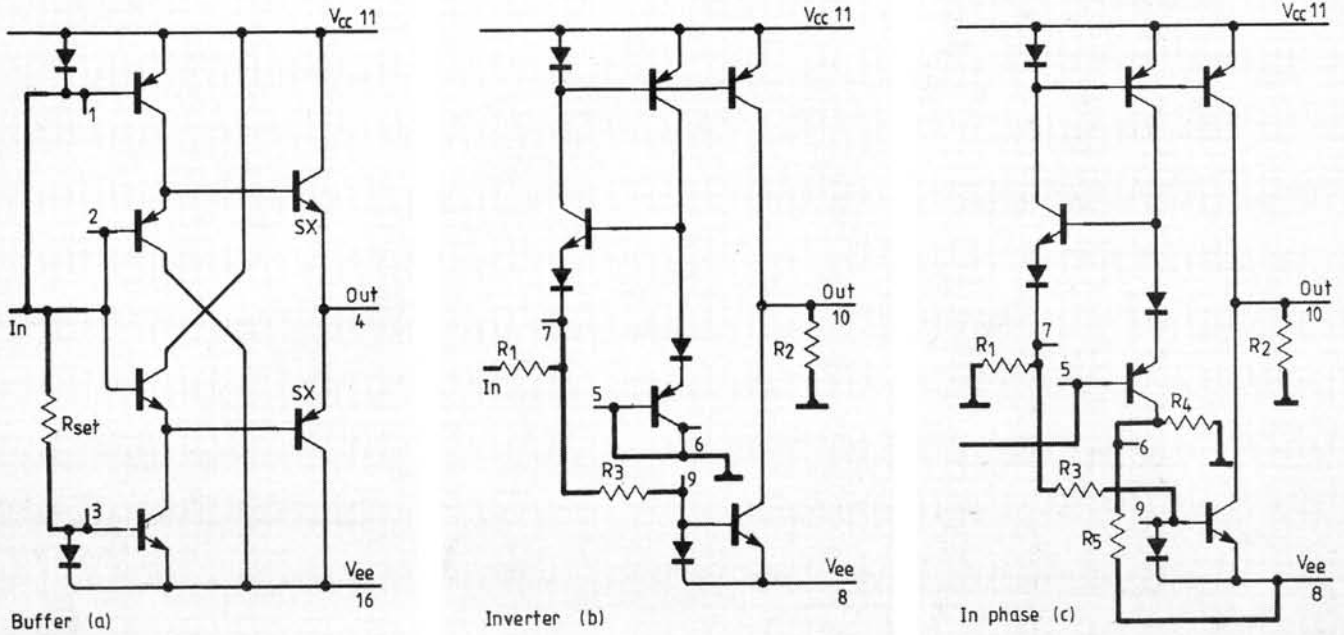


Fig. 2 shows the PA630 used in a typical compact disc player where the current output of a D-to-A converter, which must drive into a virtual ground, is opposed by a 2mA current to establish the zero reference for the audio signal. The current conveyor together with a buffer section provides the virtual ground and performs the I to V conversion with a high frequency roll off. The filter is a Salen and Key second order linear phase based around a buffer connected as a unity gain op-amp.

## Operation

Each unity gain buffer amplifier consists of four emitter followers and two current sources as shown in (a). The quiescent operating point of each can be set independently with an external resistor ( $R_{set}$ ) connected as indicated. Pin 1 and pin 3 may be left open to save current if this buffer is not required, but since the other buffer provides internal bias, it must be powered up with an output stage current of no less than one tenth of the conveyor quiescent current. As the current sources are actually Wilson mirrors ( $2 V_{be}$ ), and the output devices are five times larger than the input transistors, the quiescent current in the output stage can be calculated as:

$$5 [V_{cc} + V_{ee} - 2.8V] / R_{set}$$

The current conveyor block consists basically of two complementary cross-coupled current mirrors and an output transistor. Referring to (b) if pins 5 and 6 are shorted to ground, and current is sourced from pin 7, then to a first

**Conveyor configurations: (a) buffer; (b) inverter; (c) in phase; (d) jfet output; and (e) rectifier.**

order, equal currents are sourced into the ground and pin 10. Of particular interest is the fact that pin 7 will be driven to a virtual ground potential, regardless of the current levels being sourced. Conversely, pin 10 becomes a high impedance output. Current is therefore conveyed from pin 7 to pin 10 unaltered, except for impedance level. This arrangement produces a virtual ground without the global negative feedback required in op-amp type circuits.

By using both the conveyor and the current mirror, the inverting gain block of (b) is produced. Since pin 7 is a virtual ground, and the mirror is a Wilson ( $2 V_{be}$ ),  $R_3$  sets up a quiescent current around the loop equal to:

$$\{V_{ee} - 1.4V\} / R_3$$

If  $V_{in}$  is left open or connected to ground, pin 10 will also be at ground, since all currents balance. The gain of this block is  $R_2/R_1$  and it is bi-directional up to the level of current set by  $R_3$ . It should be noted that both the