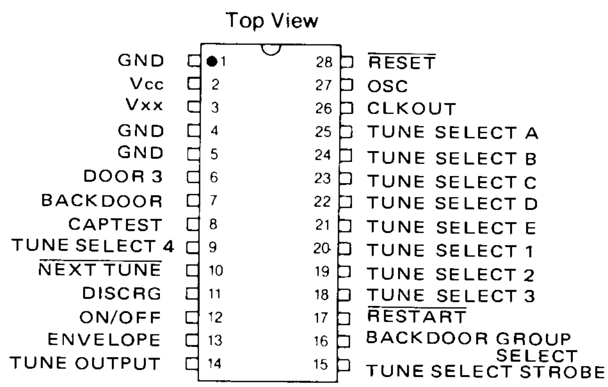
Tunes Synthesizer

FEATURES

- 25 different tunes plus 3 chimes
- Mask programmable with customer specified tunes for toys, musical boxes, etc.
- Minimal external components
- Automatic switch-off signal at end of tune for power saving
- Envelope control to give organ or piano quality
- Sequential tune mode
- 4 door capability when used as doorchime
- Operation with tunes in external PROM if required
- Single supply (4.5—7.0V) operation

PIN CONNECTIONS



DESCRIPTION

The AY-3-1350 is an N-Channel MOS microcomputer based synthesizer of pre-programmed tunes for applications in toys, musical boxes, and doorchimes. The standard device has a set of 25 different popular and classical tunes chosen for their international acceptance. In addition there are 3 chimes making a total of 28 tunes.

The chip is mask-programmable during manufacture enabling the quantity user to select his own music. The tunes chosen can be of different lengths and the number can be up to 28 (see later).

The device has multi-mode operation making it suitable for a wide variety of applications.

TUNES

The standard AY-3-1350 contains the following tunes:

AO Toreador
BO William Tell
CO Hallelujah Chorus
DO Star Spangled Banner
EO Yankee Doodle

A2 America, America
B2 Deutschland Lied
C2 Wedding March
D2 Beethoven's 5th
E2 Augustine

A4 Hell's Bells (specially composed)
B4 Jingle Bells
C4 La Vie en Rose
D4 Star Wars
E4 Beethoven's 9th

A1 John Brown's Body
B1 Clementine
C1 God Save the Queen
D1 Colonel Bogey
E1 Marseillaise

A3 O Sole Mio
B3 Santa Lucia
C3 The End
D3 Blue Danube
E3 Brahms' Lullaby

Chime X Westminster Chime
Chime Y Simple Chime
Chime Z Descending Octave Chime

ELECTRICAL CHARACTERISTICS

Maximum Ratings*

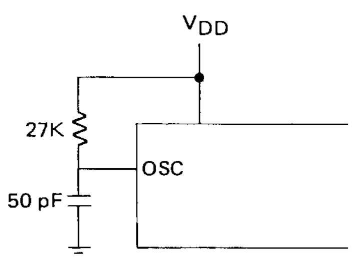
Storage Temperature . . . . –55°C to +150°C
Voltage on any pin with respect to ground (Vss) . . . . –0.3V to + 10.0V

STANDARD CONDITIONS (unless otherwise noted)
Operating Temperature (TA) = 0°C to + 40°C

*Exceeding these ratings could cause permanent damage. Functional operation of this device at these conditions is not implied—operating ranges are specified below.

Characteristics	Sym	Min	Max	Units	Conditions
DC CHARACTERISTICS					
Primary Supply Voltage	VDD	4.5	7.0	V	
Output Buffer Supply Voltage	Vxx	4.5	9.0	V	
Primary Supply Current	IDD		55	mA	No load
Output Buffer Supply Current	Ixx		5	mA	No load
Logic input Low Voltage	VIL	–0.2	0.8	V	Note 4
Logic Input High Voltage (Note 2) (Except $\overline{\text{RESET}}$) and OSC when driven externally)	VIH_1	2.4	VDD	V	
Logic Input High Voltage ($\overline{\text{RESET}}$ and OSC)	VIH_2	VDD^{-1}	VDD	V	Note 4
Logic Output High Voltage (Note 2)	VOH	2.4	VDD	V	IOH = 100 μA
Logic Output Low Voltage	VOL		0.45	V	IOL = 1.6 mA, Vxx = 4.5V
			0.90	V	IOL = 5.0 mA, Vxx = 4.5V
			0.50	V	IOL = 5.0 mA, Vxx = 9.0V
			0.90	V	IOL = 10.0 mA Vxx = 9.0V Note 1
AC CHARACTERISTICS					
Oscillator frequency variation for a fixed RC network	Δf	–20%	+20%		@ CLK OUT 167 KHz Note 3
CLK OUT Output					
Period	tCY	4	20	μS	
High Pulse Width	tCLKH	¼ tCY			
Low Pulse Width	tCLKC	¾ tCY			

NOTES:
1. Total IOL for all registers must be less than 150 mA under any conditions
2. Except following pins which have open drain outputs/inputs: 6, 7, 8, 12 and 13. Leakage 10μA max @ 9V
3. Test circuit:



4. This specification holds for the OSC input when the OSC pin is *not* controlled by an external RC network.
5. $\overline{\text{RESET}}$ should be held low at least ImS past the time when the power supply is valid.

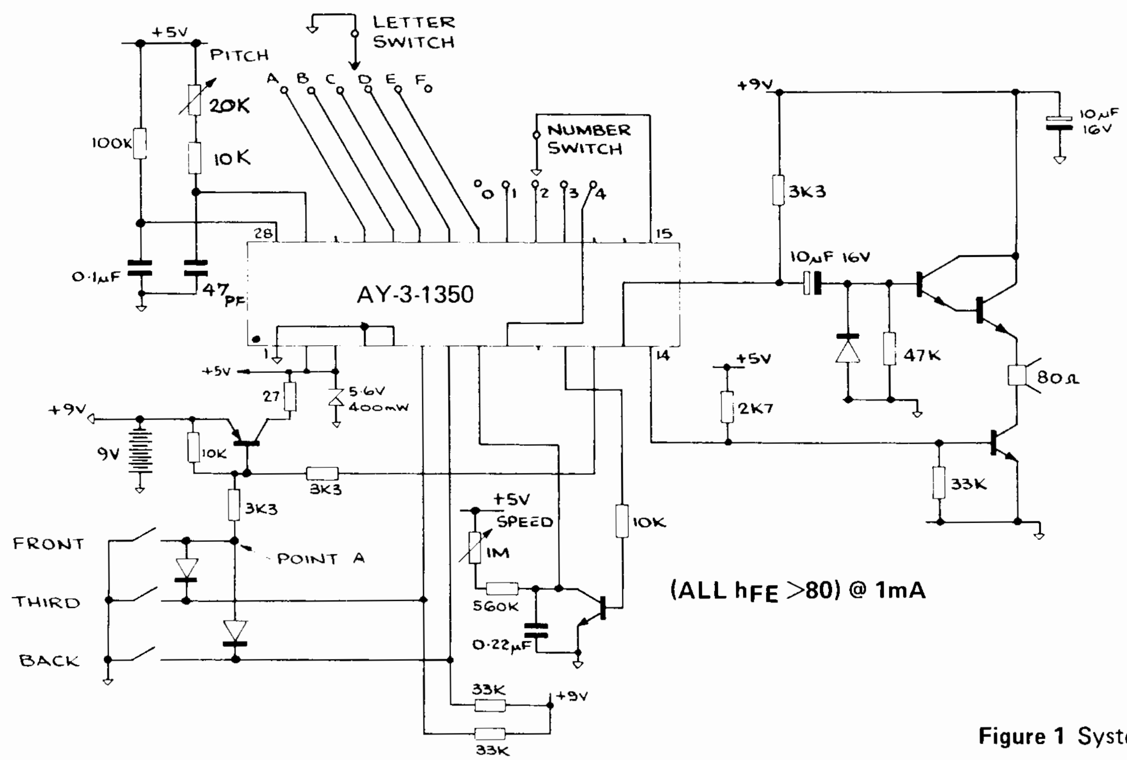


Figure 1 System Diagram

SECTION 1 OPERATION SUMMARY

Use of the AY-3-1350 can be split into three groups which are described in detail in separate sections later on:

SECTION 2 ONE CHIP AY-3-1350 system generating 25 tunes plus 3 chimes which have been pre-programmed into the standard device.

SECTION 3 ONE CHIP AY-3-1350 system generating any tunes desired. There can be any number of these. This involves a mask programming during manufacture so this is not suitable for small quantity production.

SECTION 4 TWO CHIP AY-3-1350 plus PROM system generating any tunes desired as above, but using the standard device so that applications involving small quantities become feasible. (C-MOS gate also required.)

SECTION 2 ONE CHIP STANDARD AY-3-1350 SYSTEM

2.1 Typical Implementation

There are many ways to connect up the standard device depending on the exact application. Figure 1 shows just one implementation of the device in a doorchime. This circuit gives access to all 25 tunes from the front door and one of 5 tunes from the back door as well as the descending octave chime from the third door. The tune selected for the FRONT DOOR follows the tunes list given earlier according to the setting of the two switches (A–E and 0–4). The tune selected for the BACK DOOR in Figure 1 is one of the five tunes AO to EO depending on the setting of the letter switch. For example, suppose the letter switch is at E and the number switch at 4 then the tunes given by the Figure 1 circuit will be

Front Door:	Beethoven's 9th	(E4)
Back Door:	Yankee Doodle	(E0)
Third Door:	Descending Octave Chime	(Chime Z)

When the letter switch is in position F there will be chimes on all doors independent of the number switch setting as follows

Front Door:	Westminster Chime
Back Door:	Simple Chime
Third Door:	Descending Octave Chime

In Figure 1 there is virtually no power consumption in the standby condition (external transistor leakages only). When any bell-push is activated the circuit powers up, plays a tune, and then automatically powers down again to conserve the battery, even if the visitor keeps his finger on the push to the end of the tune. He must release it and re-press to play again with the circuit of Figure 1. Any of the bell-pushes will pull point A to ground turning on the PNP transistor in the power supply line. This causes +5V to be applied to the AY-3-1350 and the first operation of the chip is to put ON/OFF (pin 12) to logic 0. This maintains the power through the PNP, even when the bell-push is released. The device can turn off its own power at the end of a tune by raising ON/OFF to logic 1.

Figure 1 shows only a typical one-chip implementation. Further options come from use of different switching and/or from use of the next tune facilities built into the chip. These will now be considered in turn.

2.2 Switching Options

In Figure 1 the Back-door Group Select pin (16) is not connected, and one of the five tunes A0 to E0 will play if the back-door push is activated. Other number groups can be chosen by connecting the Back-door Group Select pin as follows:

TABLE 2

Back-door Group Select pin (16) is connected to:	Back-door Tunes
no other pin	A0–E0
Tune Select 1 (pin 20)	A1–E1
Tune Select 2 (pin 19)	A2–E2
Tune Select 3 (pin 18)	A3–E3
Tune Select 4 (pin 9)	A4–E4

Which one of the five possible back-door tunes will be played depends on the current setting of the letter switch A–E.

The back-door group selection can be made by hard-wire connection for a permanent selection or a third switch can be added to give a back-door group selection feature to a top of the range model.

Going in the other direction, either the letter or the number switch can be replaced by a hard-wire connection to reduce the number of tunes in a bottom of the range model.

The three tune select switches (Letter, Number and Back-door Group) do not all have to be on the doorchime itself. As an example, TUNESELECT A to TUNESELECT E can be pulled to ground by one of several bell-pushes on the front door to give the caller a choice of tunes (maybe to indicate who is wanted. The bell-pushes can be labelled with family names). The start-up of the circuit can be achieved by extra diodes in this application as shown in Figure 4.

OSCILLATOR INPUT

The oscillator input (OSC) can be driven directly by a crystal with compatible output or by an external RC network. (See figure 2).

OSCILLATOR INPUT

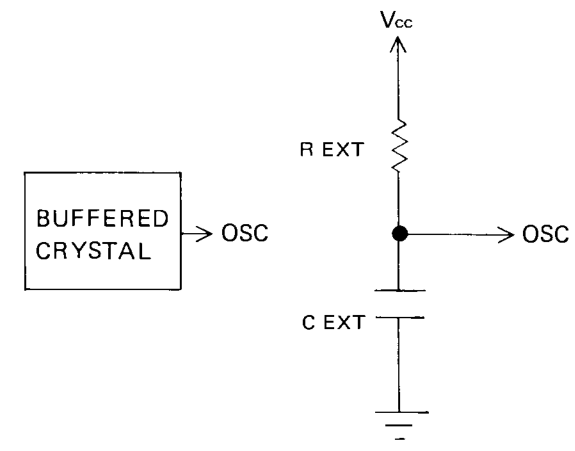


Figure 2

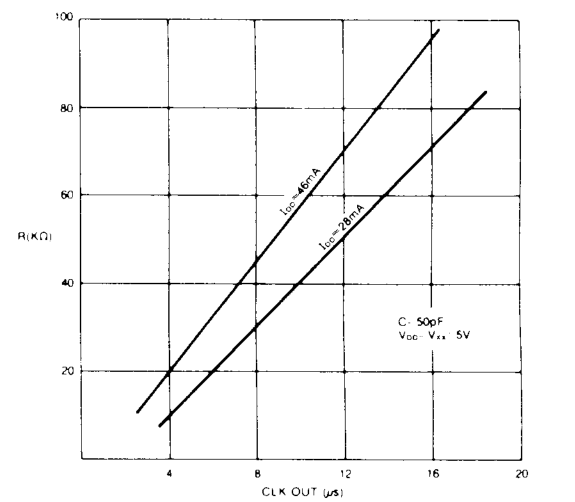


Figure 3 TYPICAL OSCILLATOR RC CHART @ 25°C

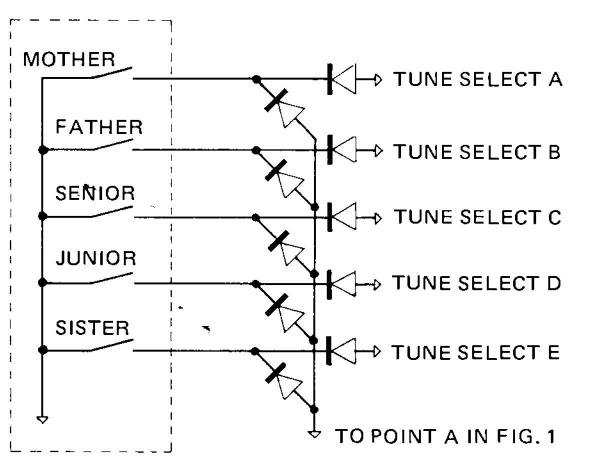
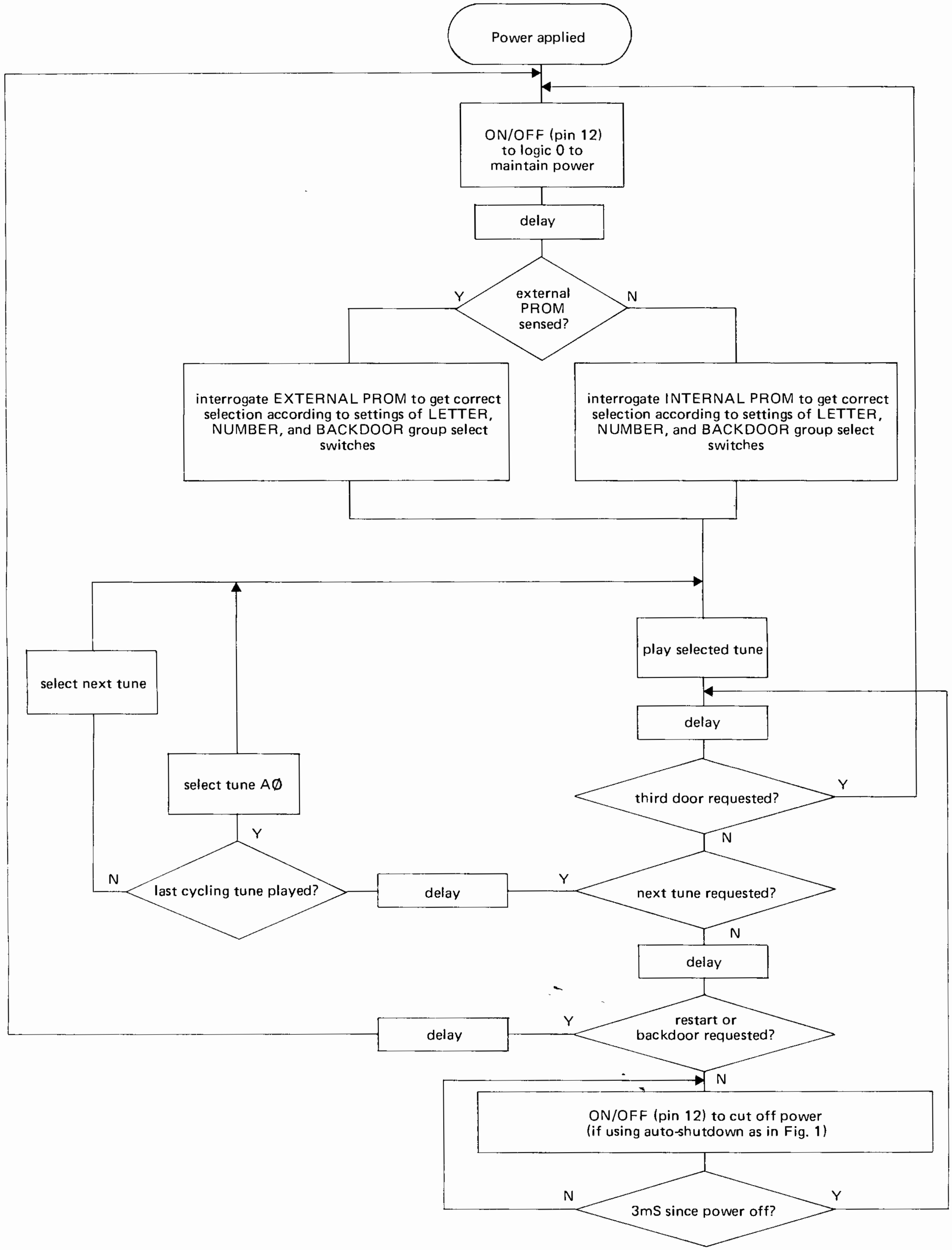


Figure 4 FRONT DOOR BELL PUSHES

Figure 5 SIMPLIFIED FLOW DIAGRAM



Using the power-up circuit of Figure 1 the AY-3-1350 will have +5V supplied to it and latched within a few microseconds (depends on external components) from any bell-push closing. The device starts to operate when the RESET pin reaches logic 1 (about 10mS with components shown) but in fact the tune select switches are not interrogated until approximately 6mS later. The total is sufficient for most bell-pushes to complete any bounce period and for a firm selection of tunes to be made.

2.3 Next Tune Facilities

At the end of playing a tune the example circuit of Figure 1 powers down because ON/OFF (pin 12) is raised to a logic 1 by the device at the end of a tune. The simplified flow diagram in Figure 5 shows that before the power down there is a test for connection between NEXT TUNE (pin 10) then RESTART (pin 17) with TUNESELECT 4 (pin 9). At these times NEXT TUNE (pin 10) then RESTART (pin 17), which are normally at logic 1, output a logic ϕ pulse. This is looked for at input TUNESELECT 4 (pin 9).

If neither is found the power down system is reached as in Figure 1.

A NEXT TUNE (pin 10) – TUNE SELECT 4 (pin 9) connection at the moment of test causes the next tune in the list to be played after a short pause (equal to a musical breve – the actual time depends on the setting of the tune speed control). The order of the tunes is A0 to E4 as given in the listing of standard AY-3-1350 tunes. If the last tune (E4) was played then the circuit will go on to play the first tune AO (and then successive ones). Figure 5 shows this pictorially. The chimes are not included in the cycling sequence.

A RESTART (pin 17) – TUNESELECT 4 (pin 9) connection at the moment of test at the end of a tune causes the same selected tune to be played again. Figure 5 shows that in this case the tune sensing mechanism is passed through once more however, so the tune would be different second time if the switches were altered while the first tune was playing.

The connections referred to cannot be permanent because otherwise the circuit would never stop playing tunes. Figure 6 shows how transistors are used to make the connection in a practical application.

There are many ways to connect the two transistors to the main bell-pushes but in Figure 6 example the following features result.

FRONT DOOR: Every time a visitor presses the push the successive tune plays. After E4 (the last cycling one), tune A0 plays (the first one). If the visitor keeps his finger on the push till the end of a tune the next one will play and the whole cycle will be heard continuously until he lets go.

BACK DOOR: Every time a visitor presses the push the selected back door tune will play. This depends on the setting of the Letter switch (A–F) and the Back Door Group select switch (or hard-wire connection) see Table 2. If the visitor keeps his finger on the push till the end of the tune the same one will be repeated until he lets go.

THIRD DOOR: Every time a visitor presses the push, Chime Z will play (descending octave chime). Keeping the finger on will cause it to re-play until released.

FOURTH DOOR: Every time a visitor presses the push the tune played will be that selected by combination of the letter and number switches. Keeping the finger on will cause it to re-play until released.

To summarise by an example, you could set the Letter switch to B, the number switch to 4, and hard-wire the Back Door Group Select (pin 16) to TUNESELECT 3 (pin 18) and then, with the circuit of Figure 6, you would hear

FRONT DOOR:	All tunes sequentially	
BACK DOOR:	Santa Lucia	(B3)
THIRD DOOR:	Descending Octave Chime	(Chime Z)
FOURTH DOOR:	Jingle Bells	(B4)

PIN	FUNCTION
6	DOOR 3
7	BACKDOOR
9	TUNESELECT 4
10	$\overline{\text{NEXT TUNE}}$
17	$\overline{\text{RESTART}}$

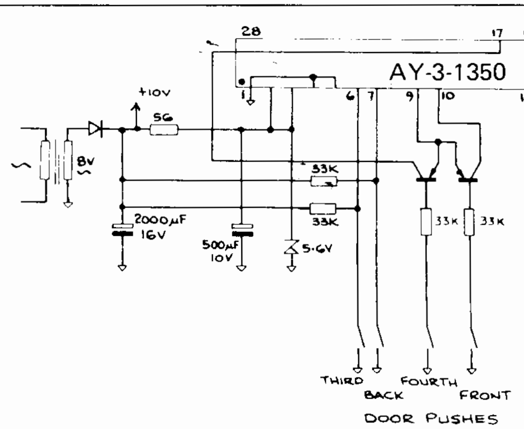


Figure 6

2.4 Start Switches

The signal to start the tunes can be an ordinary bell-push or a touch plate as shown in Figure 7 (which replaces the push circuitry of Figure 1).

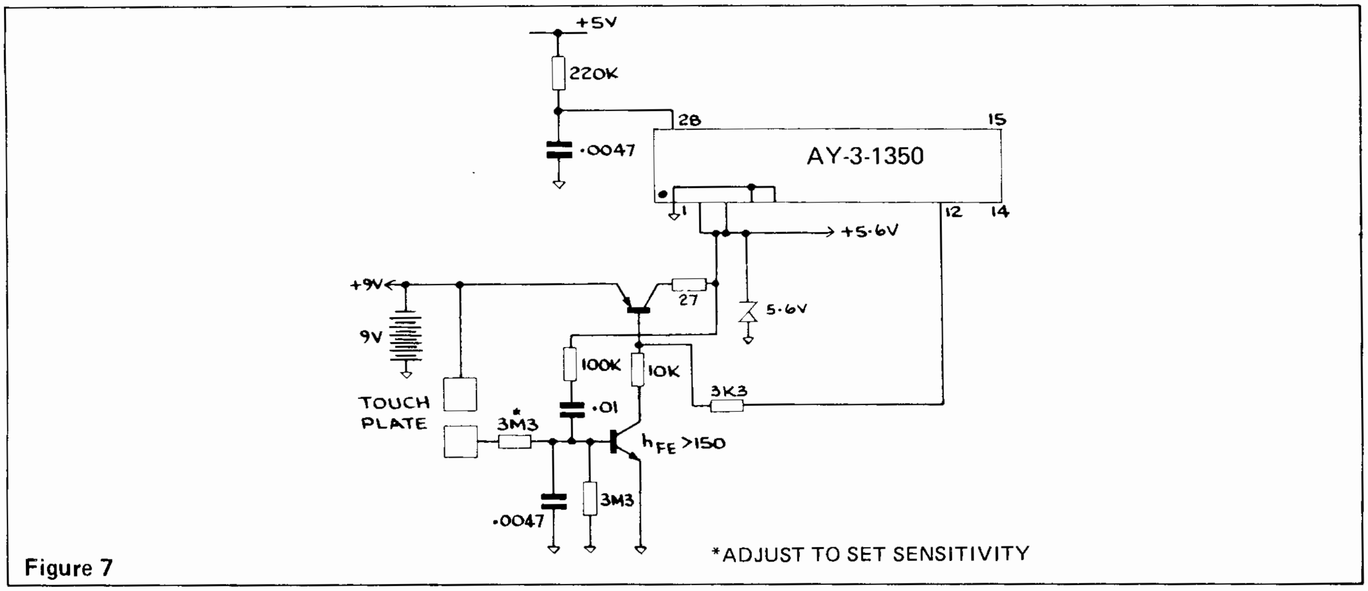


Figure 7

2.5 Output Circuits

Figure 1 shows a low cost output circuit which provides an exponential decay on each note to simulate a piano sound. Figure 8 eliminates this and delivers an organ quality. Care has been taken to include short pauses between notes to avoid them running into each other in this application. TUNE OUTPUT (pin 14) is at logic 0 when a tune is not playing to avoid current drain through the loudspeaker. Figure 8 replaces the output circuit of Figure 1 when an organ sound is required.

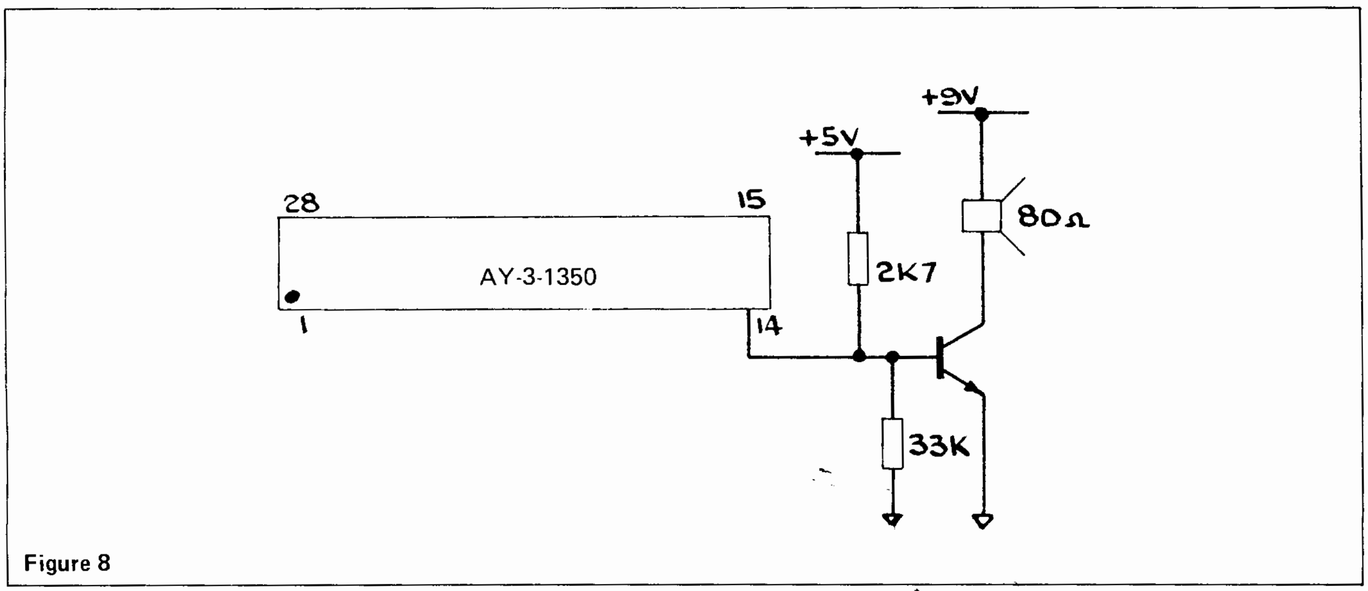


Figure 8

2.6 Pitch Control

The 20K potentiometer in Figure 1 sets the pitch of the tunes played by the AY-3-1350. This potentiometer and the associated capacitor together with internal circuitry form an oscillator. This is divided down by a factor of 4 and can be monitored at CLKOUT (pin 26). Operation is only guaranteed with the potentiometer adjusted to give 50KHz to 250 KHz at pin 26 (a pitch range of 5:1 or $2\frac{1}{3}$ octaves). If the potentiometer is not pre-set but given as a user control, the capacitor and/or padding resistor may need adjustment to ensure this.

2.7 Speed Control

The speed at which the tunes are played is dependent on the setting of the 1M potentiometer of Figure 1. This can be pre-set or left as a user control.

SECTION 3: ONE CHIP CUSTOM TUNES SYSTEM

3.1 Customising the Tunes

The AY-3-1350 has pre-programmed tunes, but the device is mask programmable during manufacture with any music required. A minimum of 1 tune to a maximum of 28 tunes can be incorporated. Examples as follows:

Tunes	Total No. of notes, all tunes together	Average notes per tune
1	252	252
2	251	126
5	248	50
10	243	24
20	233	12
25	228	9

(The general formula is Total No. of notes = 253–No. of tunes.)

As an indication, about 90 seconds of music can be incorporated.

All musical rests are counted as one note. Semiquavers, quavers, dotted quavers, crotchets, dotted crotchets, minims, dotted minims and semibreves can all be accommodated and the range is about 2½ octaves. The position of these octaves can be chosen by the user up to a maximum pitch of about A = 1760Hz. The tunes for incorporation in the device should be presented to General Instrument as normal music manuscript. This method is only suitable for quantity production. Customised tunes for small quantity purposes can be realised using the AY-3-1350 plus an external PROM as detailed in SECTION 4.

3.2 Applications for Customised Tunes

If the number of tunes is less than the number of switch positions then the circuit will automatically proceed directly to power down if this mode is being used, or will find the next available tune if in the sequential mode.

All the different facilities described in SECTION 2 are still available when user tunes are masked into the device.

For TOYS, sequential tune playing adds variety and reduces the number of switches required, keeping costs to a minimum.

For MUSICAL BOXES playing the same tune repeatedly preserves one of the traditional features.

Several start buttons are shown in Figure 4 each giving a different tune, can be incorporated into any of these applications. Likewise the touch switch described in SECTION 2 as well as the organ-type output should be considered.

SECTION 4: TWO CHIP STANDARD AY-3-1350 PLUS PROM SYSTEM

4.1 Introduction

With the addition of an external ROM or PROM the standard AY-3-1350 will play almost any tune or tunes you desire. There could be 28 tunes averaging 8 notes each or one tune of up to 252 notes for example. In all about 1–2 minutes worth of music. For significant production volume General Instrument can later integrate the external tunes into the main synthesizer to give a one chip system. This section shows how to write the music for incorporation in the external PROM and Figure 14 shows the hardware.

4.2 Overall Coding Scheme

The external PROM should be 256 x 8 bits and of any static TTL compatible type.

It can have more words, but the tunes synthesizer will only use 256 x 8 bits at a time, e.g. if PROM type 2708 is used (1K x 8 bits), the two higher order address lines should be strapped to ground or switches put on them to give 4 times the amount of music (see logic diagram Figure 14). The rest of this article will assume a 256 x 8 bit PROM, and the addresses will be referred to as 000 to 377. Octal notation is used throughout.

The PROM address 000 must contain data 377 and address 377 must contain data 125 which is a key to open up the external PROM features. All other addresses can contain tune data.

Each tune consists of a series of notes with one byte of PROM for each. Every tune must have a tune end marker byte 377 after the last note, and the final tune must have a byte 376 after the 377 end marker. The memory allocation is shown diagrammatically in Figure 9. Tunes can be of any length and there can be any number of them subject only to the memory limit. (28 max.)

4.3 Note Coding Scheme

Each note of a tune occupies 1 byte (8 bits) of PROM, and this can be considered as split into two fields:

7	6	5	4	3	2	1	0
pitch					length		

The three least significant bits specify the length (quaver, crotchet, etc.) and the five most significant bits specify the pitch. This gives $2^5 = 32$ different pitches and $2^3 = 8$ different lengths. In practice one pitch code is allocated as silence to allow musical rests of different lengths to be implemented. Figure 10 gives the length table and Figure 11 the note pitch table. It can be seen that the lengths from semiquaver to semibreve, and 2½ octaves of notes can be produced. The pitches shown assume that the on-chip clock of the AY-3-1350 is trimmed to 1MHz. The pitches can be made lower by using a slower clock. Every reduction by 5.61257% decreases the pitch by a semitone. The note pitches produced by the AY-3-1350 are approximately equi-tempered. It should be noted that codes 377 and 376 are used as end of tune markers and are illegal as notes. They correspond to semibreve and dotted minim rests which can however be made up by combining two smaller rests in place of the required 377.

Let us take a specific example. The music for the first part of Star Spangled Banner is shown in Figure 12 with the notes coded in octal below the music. Figure 13 represents just one of the tunes shown in the overall memory scheme of Figure 9 and it shows the actual data that would have to be incorporated into the external PROM to get a tune consisting of these 6 notes.

4.4 Hardware Implementations

To play the 28 internal tunes of the AY-3-1350 Tunes Synthesizer the device should be connected up as shown in SECTION 2. To play tunes which you have written into the PROM in the manner described above, the AY-3-1350 and the PROM should be interconnected as shown in Figure 14. This can be used for demonstrations, one-off implementations or small scale productions. This circuit will also play the internal tunes (see internal/external switch).

4.5 One Chip Implementation

For manufacturing purposes, send PROM and code listing to GI and we will incorporate your tunes into a specially made one chip Tunes Synthesizer in place of the standard 28 tunes. Manuscript can also be accepted.

Figure 9

PROM Memory Allocation

Address	DATA	
0	377	(tune select timeslot)
		Tune 1
	377	(end of tune marker)
		Tune 2
	377	(end of tune marker)
		More tunes
		Last Tune
	377	(end of tune marker)
	376	(end of listing)
	000	Not Used
	000	
	000	
	000	
377	125	(external ROM enable key)

Figure 10 Note Length Table

Note Length Table

Name	**Musical notation**	**Octal**	**Binary**
Semiquaver	𝅘𝅥𝅯	0	000
Quaver	𝅘𝅥𝅮	1	001
Dotted quaver	𝅘𝅥𝅮.	2	010
Crochet	𝅘𝅥	3	011
Dotted crochet	𝅘𝅥.	4	100
Minim	𝅗𝅥	5	101
Dotted minim	𝅗𝅥.	6	110
Semibreve	𝅝	7	111

Figure 11 Note Pitch Table (with CLKOUT set at 250 kHz)

Name	Frequency (HZ)	Octal	Binary
F	175	00	00000
F #	185	01	00001
G	196	02	00010
G #	208	03	00011
A	220	04	00100
A #	233	05	00101
B	247	06	00110
C (middle C)	262	07	00111
C #	277	10	01000
D	294	11	01001
D #	311	12	01010
E	330	13	01011
F	349	14	01100
F #	370	15	01101
G	392	16	01110
G #	415	17	01111
A (international A)	440	20	10000
A #	466	21	10001
B	494	22	10010
C	523	23	10011
C #	554	24	10100
D	587	25	10101
D #	622	26	10110
E	659	27	10111
F	698	30	11000
F #	740	31	11001
G	784	32	11010
G #	831	33	11011
A	880	34	11100
A #	932	35	11101
B	988	36	11110
Rest	silent	37	11111

Figure 12 STAR SPANGLED BANNER – MUSIC

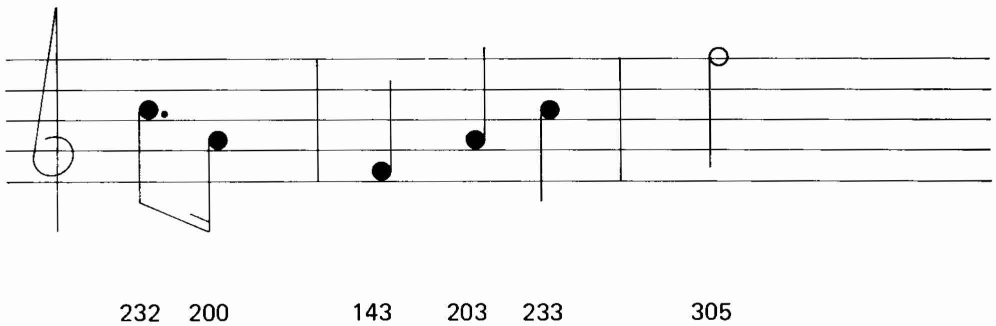
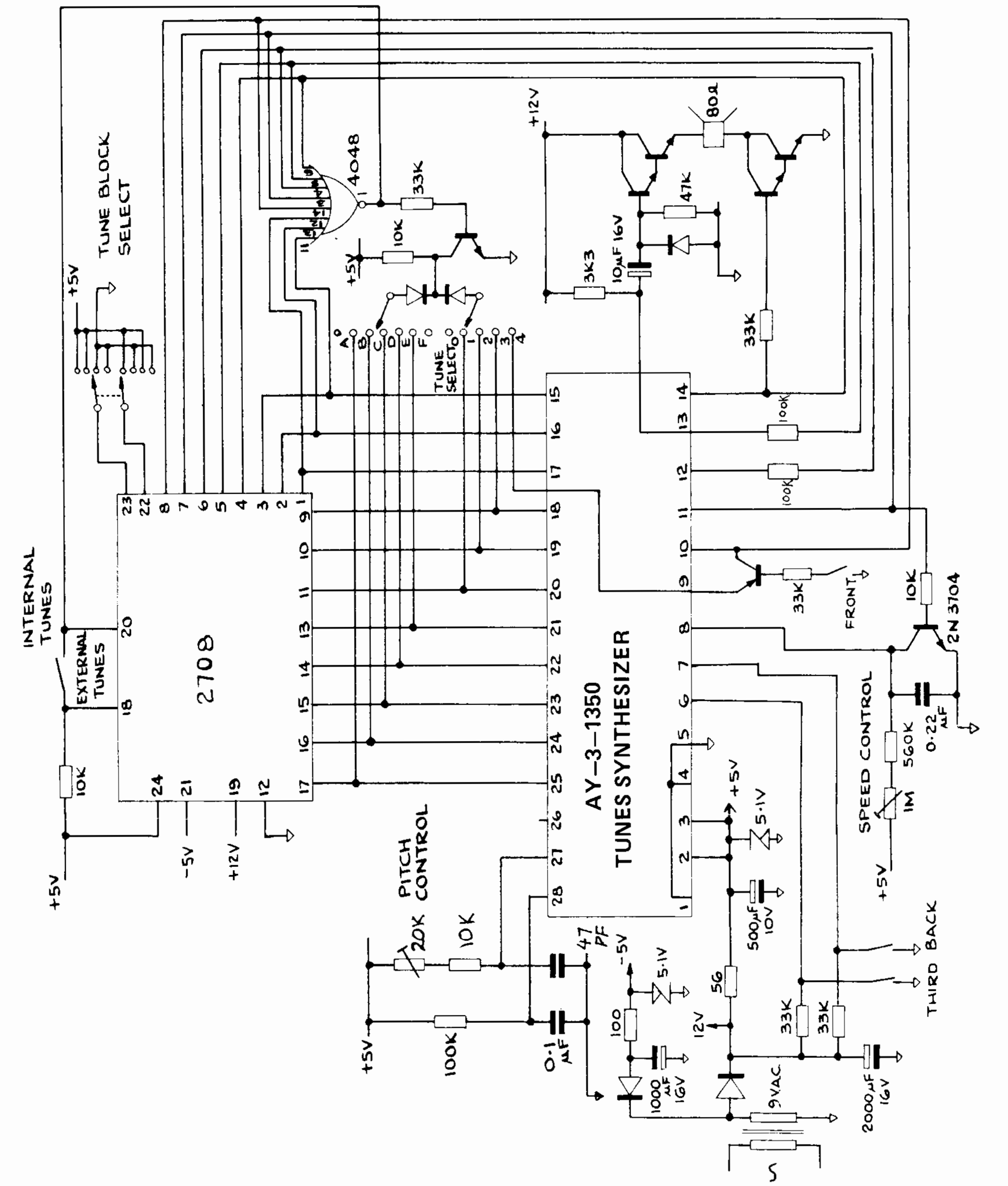


Figure 13 STAR SPANGLED BANNER – CODING

	Octal Data	Binary Data
	232	10011010
	200	10000000
	143	01100011
Star Spangled Banner	203	10000011
	233	10011011
	305	11000101
	377	11111111

(The last 377 is the end of tune code)

Figure. 14 PLAYING YOUR OWN TUNES WITH EXTERNAL PROM. (OR INTERNAL TUNES)



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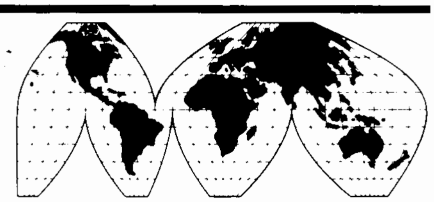

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