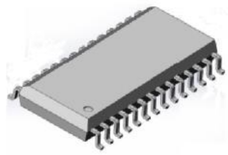
# AS3397 µP CONTROLLABLE DUAL WAVEFORM CONVERTER / PROCESSOR

**FEATURES**

- complete sound synthesis system:
  two multi-waveform converters, 4-pole VCF,
  CV mixer, and panoramic VCA
- 0 to +5V high Z control inputs for direct interface to CMOS multiplexer from system DAC
- numerous waveforms and waveform combinations possible for timbral variety
- independent and continuously variable waveshape and pulse width for each converter
- filter FM
- constant output v.s. resonance VCF characteristic
- open loop VCF design for rich sound
- low noise, low IM distortion VCAs
- low VCA feedthrough without trimming

**AS3397D**



SOIC-28 300mil, 1.27 mm

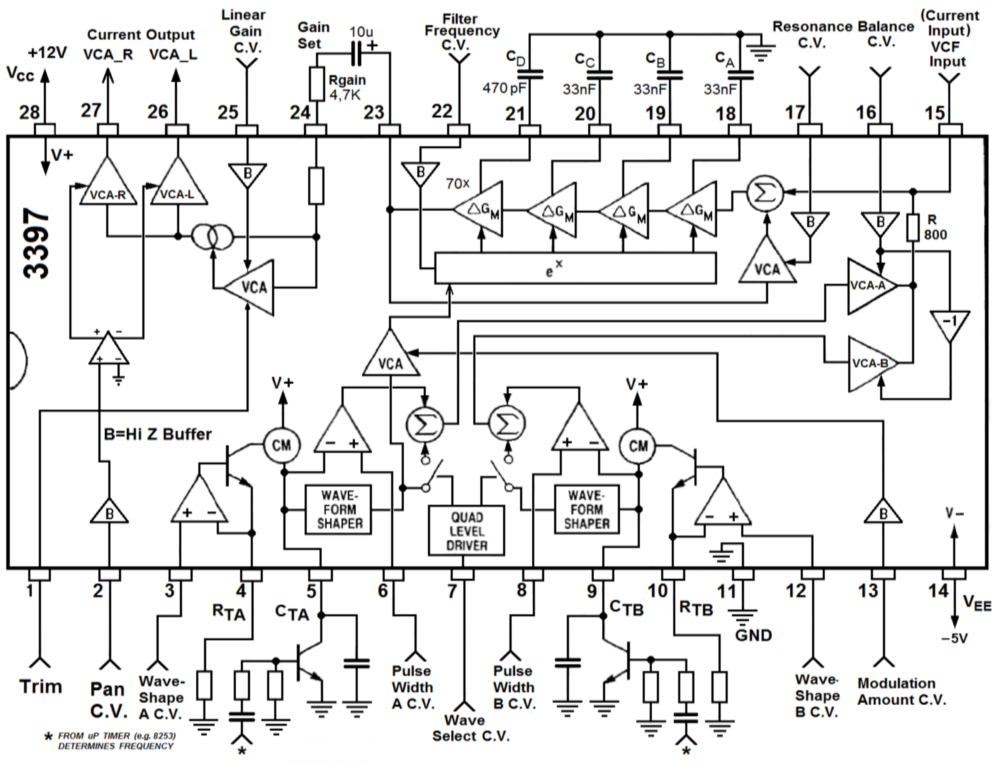
## DESCRIPTION

The AS3397 is a complete system for the generation and processing of audio waveforms in electronic musical instruments. Intended to be driven from digitally generated square or pulse timing signals, the device includes two independent waveform converters, a mixer for voltage controlling the relative balance between the two waveform converter outputs, a dedicated four-pole low—pass voltage controlled filter with voltage controllable resonance, a VCA for allowing one converter output to frequency modulate the filter, and panoramic output VCAs. All control inputs are high impedance, low bias current inputs which range from 0 to +5V, a feature which eliminates the usual Sample & Hold Buffers in a multiplexed DAC system.

Each waveform converter is capable of forming numerous continuously variable waveforms, including sawtooth, triangle, clipped triangle, and variable width pulse, and allowing various combinations of these to be selected. The frequency of these waveforms is equal to the input digital timing signal (typically generated by a programmable divider), allowing precise and stable control of pitch. Additional VCF input gives flexibility in system design.

Low noise, low feedthrough filter keeps the peak-to-peak output level constant as the resonance is varied, producing a rich and full resonance sound. Special attention has been paid to the filter to ensure low intermodulation distortion for clean processing of even complex signals.

**FUNCTIONAL BLOCK DIAGRAM**



**Pin Information**

| Pin Nr | Pin Name | Description | Pin Nr | Pin Name | Description |
|---|---|---|---|---|---|
| 1 | Trim | VCA trim | 15 | VcfIn | Filter input |
| 2 | Pan | Panner CV | 16 | Bal | Balance CV |
| 3 | $WS_A$ | A channel wave-shape CV | 17 | Res | Resonance CV |
| 4 | $R_{TA}$ | A channel current | 18 | $C_A$ | Filter capacitor A |
| 5 | $C_{TA}$ | A channel timing capacitor | 19 | $C_B$ | Filter capacitor B |
| 6 | $PWM_A$ | A channel pulse width CV | 20 | $C_C$ | Filter capacitor C |
| 7 | WaveSel | Wave select CV | 21 | $C_D$ | Filter capacitor D |
| 8 | $PWM_B$ | B channel pulse width CV | 22 | Freq | Filter frequency CV |
| 9 | $C_{TB}$ | B channel timing capacitor | 23 | FiltOut | Filter output |
| 10 | $R_{TB}$ | B channel current | 24 | Gain | Gain set |
| 11 | GND | Ground | 25 | LGain | Linear gain CV |
| 12 | $WS_B$ | B channel wave-shape CV | 26 | VCA_L | VCA left channel output |
| 13 | Mod | Modulation amount CV | 27 | VCA_R | VCA right channel output |
| 14 | $V_{EE}$ | Negative supply voltage | 28 | Vcc | Positive supply voltage |

## Electrical Characteristics

| PARAMETER | MIN | TYPICAL | MAX | UNITS |
|---|---|---|---|---|
| **V/I CONVERTER** | | | | |
| Input Voltage Range | -2,5 | --- | +10 | V |
| Output Current Range | 0,003 | | 1000 | μA |
| Input Offset Voltage | | ±3 | ±7 | mV |
| Output Offset. Current (note 1) | | ±1 | ±3 | nA |
| Output Current Error (note 2) | | ±3 | ±15 | % |
| Conversion Linearity | | | | |
| 5 μA - 250 μA | | ±0,3 | ±1,5 | % |
| 250 nA - 250 μA | | ±1,5 | ±5 | % |
| **WAVEFORM SHAPER** | | | | |
| Waveshape C.V. Input Bias Current | | ±0,5 | ±3 | nA |
| Input Low Voltage For Minimum Output (note 3) | -20 | 0 | +20 | mV |
| Input Voltage for Maximum Output | + 2,4 | +2,5 | +2,6 | V |
| Input High Voltage For Minimum Output (note 3) | +4,8 | +5 | + 5,2 | V |
| Pulse Width Comparator Offset Voltage | -12 | 0 | +12 | mV |
| Pulse Width C.V. Input Bias Current | | ±0,5 | ±3 | nA |
| **WAVEFORM SELECT** | | | | |
| Waveform Select Thresholds | | | | |
| Converter A and B | | -1,0 | <-0,4 | V |
| Converter B Only | -0,2 | +0,5 | +1,1 | V |
| None | + 1,5 | + 2,0 | +2,4 | V |
| Converter A Only | +2,8 | +3,4 | +4 | V |
| Wave Select CV Input Bias Current | | -50 | -300 | nA |
| Wave Select C.V. Feedthrough (note 4) | | | | |
| Converter A Only | | -30 | -15 | dB |
| Converter B Only | | -30 | -15 | dB |
| Converter A and B | | -25 | -10 | dB |
| | | | | |

| | | | | |
|---|---|---|---|---|
| **FILTER MODULATOR** | | | | |
| Maximum Modulation Depth | 0,01X | - | 2,0X | Freq. |
| Mod. C.V. for Max. Modulation | 4 | 4,5 | 5 | V |
| Modulation Amount for CV=0 | | 1 | 5 | % |
| Mod. C.V. Input Bias Current | | -0,07 | -0,4 | nA/V |
| **FILTER INPUT MIXER** | | | | |
| Mix. C.V. for 80 dB Attenuation of Converter A & Max. Converter B | -1,8 | --- | -2,2 | V |
| Mix. C.V. for Max. Converter A & 80 dB Attenuation of Converter B | +1,8 | --- | +2,2 | V |
| Mix. C.V. Input Bias Current | --- | -0,3 | -2 | nA |
| Mix. C.V. Feedthrough (note 5) | --- | -30 | -15 | dB |

| | | | | |
|---|---|---|---|---|
| **FOUR-POLE LOW-PASS FILTER** | | | | |
| Frequency Sweep Range | 12 | 14 | --- | Octaves |
| Frequency C.V. Input Range | -2,5 | --- | +5 | V |
| Frequency Control Scale, Midrange | -0,47 | -0,5 | -0,53 | V/octave |
| Frequency Scale Error (note 6) | | 0,3 | 1 | % |
| Temperature Coefficient of Scale | + 3000 | +3300 | + 3600 | ppm |
| Frequency at CV= 0 (Ca=Cb=Cc=33nF; Cd=430pF) | 500 | 700 | 980 | Hz |
| Tempco of Frequency at CV=0 | | +500 | | ppm |
| Frequency CV Input Bias Current | | -0,5 | -3 | nA |
| Resonance Control Range | 0dB | --- | Oscillat. | |
| Resonance CV for no resonance | 0 | --- | +0,3 | V |
| Resonance CV for oscillation | + 3,5 | +4 | +4,5 | V |
| V p-p Output Change from 0 to Max. Resonance | -2 | 0 | +2 | dB |
| Freq. Control Feedthrough (note 5,7) | | -30 | -18 | dB |
| Res. Control Feedthrough (note 5,8) | | -30 | -10 | dB |
| Signal to Noise Ratio (note 9) | | -93 | -87 | dB |
| **TWO OUTPUT PANNING VCAs** | | | | |
| Pan CV Input | | | | |
| Pan CV Maximum Gain VCA-L | | 0,15 | | V |
| Pan CV Maximum Gain VCA-R | | 4,5 | | V |
| Pan CV Input Bias Current | | -0,5 | 3 | nA |
| Linear Gain Control Input | | | | |
| For 90 dB Attenuation (note 10) | 0 | --- | + 0,15 | V |
| For Maximum Gain | +4 | +4,5 | +5 | V |
| Linear Gain Control Input Bias Current | | -0,5 | 3 | nA |
| Control Voltage Feedthrough | | 0,3 | 2 | |
| Signal to Noise Ratio | | -96 | -90 | dB |
| Output Voltage Compliance | -0,2 | --- | Vcc-1.2 | V |
| Maximum Output Current | 300 | 400 | --- | μA |
| **POWER SUPPLIES** | | | | |
| Positive Supply Range (note 11) | +11 | | +16 | V |
| Negative Supply Range (note 11) | -4,5 | | -12,5 | V |
| Positive Supply Current | 12 | 15 | 18,5 | mA |
| Negative Supply Current | 9 | 12 | 15 | mA |
| | | | | |
| | | | | |

Notes:
Note 1: Current at Ct pin when Rt = ∞.
Note 2: Difference between current at Ct pin and current through Rt.
Note 3: Minimum output is defined as 1% of maximum output.
Note 4: With reference to the P.P. output voltage of selected waveform when switching from no waveforms at all.
Note 5: With reference to maximum P.P. output voltage generated by waveform converters.
Note 6: For Frequency Control Voltages between -1,5V and +2,5V.
For voltage outside this range, maximum error increases to 8%.
Note 7: Over frequency C.V. range of -1,5V to +3,5V (10 octaves).
Note 8: Both converters are generating 50% duty cycle pulse waveforms.
Note 9: As measured at filter capacitor D pin with reference to maximum RMS signal voltage generated by waveform converters at that pin, and with cutoff frequency = 20KHz
Note 10: With reference to maximum gain with other gain control voltage fixed at +5V.
Note 11: Maximum supply across IC is 26V.

## APPLICATION HINTS

### POWER SUPPLY

The maximum supply allowed across the chip is 25 volts. The positive supply may range from +11V to +16V while the negative supply may range from -4,5 to -12,5V. Thus, +12V/-12V, +15V/-5V, and +12V/-5V would all be acceptable power supplies. For lowest warm-up and best performance, +12V/-5V supply is recommended.

### Waveform Converters

Each waveform converter consists of a very linear voltage-to-current converter which charges capacitor Ct from 0 volts to some peak value Vp. The capacitor is quickly discharged back to 0 volts every time the external computer-generated timing signal makes a low to high transition. The brief discharge is generally accomplished by differentiating the digital timing signal with a capacitor and resistor and applying the resulting narrow pulse to the base or gate of an external NPN or N channel MOS transistor connected to the capacitor. (Open collector gates may also be used for this purpose).

The resulting sawtooth waveform generated across the capacitor is applied to one input of a comparator for generating a variable width pulse waveform, and to a waveform shaper for generating all sloped waveforms.

The waveform shaper operates as follows: From 0 to 5/24 Vcc (+2,5V for Vcc = +12V), the converter output increases minimum to maximum; from 5/24 Vcc to 5/12 Vcc (+5.0V for Vcc = +12V), the output decreases from maximum back to minimum; and beyond 5/12 Vcc, the converter output remains at minimum.

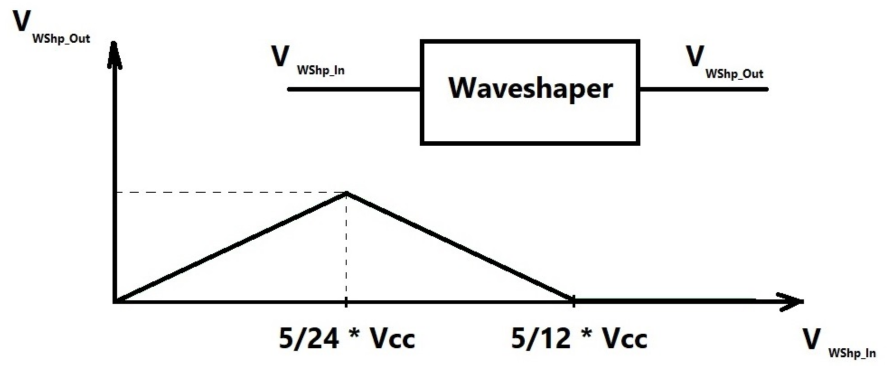



Fig.1 Waveshaper Input-Output

Thus, numerous waveforms may be produced simply by controlling the amplitude of the sawtooth generated across the capacitor Ct: a 0 to 5/24 Vcc sawtooth results in a sawtooth at the output while a 0 to 5/12 Vcc sawtooth produces a perfect triangle waveform at the output; a

sawtooth with a peak level between 5/24 and 5/12 Vcc generates a sawed-off triangle waveform which is very close to a mixture of sawtooth and triangle waveforms; and finally, a peak level greater than 5/12 Vcc results in a triangle waveform with the bottom flattened (clipped). Varying the peak level continuously over these voltages thus varies the waveshape continuously between these various waveshapes, adding more or less harmonics with different harmonic structures.
The peak level Vp of the sawtooth across Ct is determined by the period T between discharge pulses, the value of Ct, and the current charging Ct from the voltage to current converter, which in turn is simply the waveform control voltage Vwf divided by the conversion resistance, Rt.

$$Vp = Vwf * T / Rt * Ct = Vwf / Rt * Ct * f$$

For any given waveform, Vp must remain constant with frequency. Thus, as the frequency is changed, the waveform control voltage Vwf must be changed proportionately to keep the waveform unchanged. Conversely, for any given frequency, changing Vwf only will alter the waveshape.

To include all these variables in one easy expression, $\alpha$ is defined as a waveshape factor, and ranges from 1/2 to 2, where 1/2 is a sawtooth, 1 is a perfect triangle, and 2 is a clipped triangle with 50% duty cycle. Then the voltage Vwf required at any given frequency and waveshape is:

$$Vwf = F * Rt * Ct * 5/12 * Vcc * \alpha$$

Vwf – in range 0 - +5V
F – control frequency of charging capacitor Ct,
Rt – resistor, defines charging current for Ct (typical 20k),
Ct – timing capacitor (1,5 nF typical),
Vcc – supply voltage +12 V,
α – wave shape factor:
α = 0,5 – sawtooth waveform,
α = 1 – triangle waveform,
α = 2 – clipped triangle waveform (50% duty).

The largest required voltage will be at the highest desired frequency and with a clipped triangle waveform ($\alpha$= 2), while the minimum required voltage will occur at the lowest desired frequency and with a sawtooth waveform ($\alpha$= 1/2).

Main slope signals which can be received on output of WaveShaper by changing Vwf on CV inputs of channels A and B (pin3, pin 12). In these blocks sawtooth charging signal on capacitor Ct converts in other slope signals. In order to remain form of signal stable while frequency is changed, control voltage Vwf must be in strong relationship with frequency of control signal on the base of external transistor which discharge Ct. Vwf can be changed in 0 - +5V range.

In a typical system, the waveform control voltage will be generated by a single DAC multiplexed with a CMOS multiplexer operating from a +5V supply, constraining the maximum value for Vwf to +5 volts. For best performance, the V/I converter charge current should be limited to 250μA. The conversion resistor therefore is 5V/250μA = 20K.

Suppose, for example, that the desired frequency range is 64Hz – 4,096 kHz (6 octaves), and Vcc = +12V. From the above equation, Ct would have to equal 6,1 nF, and the minimum required voltage would be approximately 20 mV.

At this low level, several sources of error must be taken into consideration. The most important is the input offset of the V/I converter. A 5mV offset with a 20mV input will generate a 25% error in the charge current. Thus the sawtooth at 64Hz will either be 25% lower in amplitude than it should be, or it will be 25% part triangle wave (not very noticeable). The triangle wave at 64 Hz (Vwf = 40 mV) will have a 12,5% error, resulting in a 12,5% sawtooth wave present in the triangle wave, or in its bottom clipped by 12,5% (more noticeable).

Other sources of error come from the DAC output offset voltage and differential non-linearity. A 1 LSB linearity error is 20 mV for an 8 bit DAC, 4,88 mV for a 10 bit DAC, and 1,22 mV for a 12 bit DAC.

As a practical matter, therefore, the maximum frequency range with a single conversion resistor is limited to about six octaves. For a wider range, while still maintaining good waveshape at all frequencies, range switching of the conversion resistor is recommended.

Suppose for an example that the desired frequency range is 16 Hz to 16,4 KHz (10 octaves). The upper 5 octaves (512 Hz – 16384 Hz) could be served by a conversion resister Rt=20k and timing capacitor Ct = 1,5 nF. Then for 512Hz - Uwf=39 mV, Vp=2,539V.

For the lower 5 octaves (16 Hz – 512 Hz) the highest frequency could achieved by Rt=640k and timing capacitor Ct=1,5nF. Then for 16Hz – Uwf=39mV, Vp=2,539V.

For both ranges, the lowest waveform control voltage remains 39 mV.

The range switching is most easily accomplished with the larger value resistor (640k) always connected to ground, and shorting a smaller value resistor to ground with a NPN or MOS transistor to select the higher frequency range (open collector or drain gates may be used for this purpose). In the above case, the smaller resistor would be 20,65K so that the parallel combination of the two resistors is the desired 20K.

Description of the formation of oblique signals in the Wave Form Shaper blocks (A and B)

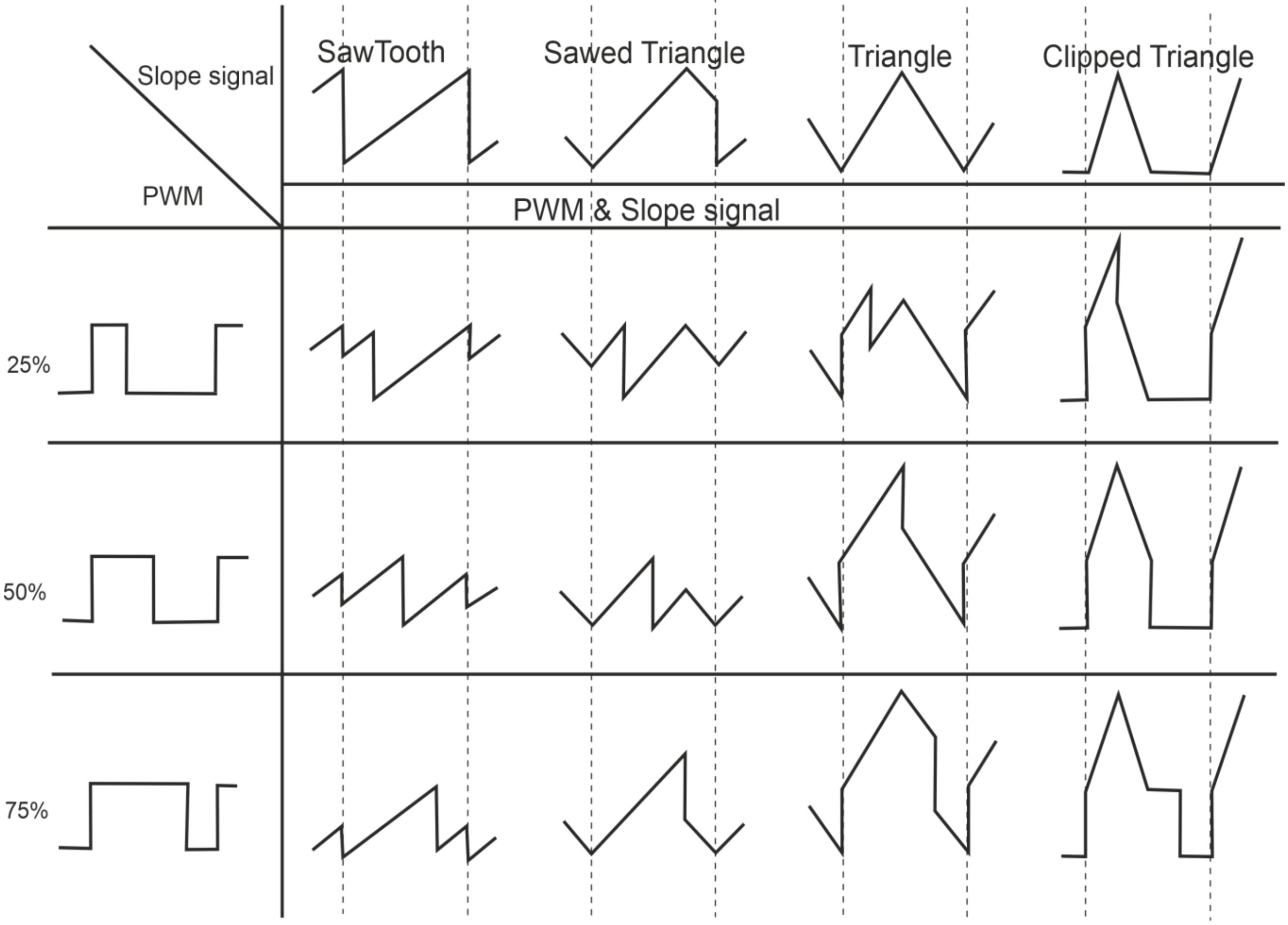



Fig. 2 Waveform shaper A and B

On Fig.2 main slope signals which can be received on output of WaveShaper blocks by changing Vwf on CV inputs of channels A and B (pin3, pin 12) are shown. In these blocks sawtooth charging signal on capacitor Ct converts in other slope signals. In order to remain form of signal stable while frequency is changed, control voltage Vwf must be in strong relationship with frequency of control signal on the base of external transistor which discharge Ct. Vwf can be changed in 0 - +5V range.

PWM signals from comparators outputs can be mixed with those slope signals depending from control voltages Pulse width CV A and Pulse width CV B (pin 6 and pin 8).

Those signals can be observed on pin 15 (combined output of VCA_AB which is connected through resistor 800 Ohm to pin 15 and after that via resistor 8k to the VCF input and GND). Signal amplitude on pin 15 is approximately ±150 – ±200 mV.

The purpose of pin15 - availability of adding to main signal any external signals (through resistor 47k).

It is possible to choose signal from VCA_A or from VCA_B by control signal Balance CV (pin 16). For choosing VCA_A - Balance CV should be +2V, for choosing VCA_B – Balance_CV should be -2V.

For controlling Quad Level Drive block and choosing A, B or A & B controlling voltage (pin 7) must applied according to Table 1 and Fig.3:

| Wave Select Control Voltage | | | Converter |
|---|---|---|---|
| min. | | max | |
| -2 V | -1 V | < -0,4 V | A & B |
| -0,2 V | +0,5 V | +1,1 V | B |
| +1,5 V | +2 V | +2,4 V | ----- |
| +2,8 V | + 3,4 V | +4 V | A |

Table 1

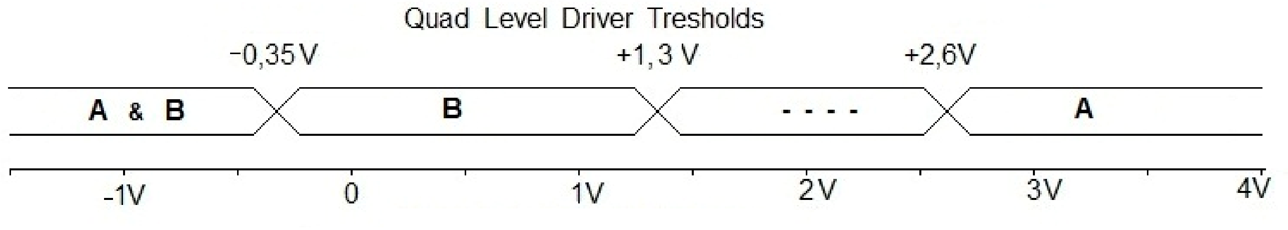



Fig.3 Wave select control voltage and switch thresholds

**Pulse Width Comparator**

The variable width pulse waveform is generated by comparing the sawtooth developed across the capacitor Ct with the pulse width control voltage Vpw. The pulse duty cycle is therefore Vpw/Vp, or put in terms of the other variables, is:

$$\text{duty cycle} = \frac{Vpw}{5/12\ Vcc * \alpha} \times 100\% = \frac{Vpw * f * Rt * Ct}{Vwf} \times 100\%$$

As can be seen, the duty cycle is also affected by the particular waveshape selected for the sloped waveform ($\alpha$ fixed). Therefore, to keep the duty cycle (pulse width) constant as the waveshape is changed with the waveform control voltage Vwf, the pulse width control voltage Vpw must also be changed in direct proportion.

For example to generate a 50% duty cycle pulse with Vcc = +12V will required a pulse width control voltage equal to -1,25V when sawtooth is selected ($\alpha$ =1/2), +2,5V when a perfect triangle is selected ($\alpha$ =1), and +5V when a 50% clipped triangle is being outputted ($\alpha$ =2).

**Waveform Selection**

The sloped waveforms and pulse waveforms from each converter may be independently selected and mixed together by using the waveform select control voltage and pulse width control voltages. The waveform select control voltage is a four-level control which allows the sloped waveforms to be selected (on) or not selected (off). From -5V to -1,5V-2,5V to -0,4V, both the sloped waveforms from converter A and from converter B are "on"; from -1,5V to +0,5V-0,2V to +1,1V, the sloped waveform from converter A turns "off" while that from B remains "on"; from +0,5V to +2V+1,5V to +2,4V, the sloped waveforms from both converters are "off"; and from +2V to +5V+2,8V to +4V, the sloped waveform from converter A is now "on" while that from converter B remains "off".

Since the waveform select input is also a high impedance input, the necessary voltages may be generated in the same manner as the other control voltages — multiplexed onto a hold capacitor from the system DAC. Another method for deriving the four select voltages is simply to use two logic level outputs which drive the resistor-transistor network shown in Figure 2. For this method to work properly, the two digital outputs should swing from near zero to at least +4,5 volts,

The pulse waveforms from each converter may be turned "off" simply by setting the duty cycle (pulse width) to 0% with Vpw, and may be turned "on" by setting the duty cycle to anything greater than 0%. To ensure that the pulse is completely "off", it is recommended that Vpw be set slightly negative (e.g. -50 to -500 mV.

### Trimming the Waveform Converters

As can be seen from the equation for waveshape control voltage Vwf, the value of Vwf required to produce a particular waveform ($\alpha$< fixed) is a function also of the conversion resistance Rt and timing capacitor Ct. Since these two components have tolerance (typically 1% or 5% for Rt and 5% or 10% for Ct), the required Vwf will also have a tolerance. In addition, there is an internal conversion error not shown in the equation of ±5% (±15% worst case). The result is that with the theoretical Vwf required to generate a particular waveform, that waveform could have a 20% or more error in waveshape. For a sawtooth or clipped triangle, such an error is only mildly discernable; but for a triangle waveform, errors in excess of 5% can be easily heard.

If lower error in the waveshape is required, there are two possible methods for trimming. In both methods, the trimming needs only to be done at one point since the V/I converter is very linear and has low offset. The recommended point is at a Vwf between 0,2V and 1V.

The first method is simply to trim the conversion resistance for the proper waveshape (triangle is easiest) at a given Vwf and frequency. Then all other waveshapes at other frequencies will follow the theoretical values for Vwf. Besides requiring manual trimming, this method becomes impractical when range switching of Rt is used.

The second method is to trim Vwf with software for the proper waveshape at a particular frequency. Then once the corrected Vwf is found for this one waveform and frequency, the waveshape voltages required for all other waveforms and frequencies are derived from this value simply through calculation.

The easiest method for automatic adjustment of Vwf utilizes the fact that when the pulse width control voltage Vpw is 5/12 Vcc, the pulse width will be 100% when the sloped waveform is a perfect triangle regardless of the values of Rt, Ct, or the internal conversion error of the V/I converter. Thus, the software adjusts Vwf at one particular frequency using successive approximation techniques until the pulse output just begins to produce a very narrow pulse. The resulting error in the corresponding triangle wave will be typically less than 1%. The very narrow pulse can be detected simply with a set-reset flip-flop. Since the accuracy of this method is partially dependent on Vpw being exactly 5/12 Vcc, it is recommended that the Vcc and the reference for the DAC be derived from the same source, and that the full scale output of the DAC be trimmed to within 1% relative to Vcc. An added benefit of trimming the sloped waveforms in this manner is that the duty cycle of the pulse waveform will also be corrected.

### Output VCAs

The microcircuit contains two panning output amplifiers VCA_L and VCA_R with current output. The transfer of current to the amplifier output VCA_L or VCA_R is determined by the control voltage at the "Pan CV" input. If the control voltage at the Pan CV input is +0.15 V, only the VCA_L amplifier will be selected, if the Pan CV voltage is +4.5 V, only the VCA_R amplifier will be selected. The maximum control voltage range at the Pan CV input is from 0 to +5 V.

The maximum total output current taken from the outputs of these amplifiers can be set by the value of the resistor Rgain. With Rgain = 4.7K, the maximum output current is approximately ± 150 μA, with Rgain = 0, the maximum output current is approximately ± 400 μA. To mix the signals of several AS3397 microcircuits, their respective outputs can be connected together. To convert the currents from the outputs of the amplifiers VCA_L and VCA_R into output voltages, external operational amplifiers can be supplied, as shown in the diagram in Fig. 4.

The gain of amplifiers VCA_L and VCA_R depends on the voltage at the Linear Gain CV input. Maximum gain will be at Linear Gain CV equal to +4.5 V, minimum gain will be at Linear Gain CV equal to 0.15 V. Maximum control voltage range of Linear Gain CV is from 0 to +5 V.

### External Signal Inputs

The microcircuit has a special current input "VCF Input" for mixing external signals. Thus, external signals can be mixed with internal signals through the adder at the VCF input, for this there is a separate current input (pin 15). For example, external signals can be applied to pin 15 through an external 47 kΩ resistor. Then, with an external signal swing of ± 1 V, the maximum swing current at the outputs of the VCA-L or VCA-R amplifiers will be approximately ± 80 μA

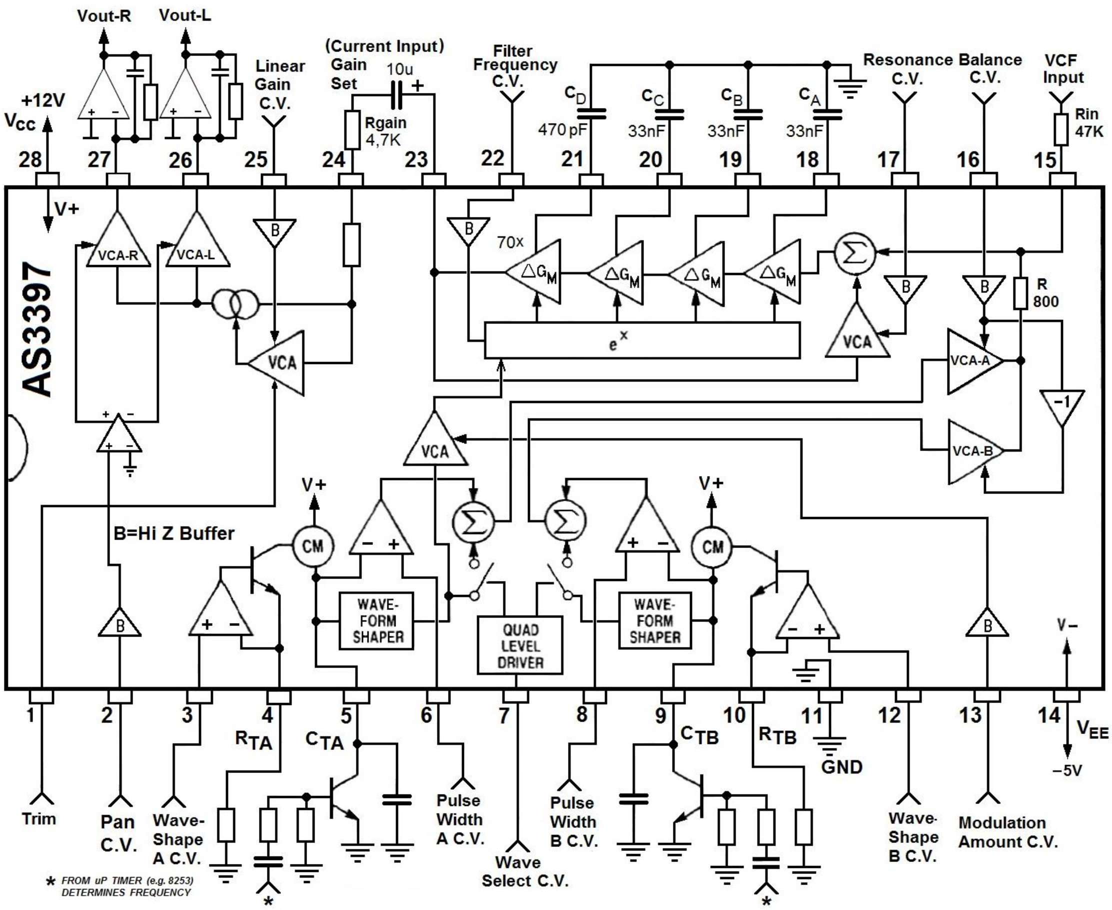
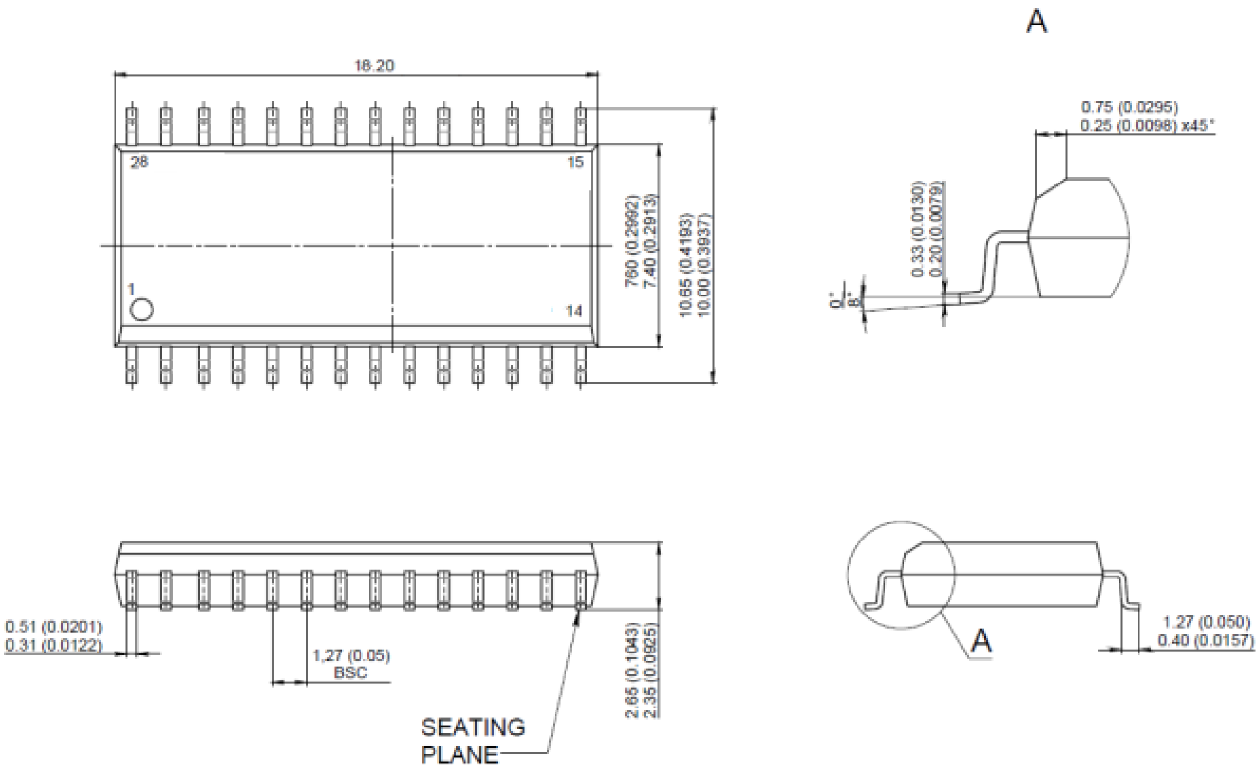



Fig.4

| Device type | Package |
|---|---|
| AS3397D | SOICW-28 (300mil) |

**28-Lead Standard Small Outline Package (SOIC_W)**
**Wide Body**
**Dimensions shown in millimeters and (inches)**




Revision history

| Date | Revision | Changes |
|---|---|---|
| 15-Jan-2020 | 1 | Short version |
| 09-Jul-2021 | 2 | Initial version |
| 29-Oct-2021 | 3 | Initial revision – minor changes |
| 10-Mar-2023 | 4 | Typing errors correction |