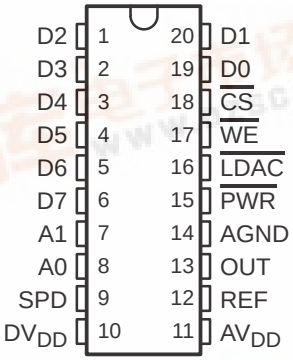
2.7 V TO 5.5 V LOW POWER 12-BIT DIGITAL-TO-ANALOG CONVERTERS WITH INTERNAL REFERENCE AND POWER DOWN

SLAS190B − MARCH 1999 − REVISED AUGUST 2003

- 12-Bit Voltage Output DAC
- Programmable Internal Reference
- Programmable Settling Time vs Power Consumption
  - 1 μs in Fast Mode
  - 3.5 μs in Slow Mode
- 8-Bit μController Compatible Interface
- Differential Nonlinearity . . . <0.5 LSB Typ
- Voltage Output Range . . . 2x the Reference Voltage
- Monotonic Over Temperature

DW OR PW PACKAGE
(TOP VIEW)



applications

- Digital Servo Control Loops
- Digital Offset and Gain Adjustment
- Industrial Process Control
- Machine and Motion Control Devices
- Mass Storage Devices

description

The TLV5633 is a 12-bit voltage output digital-to-analog converter (DAC) with an 8-bit microcontroller compatible parallel interface. The 8 LSBs, the 4 MSBs, and 5 control bits are written using three different addresses. Developed for a wide range of supply voltages, the TLV5633 can be operated from 2.7 V to 5.5 V.

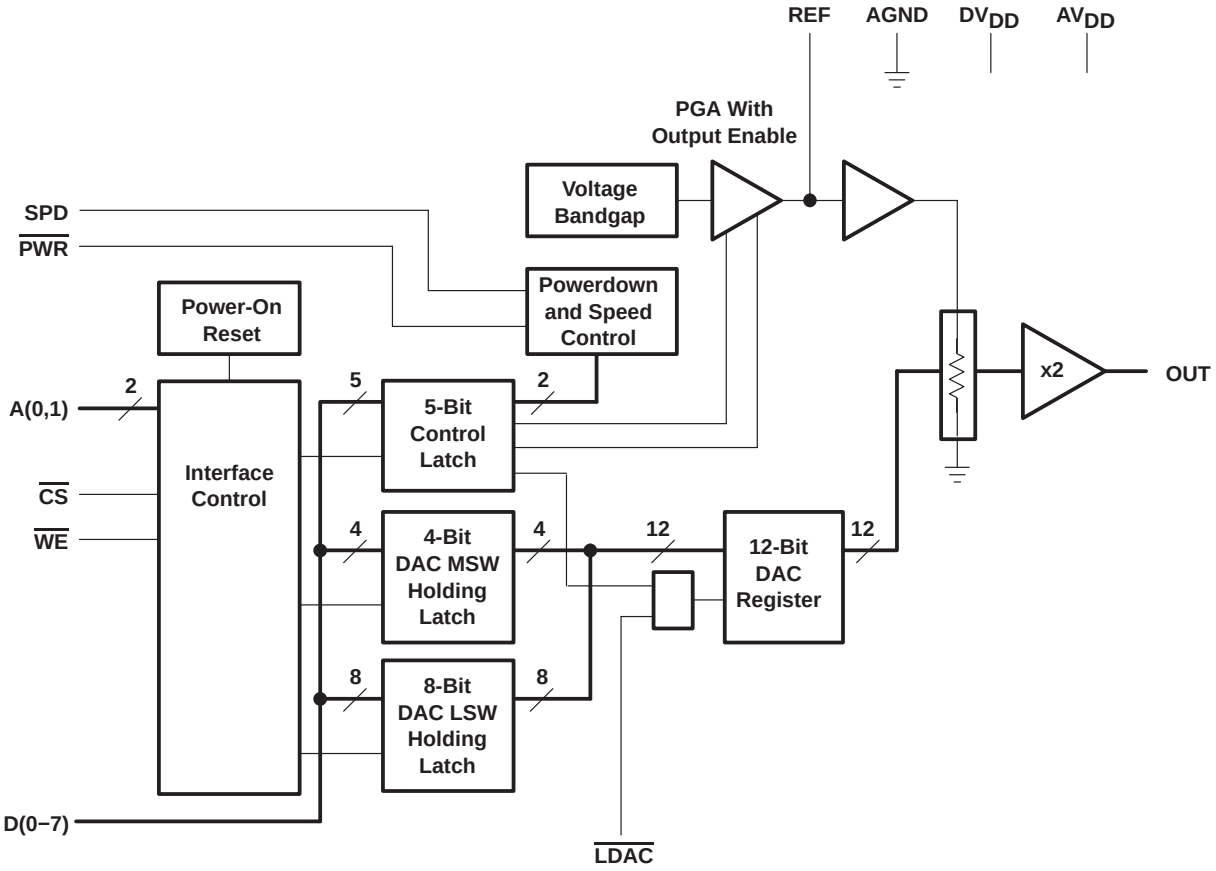
The resistor string output voltage is buffered by a x2 gain rail-to-rail output buffer. The buffer features a Class A (slow mode: AB) output stage to improve stability and reduce settling time. The programmable settling time of the DAC allows the designer to optimize speed versus power dissipation. With its on-chip programmable precision voltage reference, the TLV5633 simplifies overall system design. Because of its ability to source up to 1 mA, the internal reference can also be used as a system reference. The settling time and the reference voltage can be chosen by a control register.

Implemented with a CMOS process, the device is designed for single supply operation from 2.7 V to 5.5 V. It is available in 20-pin SOIC and TSSOP packages in standard commercial and industrial temperature ranges.

AVAILABLE OPTIONS

T_A	PACKAGE	
	SOIC (DW)	TSSOP (PW)
0°C to 70°C	TLV5633CDW	TLV5633CPW
−40°C to 85°C	TLV5633IDW	TLV5633IPW

functional block diagram



Terminal Functions

TERMINAL NAME	TERMINAL NO.	I/O/P	DESCRIPTION
A1, A0	7, 8	I	Address input
AGND	14	P	Ground
AV_{DD}	11	P	Positive power supply (analog part)
$\overline{CS}$	18	I	Chip select. Digital input active low, used to enable/disable inputs
D0 − D1	19, 20	I	Data input
D2 − D7	1−6	I	Data input
DV_{DD}	10	P	Positive power supply (digital part)
$\overline{LDAC}$	16	I	Load DAC. Digital input active low, used to load DAC output
OUT	13	O	DAC analog voltage output
$\overline{PWR}$	15	I	Power down. Digital input active low
REF	12	I/O	Analog reference voltage input/output
SPD	9	I	Speed select. Digital input
$\overline{WE}$	17	I	Write enable. Digital input active low, used to latch data

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage (DV_{DD}, AV_{DD} to AGND) . . . . . 7 V
Supply voltage difference range, $AV_{DD} - DV_{DD}$ . . . . . − 2.8 V to 2.8 V
Reference input voltage range . . . . . − 0.3 V to V_{DD} + 0.3 V
Digital input voltage range . . . . . − 0.3 V to V_{DD} + 0.3 V
Operating free-air temperature range, T_A: TLV5633C . . . . . 0°C to 70°C
TLV5633I . . . . . −40°C to 85°C
Storage temperature range, T_{stg} . . . . . −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . . 260°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

recommended operating conditions

		MIN	NOM	MAX	UNIT
Supply voltage, DV_{DD}, AV_{DD}	5-V operation	4.5	5	5.5	V
	3-V operation	2.7	3	3.3	V
Supply voltage difference, $\Delta V_{DD} = AV_{DD} - DV_{DD}$		0	0	0	V
Power on reset voltage, POR		0.55		2	V
High-level digital input voltage, V_{IH}	DV_{DD} = 2.7 V	2			V
	DV_{DD} = 5.5 V	2.4			
Low-level digital input voltage, V_{IL}	DV_{DD} = 2.7 V			0.6	V
	DV_{DD} = 5.5 V			1	
Reference voltage, V_{ref} to REF terminal (5-V supply), See Note 1		AGND	2.048	AV_{DD}−1.5	V
Reference voltage, V_{ref} to REF terminal (3-V supply), See Note 1		AGND	1.024	AV_{DD}−1.5	V
Load resistance, R_L		2			kΩ
Load capacitance, C_L				100	pF
Operating free-air temperature, T_A	TLV5633C	0		70	°C
	TLV5633I	−40		85	

NOTE 1: Due to the x2 output buffer, a reference input voltage ≥ $AV_{DD/2}$ causes clipping of the transfer function. The output buffer of the internal reference must be disabled, if an external reference is used.

electrical characteristics over recommended operating free-air temperature range, V_{ref} = 2.048 V, V_{ref} = 1.024 V (unless otherwise noted)

power supply

PARAMETER		TEST CONDITIONS				MIN	TYP	MAX	UNIT
I_{DD}	Power supply current	No load, All inputs = AGND or DV_{DD}, DAC latch = 0x800	AV_{DD} = 5 V, DV_{DD} = 5 V	REF on	Fast		2.3	2.8	mA
					Slow		1.3	1.6	mA
				REF off	Fast		1.9	2.4	mA
					Slow		0.9	1.2	mA
			AV_{DD} = 3 V, DV_{DD} = 3 V	REF on	Fast		2.1	2.6	mA
					Slow		1.2	1.5	mA
				REF off	Fast		1.8	2.3	mA
					Slow		0.9	1.1	mA
	Power down supply current						0.01	1	μA
PSRR	Power supply rejection ratio	Zero scale, external reference, See Note 2					−60		dB
		Full scale, external reference, See Note 3					−60		

NOTES: 2. Power supply rejection ratio at zero scale is measured by varying AV_{DD} and is given by:
PSRR = 20 log [(E_{ZS}(AV_{DD}max) − E_{ZS}(AV_{DD}min))/AV_{DD}max]
3. Power supply rejection ratio at full scale is measured by varying AV_{DD} and is given by:
PSRR = 20 log [(E_G(AV_{DD}max) − E_G(AV_{DD}min))/AV_{DD}max]

static DAC specifications

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Resolution			12		bits
INL	Integral nonlinearity, end point adjusted	R_L = 10 kΩ, C_L = 100 pF, See Note 4		±1.2	±3	LSB
DNL	Differential nonlinearity	R_L = 10 kΩ, C_L = 100 pF, See Note 5		±0.3	±0.5	LSB
E_{ZS}	Zero-scale error (offset error at zero scale)	See Note 6			20	mV
E_{ZS} TC	Zero-scale-error temperature coefficient	See Note 7		20		ppm/°C
E_G	Gain error	See Note 8			±0.3	% full scale V
E_G TC	Gain error temperature coefficient	See Note 9		20		ppm/°C

NOTES: 4. The relative accuracy or integral nonlinearity (INL) sometimes referred to as linearity error, is the maximum deviation of the output from the line between zero and full scale excluding the effects of zero code and full-scale errors (see text).
5. The differential nonlinearity (DNL) sometimes referred to as differential error, is the difference between the measured and ideal 1 LSB amplitude change of any two adjacent codes. Monotonic means the output voltage changes in the same direction (or remains constant) as a change in the digital input code.
6. Zero-scale error is the deviation from zero voltage output when the digital input code is zero (see text).
7. Zero-scale-error temperature coefficient is given by: E_{ZS} TC = [E_{ZS} (T_{max}) − E_{ZS} (T_{min})]/2V_{ref} × 10^6/(T_{max} − T_{min}).
8. Gain error is the deviation from the ideal output (2V_{ref} − 1 LSB) with an output load of 10 kΩ excluding the effects of the zero-error.
9. Gain temperature coefficient is given by: E_G TC = [E_G(T_{max}) − E_G (T_{min})]/2V_{ref} × 10^6/(T_{max} − T_{min}).

output specifications

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_O	Output voltage	R_L = 10 kΩ			AV_{DD}−0.4	V
	Output load regulation accuracy	V_O = 4.096 V, 2.048 V, R_L = 2 kΩ			±0.29	% full scale V

electrical characteristics over recommended operating free-air temperature range, V_{ref} = 2.048 V, V_{ref} = 1.024 V (unless otherwise noted) (Continued)

reference pin configured as output (REF)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{ref(OUTL)}$	Low reference voltage		1.003	1.024	1.045	V
$V_{ref(OUTH)}$	High reference voltage	AV_{DD} = DV_{DD} > 4.75 V	2.027	2.048	2.069	V
$I_{ref(source)}$	Output source current				1	mA
$I_{ref(sink)}$	Output sink current		−1			mA
PSRR	Power supply rejection ratio			−48		dB

reference pin configured as input (REF)

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
V_I	Input voltage				0		AV_{DD}−1.5	V
R_I	Input resistance					10		MΩ
C_I	Input capacitance					5		pF
	Reference input bandwidth	REF = 0.2 V_{pp} + 1.024 V dc		Fast		900		kHz
				Slow		500		
	Harmonic distortion, reference input	REF = 1 V_{pp} + 2.048 V dc, AV_{DD} = 5 V	10 kHz	Fast		−87		dB
				Slow		−77		
			50 kHz	Fast		−74		dB
				Slow		−61		
			100 kHz	Fast		−66		dB
	Reference feedthrough	REF = 1 V_{pp} at 1 kHz + 1.024 V dc (see Note 10)				−80		dB

NOTE 10: Reference feedthrough is measured at the DAC output with an input code = 0x000.

digital inputs

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{IH}	High-level digital input current	V_I = DV_{DD}			1	µA
I_{IL}	Low-level digital input current	V_I = 0 V	−1			µA
C_I	Input capacitance			8		pF

operating characteristics over recommended operating free-air temperature range, V_{ref} = 2.048 V, and V_{ref} = 1.024 V, (unless otherwise noted)

analog output dynamic performance

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{s(FS)}$	Output settling time, full scale	R_L = 10 kΩ, C_L = 100 pF, See Note 11	Fast		1	3	µs
			Slow		3.5	7	
$t_{s(CC)}$	Output settling time, code to code	R_L = 10 kΩ, C_L = 100 pF, See Note 12	Fast		0.5	1.5	µs
			Slow		1	2	
SR	Slew rate	R_L = 10 kΩ, C_L = 100 pF, See Note 13	Fast	6	10		V/µs
			Slow	1.2	1.7		
	Glitch energy	$\overline{DIN}$ = 0 to 1, $\overline{CS}$ = V_{DD}, f_{CLK} = 100 kHz,			5		nV−S
SNR	Signal-to-noise ratio	f_S = 480 kSPS, R_L = 10 kΩ,, f_B = 20 kHz, f_{out} = 1 kHz, C_L = 100 pF		73	78		dB
SINAD	Signal-to-noise + distortion			61	67		
THD	Total harmonic distortion				−69	−62	
SFDR	Spurious free dynamic range			63	74		

NOTES: 11. Settling time is the time for the output signal to remain within ±0.5 LSB of the final measured value for a digital input code change of 0x020 to 0xFDF or 0xFDF to 0x020 respectively.
12. Settling time is the time for the output signal to remain within ±0.5 LSB of the final measured value for a digital input code change of one count.
13. Slew rate determines the time it takes for a change of the DAC output from 10% to 90% full-scale voltage.

digital input timing requirements

		MIN	NOM	MAX	UNIT
$t_{su(CS-WE)}$	Setup time, $\overline{CS}$ low before negative $\overline{WE}$ edge	15			ns
$t_{su(D)}$	Setup time, data ready before positive $\overline{WE}$ edge	10			ns
$t_{su(A)}$	Setup time, addresses ready before positive $\overline{WE}$ edge	20			ns
$t_{h(DA)}$	Hold time, data and addresses held valid after positive $\overline{WE}$ edge	5			ns
$t_{su(WE-LD)}$	Setup time, positive $\overline{WE}$ edge before $\overline{LDAC}$ low	5			ns
$t_{wH(WE)}$	Pulse duration, $\overline{WE}$ high	20			ns
$t_{w(LD)}$	Pulse duration, $\overline{LDAC}$ low	23			ns

PARAMETER MEASUREMENT INFORMATION

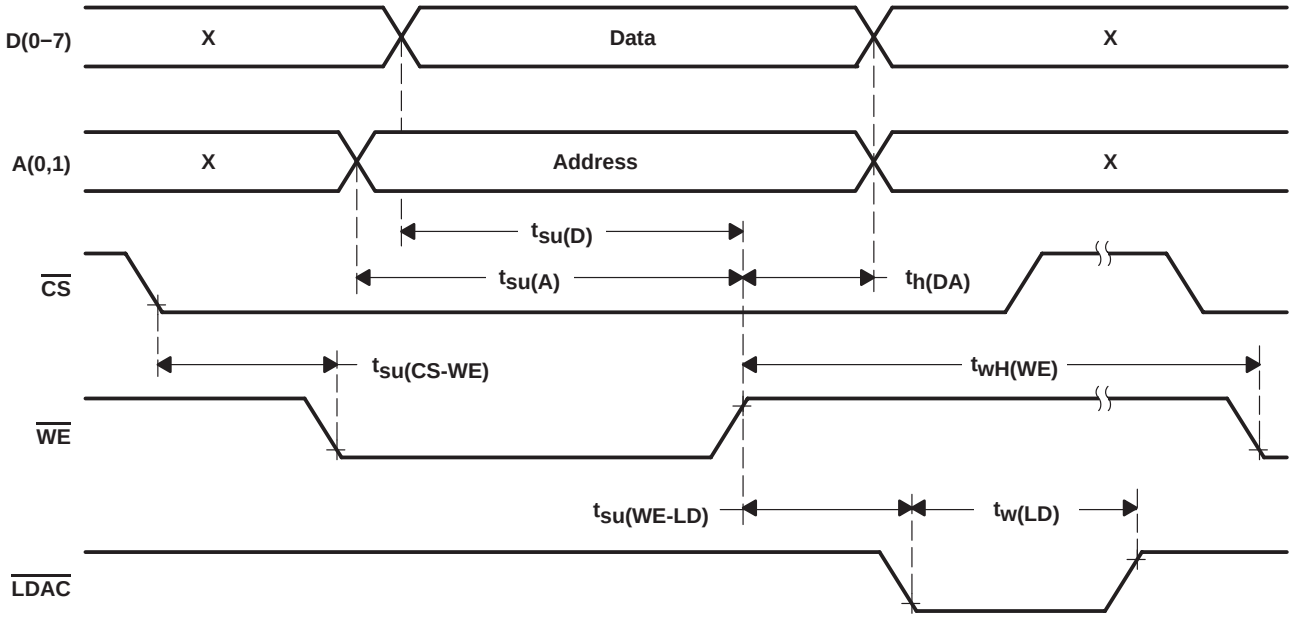


Figure 1. Timing Diagram

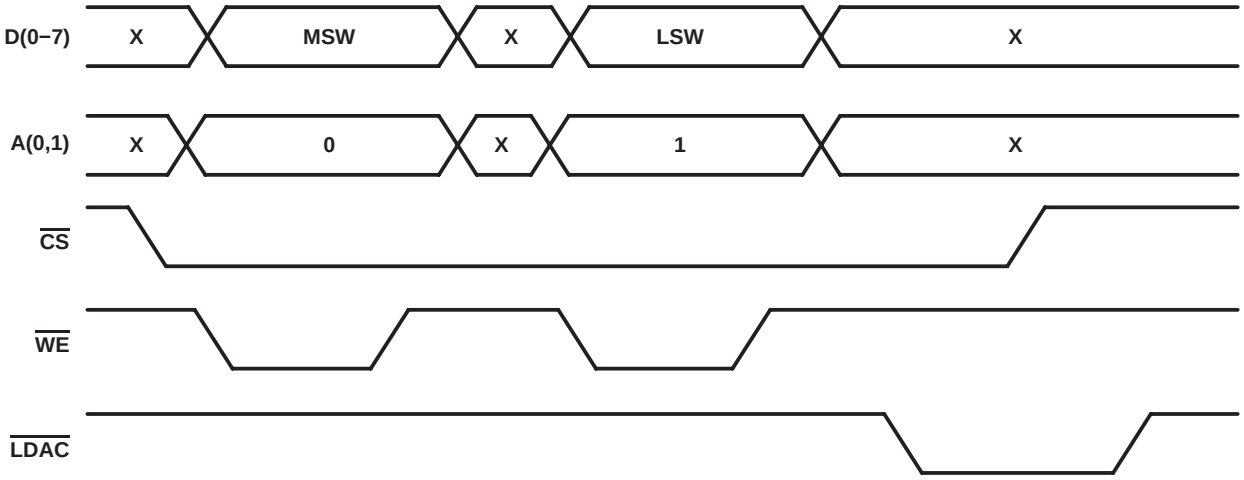


Figure 2. Example of a Complete Write Cycle (MSW, LSW) Using $\overline{\text{LDAC}}$ for Update

PARAMETER MEASUREMENT INFORMATION

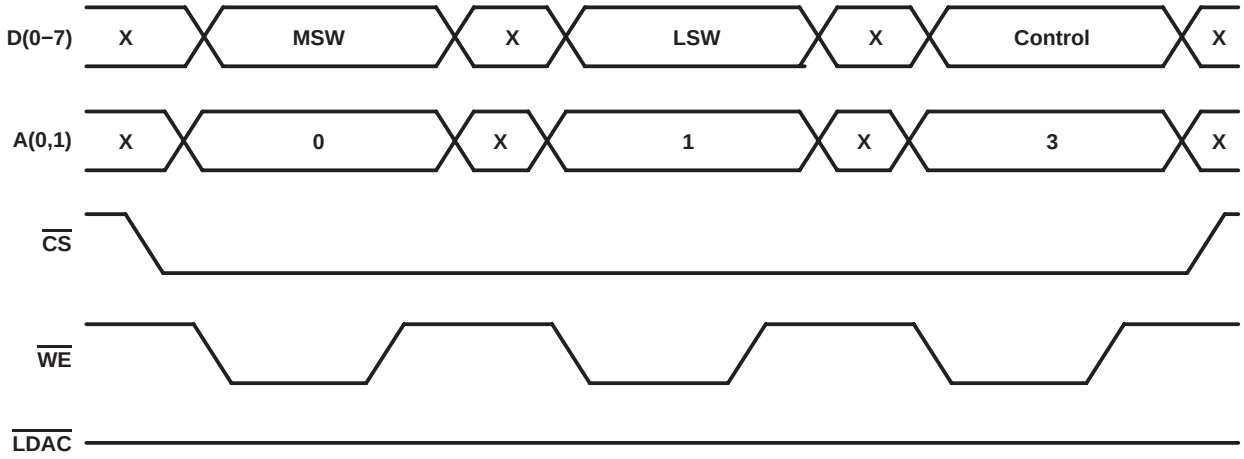


Figure 3. Example of a Complete Write Cycle (MSW, LSW, Control)

TYPICAL CHARACTERISTICS

DIFFERENTIAL NONLINEARITY ERROR

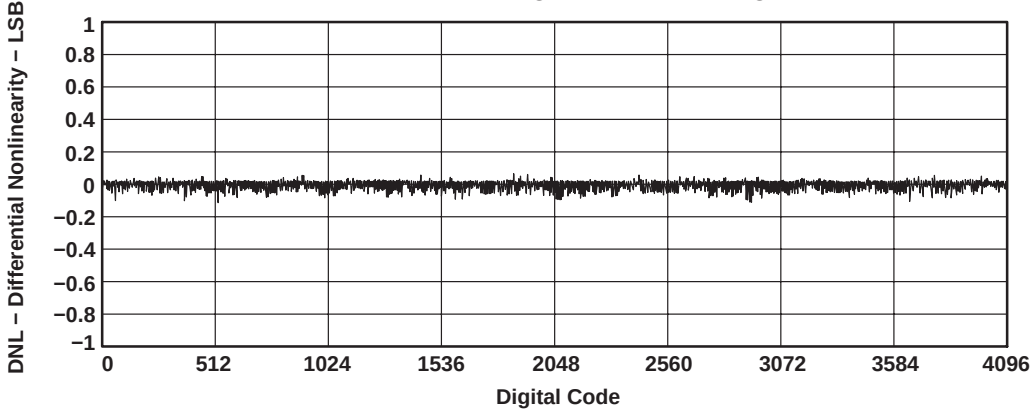


Figure 4

INTEGRAL NONLINEARITY ERROR

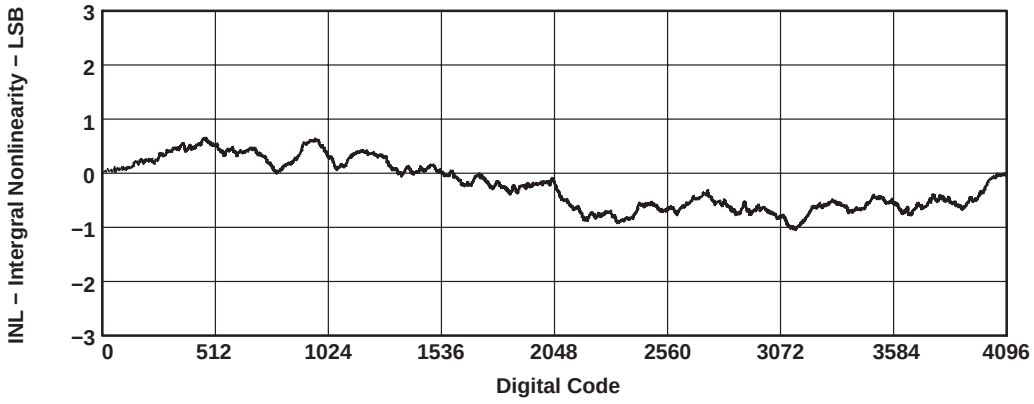


Figure 5

TYPICAL CHARACTERISTICS

MAXIMUM OUTPUT VOLTAGE
vs
LOAD CURRENT

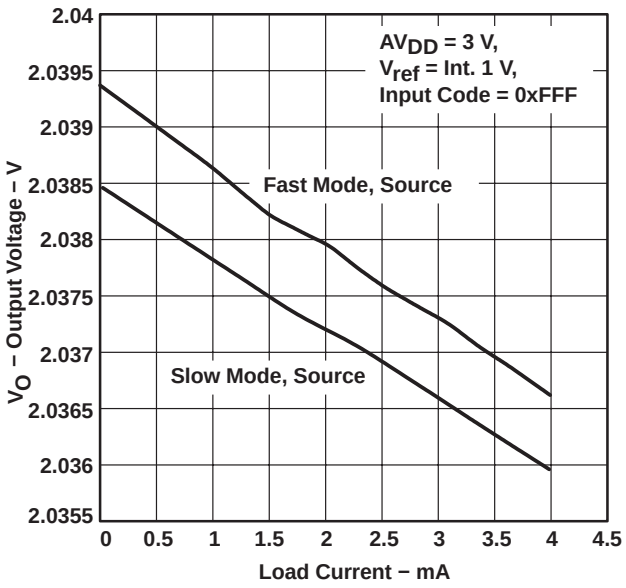


Figure 6

MAXIMUM OUTPUT VOLTAGE
vs
LOAD CURRENT

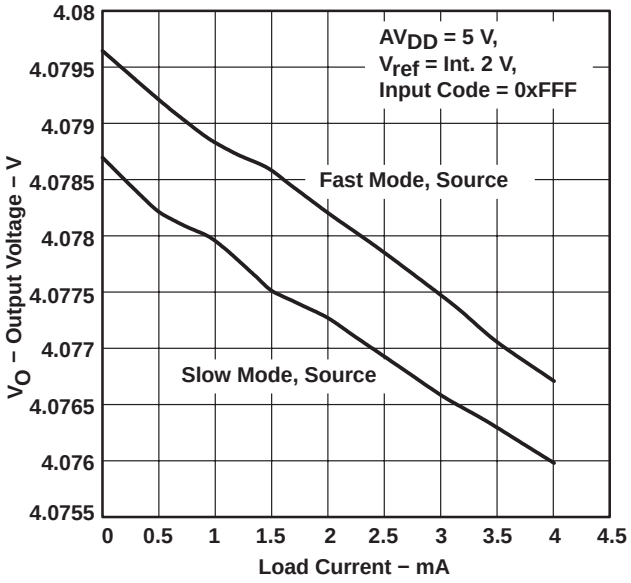


Figure 7

MINIMUM OUTPUT VOLTAGE
vs
LOAD CURRENT

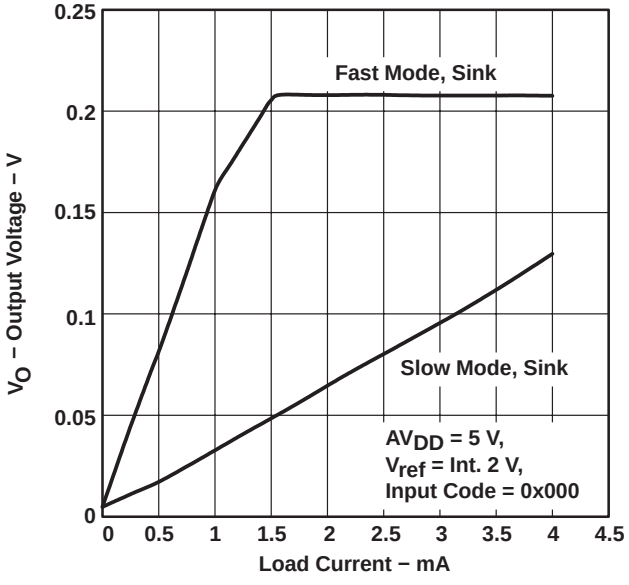


Figure 8

MINIMUM OUTPUT VOLTAGE
vs
LOAD CURRENT

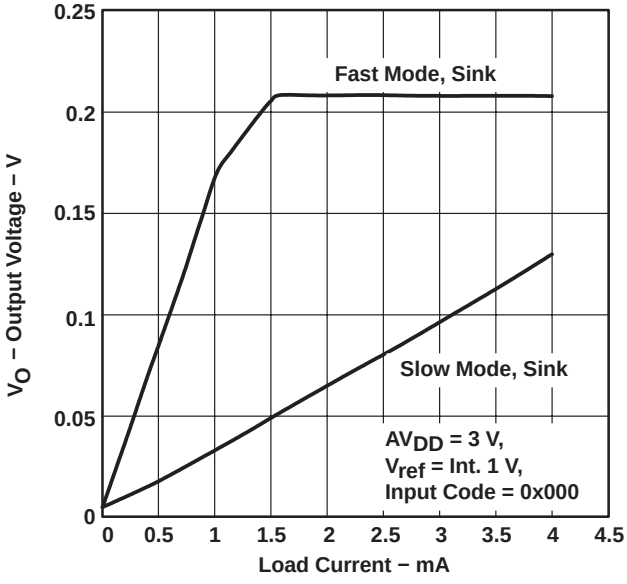


Figure 9

TYPICAL CHARACTERISTICS

**TOTAL HARMONIC DISTORTION
vs
FREQUENCY**

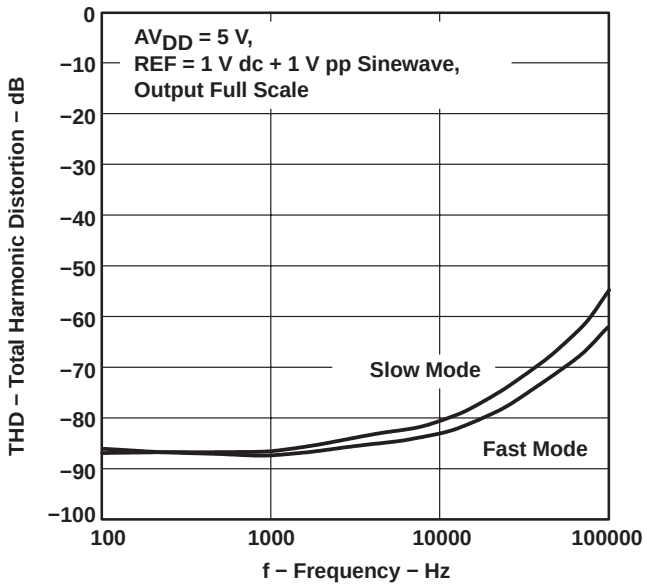


Figure 10

**TOTAL HARMONIC DISTORTION AND NOISE
vs
FREQUENCY**

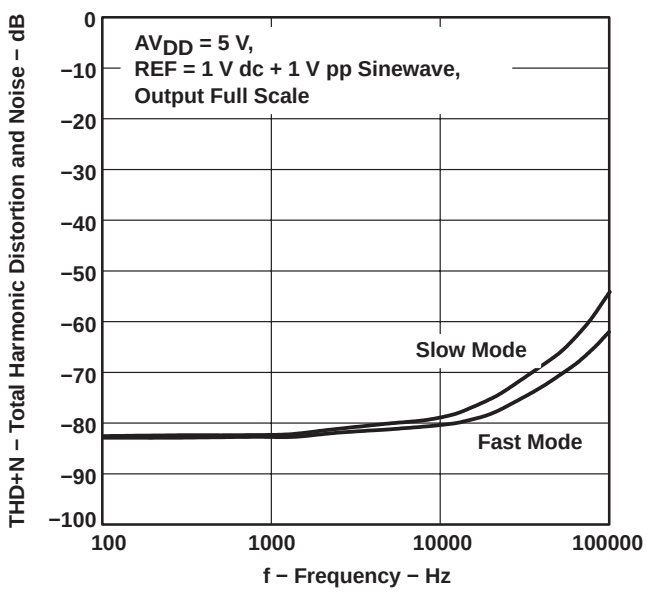


Figure 11

**POWER DOWN SUPPLY CURRENT
vs
TIME**

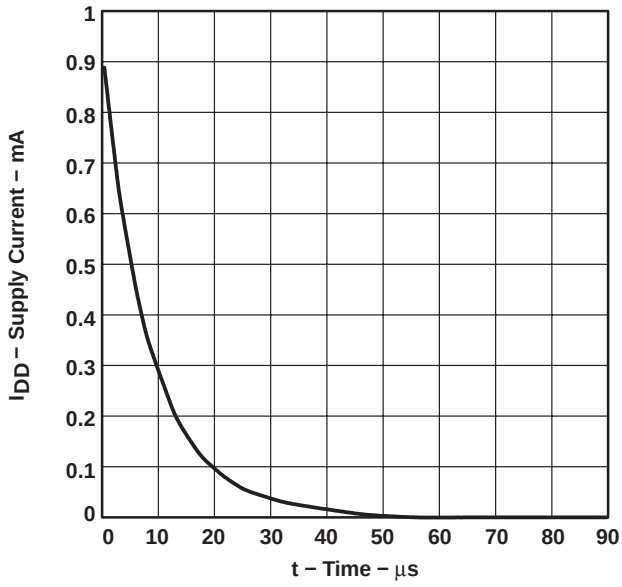


Figure 12

APPLICATION INFORMATION

general function

The TLV5633 is a 12-bit, single supply DAC, based on a resistor string architecture. It consists of a parallel interface, a speed and power down control logic, a programmable internal reference, a resistor string, and a rail-to-rail output buffer. The output voltage (full scale determined by reference) is given by:

$$2\ \mathrm{REF}\ \frac{\mathrm{CODE}}{0\times1000}\ [\mathrm{V}]$$

Where REF is the reference voltage and CODE is the digital input value in the range 0x000 to 0xFFF. A power on reset initially puts the internal latches to a defined state (all bits zero).

parallel interface

The device latches data on the positive edge of $\overline{WE}$. It must be enabled with $\overline{CS}$ low. Whether the data is written to one of the DAC holding latches (MSW, LSW) or the control register depends on the address bits A1 and A0. $\overline{LDAC}$ low updates the DAC with the value in the holding latch. $\overline{LDAC}$ is an asynchronous input and can be held low, if a separate update is not necessary. However, to control the DAC using the load feature, there should be approximately a 5 ns delay after the positive $\overline{WE}$ edge before driving $\overline{LDAC}$ low. Two more asynchronous inputs, SPD and $\overline{PWR}$ control the settling times and the power-down mode:

SPD:	Speed control	1 → fast mode	0 → slow mode
$\overline{PWR}$:	Power control	1 → normal operation	0 → power down

It is also possible to program the different modes (fast, slow, power down) and the DAC update latch using the control register. The following tables list the possible combinations of control signals and control bits.

PIN	BIT	MODE
SPD	SPD	
0	0	Slow
0	1	Fast
1	0	Fast
1	1	Fast

PIN	BIT	POWER
$\overline{PWR}$	PWD	
0	0	Down
0	1	Down
1	0	Normal
1	1	Down

PIN	BIT	LATCH
$\overline{LDAC}$	RLDAC	
0	0	Transparent
0	1	Transparent
1	0	Hold
1	1	Transparent

APPLICATION INFORMATION

data format

The TLV5633 writes data either to one of the DAC holding latches or to the control register depending on the address bits A1 and A0.

ADDRESS BITS

A1	A0	REGISTER
0	0	DAC LSW holding
0	1	DAC MSW holding
1	0	Reserved
1	1	Control

The following table lists the meaning of the bits within the control register.

D7	D6	D5	D4	D3	D2	D1	D0
X	X	X	REF1	REF0	RLDAC	PWR	SPD
X†	X†	X†	0†	0†	0†	0†	0†

† Default values
X: don't care
SPD: Speed control bit 1 → fast mode 0 → slow mode
PWR: Power control bit 1 → power down 0 → normal operation
RLDAC: Load DAC latch 1 → latch transparent 0 → DAC latch controlled by $\overline{\text{LDAC}}$ pin

REF1 and REF0 determine the reference source and the reference voltage.

REFERENCE BITS

REF1	REF0	REFERENCE
0	0	External
0	1	1.024 V
1	0	2.048 V
1	1	External

If an external reference voltage is applied to the REF pin, external reference must be selected.

layout considerations

To achieve the best performance, it is recommended to have separate power planes for GND, AV_{DD}, and DV_{DD}. Figure 13 shows how to lay out the power planes for the TLV5633. As a general rule, digital and analog signals should be separated as wide as possible. To avoid crosstalk, analog and digital traces must not be routed in parallel. The two positive power planes (AV_{DD} and DV_{DD}) should be connected together at one point with a ferrite bead.

A 100-nF ceramic low series inductance capacitor between DV_{DD} and GND and a 1-µF tantalum capacitor between AV_{DD} and GND placed as close as possible to the supply pins are recommended for optimal performance.

APPLICATION INFORMATION

layout considerations (continued)

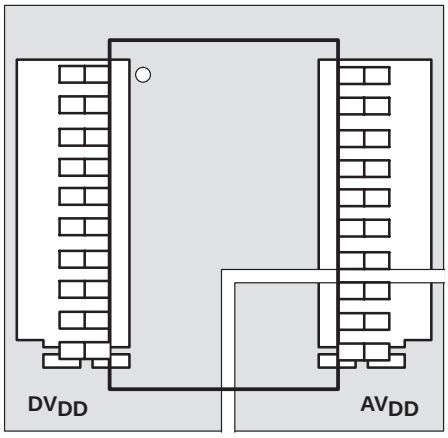


Figure 13. TLV5633 Board Layout

linearity, offset, and gain error using single end supplies

When an amplifier is operated from a single supply, the voltage offset can still be either positive or negative. With a positive offset, the output voltage changes on the first code change. With a negative offset the output voltage may not change with the first code, depending on the magnitude of the offset voltage.

The output amplifier attempts to drive the output to a negative voltage. However, because the most negative supply rail is ground, the output cannot drive below ground and clamps the output at 0 V.

The output voltage remains at zero until the input code value produces a sufficient positive output voltage to overcome the negative offset voltage, resulting in the transfer function shown in Figure 14.

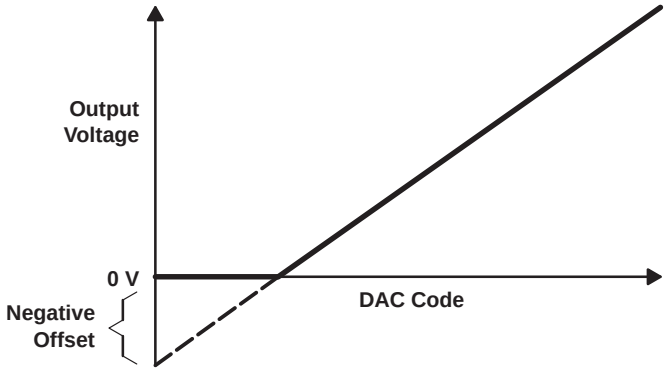


Figure 14. Effect of Negative Offset (Single Supply)

APPLICATION INFORMATION

The offset error, not the linearity error, produces this breakpoint. The transfer function would have followed the dotted line if the output buffer could drive below the ground rail.

For a DAC, linearity is measured between zero input code (all inputs 0) and full scale code (all inputs 1) after offset and full scale are adjusted out or accounted for in some way. However, single supply operation does not allow for adjustment when the offset is negative due to the breakpoint in the transfer function. So the linearity is measured between full scale code and the lowest code that produces a positive output voltage.

TLV5633 interfaced to an Intel MCS®51 controller

The circuit in Figure 15 shows how to interface the TLV5633 to an Intel MCS®51 microcontroller. The address bus and the data bus of the controller are multiplexed on port 0 (non page mode) to save port pins. To separate the address bits and the data bits, the controller provides a dedicated signal, address latch enable (ALE), which is connected to a latch at port 0.

An address decoder is required to generate the chip select signal for the TLV5633. In this example, a simple 3-to-8 decoder (74AC138) is used for the interface as shown in Figure 15. The DAC is memory mapped at addresses 0x8000/1/2/3 within the data memory address space and mirrored every 32 address locations (0x8020/1/2/3, 0x8040/1/2/3, etc.). In a typical microcontroller system, programmable logic should be used to generate the chip select signals for the entire system.

The data pins and the $\overline{WE}$ pin of the TLV5633 can be connected directly to the multiplexed address and data bus and the $\overline{WR}$ signal of the controller.

The application uses the TLV5633 device's internal reference at 2.048 V. The $\overline{LDAC}$ pin is connected to P3.5 and is used to update the DAC after both data bytes have been written.

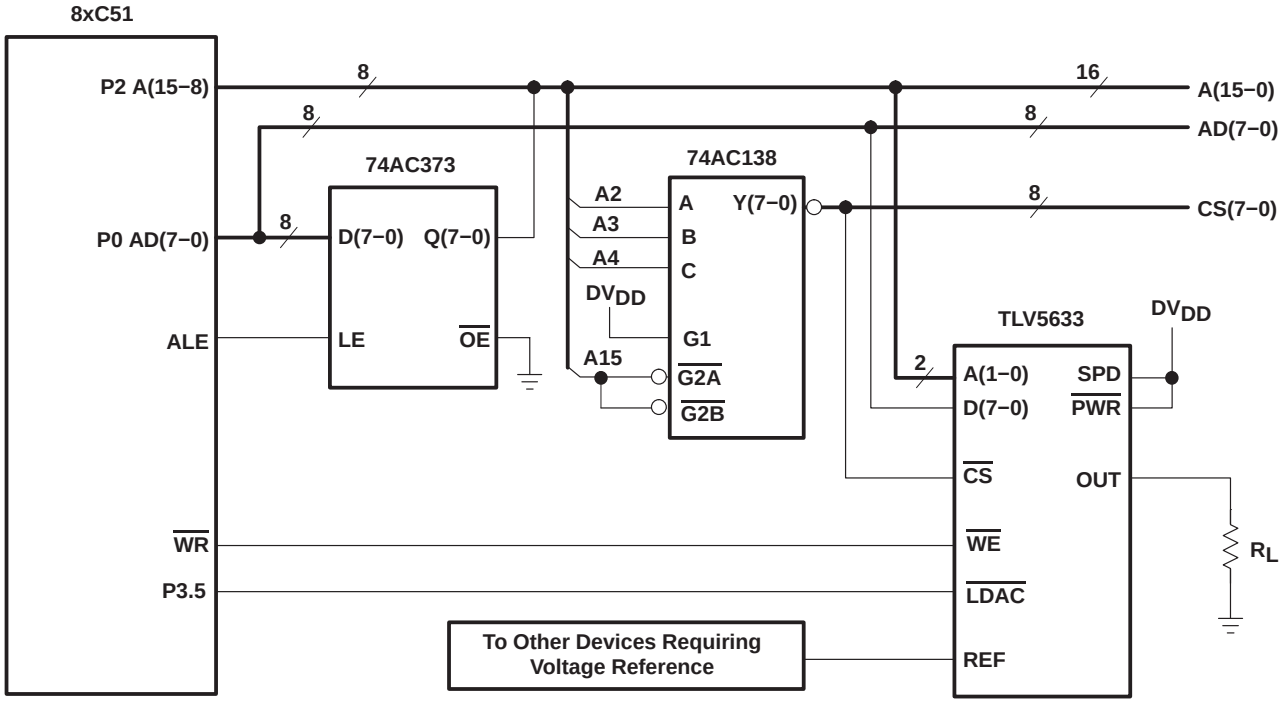


Figure 15. TLV5633 Interfaced to an Intel MCS®51 Controller

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APPLICATION INFORMATION

software

In the following example, the code generates a waveform at 20 KSPS with 32 samples stored in a table within the program memory space of the microcontroller.

The waveform data is located in the program memory space at segment SINTBL beginning with the MSW of the first 16-bit word (the 4 MSBs are ignored), followed by the LSW. Two bytes are required for each DAC word (the table is not shown in the code example).

The program consists of two parts:

- A main routine, which is executed after reset and which initializes the timer and the interrupt system of the microcontroller.
- An interrupt service routine, which reads a new value from the waveform table and writes it to the DAC.

```
;-------------------------------------------------------------------------------
; File:       WAVE.A51
; Function:   wave generation with TLV5633
; Processors: 80C51 family (running at 12MHz)
; Software:   ASM51 assembler, Keil BL51 code-banking linker
; (C) 1999 Texas Instruments
;-------------------------------------------------------------------------------

;-------------------------------------------------------------------------------
; Program function declaration
;-------------------------------------------------------------------------------
NAME   WAVE

MAIN      SEGMENT      CODE
ISR       SEGMENT      CODE
WAVTBL    SEGMENT      CODE
VAR1      SEGMENT      DATA
STACK     SEGMENT      IDATA

;-------------------------------------------------------------------------------
; Code start at address 0, jump to start
;-------------------------------------------------------------------------------
CSEG AT 0
      LJMP   start     ; Execution starts at address 0 on power-up.

;-------------------------------------------------------------------------------
; Code in the timer0 interrupt vector
;-------------------------------------------------------------------------------
      CSEG AT 0BH
      LJMP   timer0isr ; Jump vector for timer 0 interrupt is 000Bh

;-------------------------------------------------------------------------------
; Define program variables
;-------------------------------------------------------------------------------
RSEG VAR1
rolling_ptr: DS 1
```

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```
;-------------------------------------------------------------------------------
; Interrupt service routine for timer 0 interrupts
;-------------------------------------------------------------------------------
   RSEG ISR
timer0isr:
   PUSH   PSW
   PUSH   ACC

   ; The signal to be output on the dac is stored in a table
   ; as 32 samples of msb, lsb pairs (64 bytes).
   ; The pointer, rolling_ptr, rolls round the table of samples
   ; incrementing by 2 bytes (1 sample) on each interrupt
   ; (at the end of this routine).

   MOV    DPTR, #wavetable ; set DPTR to the start of the table

   MOV    R0, #001H       ; R0 selects DAC MSW
   MOV    A,rolling_ptr   ; ACC loaded with the pointer into the wave table
   MOVC   A,@A+DPTR       ; get msb from the table
   MOVX   @R0, A          ; write DAC MSW

   MOV    R0, #000H       ; R0 selects DAC LSW
   MOV    A,rolling_ptr   ; move rolling pointer back in to ACC
   INC    A               ; increment ACC holding the rolling pointer
   MOVC   A,@A+DPTR       ; which is the lsb of this sample, now in ACC
   MOVX   @R0, A          ; write DAC LSW

   MOV    A,rolling_ptr   ; load ACC with rolling pointer again
   INC    A               ; increment the ACC twice, to get next sample
   INC    A
   ANL    A,#003FH          ; wrap back round to 0 if >64
   MOV    rolling_ptr,A   ; move value held in ACC back to the rolling pointer

   CLR    T1              ; set LDACB = 0 (update DAC)
   SETB   T1              ; set LDACB = 1

   POP    ACC
   POP    PSW

   RETI

;-------------------------------------------------------------------------------
; Set up stack
;-------------------------------------------------------------------------------
   RSEG   STACK
   DS  10h    ; 16 Byte Stack!

;-------------------------------------------------------------------------------
; Main Program
;-------------------------------------------------------------------------------
   RSEG   MAIN
start:
   MOV    SP,#STACK-1   ; first set Stack Pointer

   CLR    A
   MOV    rolling_ptr,A ; set rolling pointer to 0
   MOV    TMOD,#002H    ; set timer 0 to mode 2 - auto-reload
   MOV    TH0,#0CEH     ; set timer 2 re-load value for 20 kHz interrupts

   MOV    P2, #080H     ; set A15 of address bus high to 'memory map'
                        ; device up beyond used address space
```

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```
    SETB   T1            ; set LDACB = 1 (on P3.5)

                         ; TLV5633 setup
    MOV    R0, #003H     ; R0 selects control register
    MOV    A, #011H      ; LOAD ACC with control register value:
                         ; REF1=1, REF0=0 -> 2.048V internal reference
                         ; RLDAC=0 -> use LDACB pin to control DAC
                         ; PD=0       -> DAC enabled
                         ; SPD=1 -> FAST mode
                         ; write control word:
    MOVX   @R0, A        ; write DAC control word

    SETB   ET0           ; enable timer 0 interrupts
    SETB   EA            ; enable all interrupts
    SETB   TR0           ; start timer 0

always:
    SJMP   always
    RET

;-------------------------------------------------------------------------------
; Table of 32 wave samples used as DAC data
;-------------------------------------------------------------------------------
    RSEG  WAVTBL
wavetable:
;...insert 32 samples here...
.END
```

APPLICATION INFORMATION

definitions of specifications and terminology

integral nonlinearity (INL)

The relative accuracy or integral nonlinearity (INL), sometimes referred to as linearity error, is the maximum deviation of the output from the line between zero and full scale excluding the effects of zero code and full-scale errors.

differential nonlinearity (DNL)

The differential nonlinearity (DNL), sometimes referred to as differential error, is the difference between the measured and ideal 1-LSB amplitude change of any two adjacent codes. Monotonic means the output voltage changes in the same direction (or remains constant) as a change in the digital input code.

zero-scale error (E_{ZS})

Zero-scale error is defined as the deviation of the output from 0 V at a digital input value of 0.

gain error (E_G)

Gain error is the error in slope of the DAC transfer function.

signal-to-noise ratio + distortion (SINAD)

Signal-to-noise ratio + distortion is the ratio of the rms value of the output signal to the rms sum of all other spectral components below the Nyquist frequency, including harmonics but excluding dc. The value for SINAD is expressed in decibels.

spurious free dynamic range (SFDR)

Spurious free dynamic range is the difference between the rms value of the output signal and the rms value of the spurious signal within a specified bandwidth. The value for SFDR is expressed in decibels.

total harmonic distortion (THD)

Total harmonic distortion is the ratio of the rms sum of the first six harmonic components to the rms value of the fundamental signal and is expressed in decibels.

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