RSC-200/264T
Recognition • Synthesis • Control

Speech Recognition Microcontroller Designed
Specifically For the Toy Industry

GENERAL DESCRIPTION

The RSC-200/264T, from the Interactive Speech™ family of products, is an 8-bit microcontroller designed especially for the toy industry. The RSC-200/264T is a single chip solution that combines the flexibility of a microcontroller with advanced speech technology, including high-quality speech recognition, speech and music synthesis, speaker verification, and voice record and playback. Products can use one or all of the RSC-200/264T features in a single application.

The RSC-200/264T employs a sophisticated neural network that learns to classify sound data. On-chip speech recognition algorithms reach an accuracy of greater than 96% for speaker-independent recognition and greater than 99% for speaker-dependent recognition. Sensory's neural network approach eliminates the need for expensive signal processing or extensive RAM storage.

The RSC-200/264T improves on its predecessor, the RSC-164, by integrating even more functionality such as an on-chip preamplifier. A complete system may be built with few additional parts other than a battery, speaker, microphone, and a few resistors and capacitors. The RSC-200 is designed for ROM-less for applications that need more ROM space and consequently use off-chip memory.

FEATURES

Full Range of Speech Capabilities

- Speaker-independent speech recognition
- Speaker-dependent speech recognition
- High quality speech synthesis and sound effects
- Speaker verification
- Four-voice music synthesis
- Voice record & playback

Integrated Single-Chip Solution

- 4 MIPS 8-bit microcontroller
- On-chip A/D and D/A converters, and pre-amplifier
- 32kHz clock for time keeping
- Internal 64 Kbytes ROM (RSC-264T only); 448 bytes RAM
- 16 general purpose I/O lines
- External memory bus: 16-bit Address, 8-bit Data
- On-chip output amplifier for direct speaker drive

Low Power Requirements

- 2.4 to 5.25Voperation for 2 or 3 battery applications
- ~10mA operating current
- Power down mode; <5 µA standby current

RSC-200/264T Block Diagram
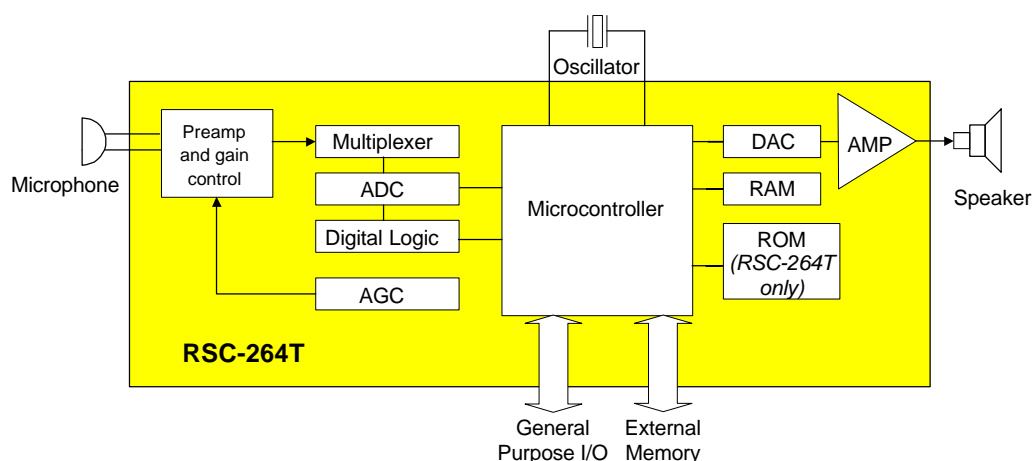
RSC-200/264T OVERVIEW

The RSC-200/264T is a member of the Interactive Speech™ line of products from Sensory. It features a high-performance 8-bit microcontroller with on-chip A/D, D/A, preamplifier, RAM and ROM (RSC-264T only). The RSC-200/264T is designed to bring a high degree of integration and versatility into low-cost, power-sensitive toy applications.

Various functional units have been integrated onto the CPU core in order to reduce total system cost and increase system reliability without degrading system performance. The RSC-200/264T delivers 4 MIPS of integer performance at 14.32 MHz providing maximum performance at minimum cost.

The CPU core embedded in the RSC-200/264T is an 8-bit, variable-length-instruction, microcontroller. The instruction set is somewhat similar to the Zilog™ Z8, and has a variety of addressing mode *mov* instructions. The RSC-200/264T processor avoids the limitations of dedicated A, B, and DPTR registers by having completely symmetrical source and destinations for all instructions. The 448 bytes of internal RAM are organized as a Register Space.

SPEECH RECOGNITION

The RSC-200/264T uses a neural network to perform speaker-independent or speaker-dependent speech recognition. Speaker-dependent recognition requires external memory to store speech recognition information (e.g., SRAM, optional Serial EEPROM, Flash Memory). Speaker-independent recognition requires on-chip or off-chip ROM to store the words to be recognized. The RSC-200/264T has several additional speech recognition features as described below.

Continuous listening allows the chip to continuously listen for a specific word. With this feature a product can be used in a normal environment and only "activates" when a specific word, preceded by quiet, is spoken.

SPEECH AND MUSIC SYNTHESIS

The RSC-200/264T provides high-quality speech synthesis by using a hybrid of a time-domain compression scheme that improves on conventional ADPCM and a customized reuse of sounds. Speech synthesis requires on-chip or off-chip ROM to store audio sounds for synthesis.

The RSC-200/264T provides high-quality, low-cost four-voice music synthesis which allows multiple, simultaneous instruments for harmonizing. The RSC-200/264T uses a MIDI-like system to generate music.

RECORD AND PLAYBACK

The RSC-200/264T can perform audio record and playback at various compression levels depending on the quantity and quality of playback desired. Data rates of under 14,000 bits per second are achievable while maintaining very high quality reproduction. The RSC-200/264T also performs silence removal to improve sound quality and reduce memory requirements.
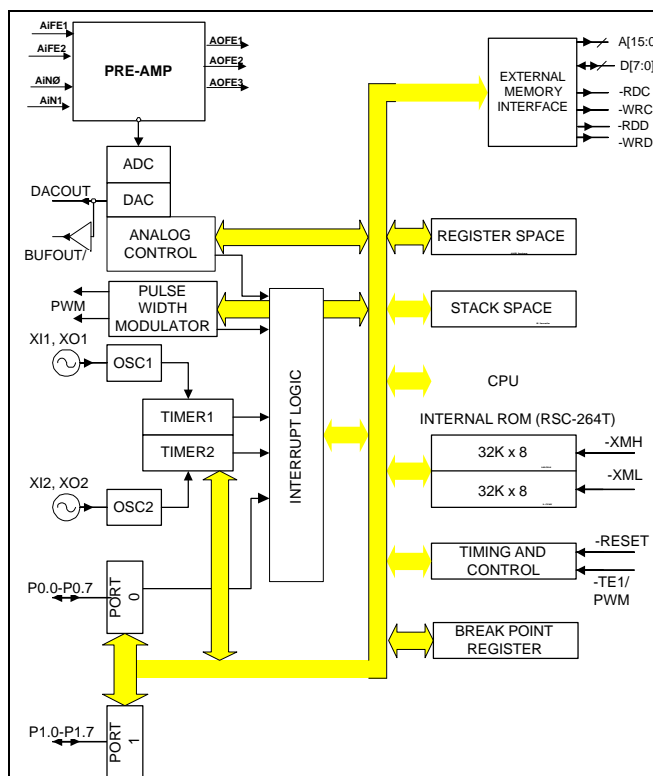
SPEAKER VERIFICATION

The RSC-200/264T can also perform text-dependent speaker verification. After a speaker trains the chip on a specific word, the chip is able to identify whether that word is spoken by the original speaker, thus providing biometric security.

POWER

The typical operating current is 10 mA operating at 14.32 MHz and 3V. Lowering clock frequency reduces power consumption, although speech recognition requires a 14.32 MHz clock. Standby current is <5µA in power down mode.

RSC-200/264T Architecture Diagram

RSC-200/264T ARCHITECTURE

The RSC-200/264T is a highly integrated device that combines:

- 8-bit microcontroller

- On-chip ROM (64 Kbytes, RSC-264T only) and RAM (448 bytes), and the ability to address off-chip RAM or ROM

- A/D converter and D/A converter

- Input amplifier and pulse width modulator

The RSC-200/264T has an external memory interface, with 16-bit addresses and 8-bit data buses, for accessing external memory. It also has an internal ROM (RSC-264T only) that can be enabled or disabled (partially or fully) by pin inputs (signals -XMH, -XML).

Two bi-directional ports provide 16 general purpose I/O pins to communicate with external devices. The RSC-200/264T has a high frequency (14.32 MHz) oscillator as well as a low frequency (32,768 Hz) oscillator suitable for timekeeping applications. The processor clock can be selected from either source, with a selectable divider value. The device performs speech recognition when running at 14.32 MHz. The RSC-200/264T also supports programmable wait states to allow the use of

slower external devices. There are two programmable 8-bit counters / timers, one derived from each oscillator.

An external microphone passes an audio signal to the preamplifier and ADC (Analog-to-Digital Converter) to convert the incoming speech signal into digital data. The output audio signal of the RSC-200/264T is derived from a DAC (Digital-to-Analog Converter) or PWM (Pulse Width Modulator).

USING THE RSC-200/264T

Creating applications using the RSC-200/264T requires the development of electronic circuitry, software code, and speech/music data files. Software code for the RSC-200/264T can be developed by Sensory or by external programmers using the RSC-264T Development Kit. For more information about development tools and services, please contact Sensory. A typical product will require about $0.30 - $1.00 (in high volume) of additional components, in addition to the RSC-200/264T.

The following sample circuit provides an example of how the RSC-200/264T might be used in a consumer electronic product.

Sample Application Circuit

RSC-200/264T INSTRUCTION SET

The instruction set for the RSC-200/264T has 54 instructions comprising 10 move, 7 rotate, 11 branch, 11 register arithmetic, 9 immediate arithmetic, and 6 miscellaneous instructions. All instructions are 3 bytes or fewer, and no instruction requires more than 10 clock cycles to execute.

GENERAL PURPOSE I/O

The RSC-200/264T has 16 general purpose I/O pins (P0.0-P0.7, P1.0-P1.7). Each pin can be programmed as an input with weak pull-up (~200kΩ equivalent device); input with strong pull-up (~10kΩ equivalent device); input without pull-up, or as an output.

EXTERNAL MEMORY

The RSC-200/264T includes an external memory interface that allows connection with memory devices for speaker-dependent speech recognition, audio record/playback, and extended durations of speech and music synthesis.

Separate data and address buses allow use of standard EPROMs, ROMs, SRAMs, and flash memory with little or no additional decoding. Support for separate read and write signals for each external memory space further simplifies interfacing. The RSC-200/264T includes 8 data lines (D[7:0]) and 16 address lines (A[15:0]), and associated control signals for memory interfacing .

OSCILLATORS

Two independent oscillators in the RSC-200/264T provide a high-frequency clock and a 32kHz time-keeping clock. Both oscillators work with an external crystal, a ceramic resonator or LC. The oscillator characteristics are:

Oscillator #1:   Pins XI1, XO1
                   14.32 MHz

Oscillator #2   Pins XI2 and XO2
                   32768 Hz

CLOCK

The RSC-200/264T uses a fully static core – the processor can be stopped (by removing the clock source) and restarted without causing a reset or losing contents of internal registers. Static operation is guaranteed from DC to 14.32 MHz.

Typically the processor clock runs from a 14.32 MHz crystal with no divisor and one wait state. This creates internal RAM cycles of 70 nsec duration and internal ROM (RSC-264T only) or external cycles of 140 nsec duration. Careful design may allow operation with memories having access times as slow as 120 nsec.

TIMERS/COUNTERS

The two independent oscillators of the RSC-200/264T provide counts to two internal timers. Each of the two timers consists of an 8-bit reload value register and an 8-bit up-counter. The reload register is readable and writeable by the processor.

INTERRUPTS

The RSC-200/264T allows for five interrupt sources, as selected by software. Each has its own mask bit and request bit in the IMR and IRQ registers respectively. The following events can generate interrupts:

- Positive edge on Port 0, bit 0
- Overflow of Timer 1
- Overflow of Timer 2
- Sensory reserved functions
- Completion of PWM sample period

PREAMPLIFIER

The on-chip preamplifier circuit consists of three stages with a maximum overall gain of about 500. The amplifier includes a Vref input that is used to set the amplifier center voltages and must be driven by a low impedance voltage supplied by an external source. The signal inputs of all stages have an 80 KΩ input impedance to the Vref pad. In a typical design, AOFE1 would be directly coupled to AIFE2, and AOFE2 would be capacitively coupled to AIN0 through an RC lowpass filter to remove DC offset and digital noise. AOFE3 would be bypassed to Vref with a small (220pF) capacitor for additional noise suppression.

ANALOG OUTPUT

The RSC-200/264T offers two separate options for analog output. The DAC output provides a general purpose 10-bit analog output that may be used for speech output (with the inclusion of an audio amplifier), or other purposes requiring an analog waveform. For speech applications that require driving a small speaker, the PWM output can be used instead of the DAC output and can directly drive a 32 ohm speaker.

PACKAGING

The RSC-200/264T is available as bare die.

DIE BOND PAD DRAWING
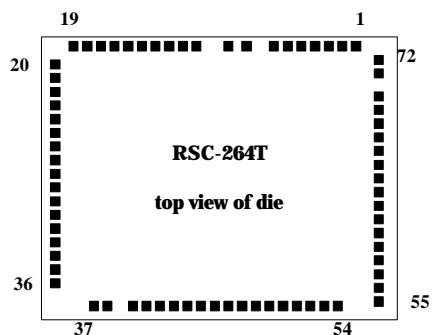
Name	Die Pad	Description	I/O
A[15:0]	20-27, 30-37	External Memory Address Bus	O
AIN0	5	Analog In, low gain. (range AGND to AVDD/2.)	I
AIN1	4	Analog In, hi gain (8X input amplitude of AIN0, same range)	I
AOFE1	72	Output of 1st stage of preamplifier	O
AOFE2	6	Output of 2nd stage (AGC stage) of preamplifier	O
AOFE3	3	Output 3rd stage of preamplifier	O
AIFE1	71	Input to 1st stage of preamplifier (Microphone input)	I
AIFE2	1	Input to 2nd stage (AGC stage) of preamplifier	I
NC	10,11,43,44	No Connect	-
PWM0	8	Pulse Width Modulator Output0	O
DACOUT	2	Analog Output (unbuffered).	O
D[7:0]	12-19	External Data Bus	I/O
VSS	7, 28, 62	VSS	-
PDN	67	Power Down. Active high when powered down.	O
P1[7:0], P0[7:0]	45-52, 53-60	General Purpose Port I/O. Pin P0.0 can act as an external interrupt input. All I/O pins can act as "wake up" inputs.	I/O
/RDC	63	External Code Read Strobe	O
/RDD	65	External Data Read Strobe	O
/RESET	42	Reset	I
/TE1 or PWM1	9	Test Mode or Pulse Width Modulator Output1 (multiplexed)	I or O
VREF	70	Reference Voltage. Has to be Vdd/2 or Vdd/4. Depends on software.	-
VDD	29, 61	Supply Voltage	-
/WRC	64	External Code Write Strobe	O
/WRD	66	External Data Write Strobe	O
/XMH	68	External Hi-memory enable (low active)	I
/XML	69	External Low-memory enable (low active)	I
XO1	40	Oscillator 1 output (high frequency)	O
XI1	41	Oscillator 1 input	I
XO2	38	Oscillator 2 output (32768 Hz)	O
XI2	39	Oscillator 2 input	I

DC CHARACTERISTICS

($T_O = 0°C$ to $+70°C$, $V_{DD} = 2.4V – 5.25V$)

SYMBOL	PARAMETER	MIN	TYP	MAX	UNITS	TEST CONDITIONS
V_{IL}	Input Low Voltage	-0.1		0.75	V	
V_{IH}(Vcc<3.6)	Input High Voltage	0.8*Vdd		Vdd+0.3	V	
V_{IH}(Vcc>3.6)	Input High Voltage	3.0		Vdd+0.3	V	
V_{OL}	Output Low Voltage		0.3	0.1*Vdd	V	I_{OL}= 2 mA
V_{OH}	Output High Voltage (I/O Pins)	0.8*Vdd	0.9*Vdd		V	I_{OL}= -2 mA
I_{IL}	Logical 0 Input Current		<1	10	uA	$V_{ss}<V_{pin}<V_{dd}$
I_{DD1}	Supply Current, Active		10	20	mA	Hi-Z Outputs
I_{DD3}	Supply Current, Powerdown		1	10	uA	Hi-Z Outputs
Rpu	Pull-up resistance P0.0-P1.7 I/O Pins	5,80, Hi-Z	4.5,200, Hi-Z		kΩ	Selected with software
	/XML,/XMH		200		kΩ	Fixed

A.C. CHARACTERISTICS (EXTERNAL MEMORY ACCESSES)

($T_O = 0°C$ to $+70°C$, $V_{DD} = 5V$; load capacitance for outputs = 80 pF; Osc=14.32 MHz)

SYMBOL	PARAMETER	CPU=osc/1, 1 WS MIN MAX		CPU=osc/2, 0WS MIN MAX		UNITS
1/TCL1	Processor Clock frequency		14.32		7.16	MHz
TRLRH	-RDC (-RDD) Pulse Width		140		140	ns
TRLAV	-RDC (-RDD) Low to Address valid		5		5	ns
TALRAX	Address hold after -RDC (-RDD)		0		0	ns
TRAVDV	Address valid to Valid Data In		135		135	ns
TRHDX	Data Hold after -RDC (-RDD)	0		0		ns
TWLWH	-WRC (-WRD) Pulse Width		140		140	ns
TAVWL	Address Valid to -WRC (-WRD)	35		70		ns
TALWAX	Address Hold after -WRC (-WRD)	35		70		ns
TWDVAV	Write Data Valid to Address Valid		5		5	ns
TWHQX	Data Hold after -WRC (-WRD)	35		70		ns

TIMING DIAGRAMS

Note that the -RDC signal does not necessarily pulse for every read from code space, but may stay low for multiple cycles.

External Read Timing   **External Write Timing**
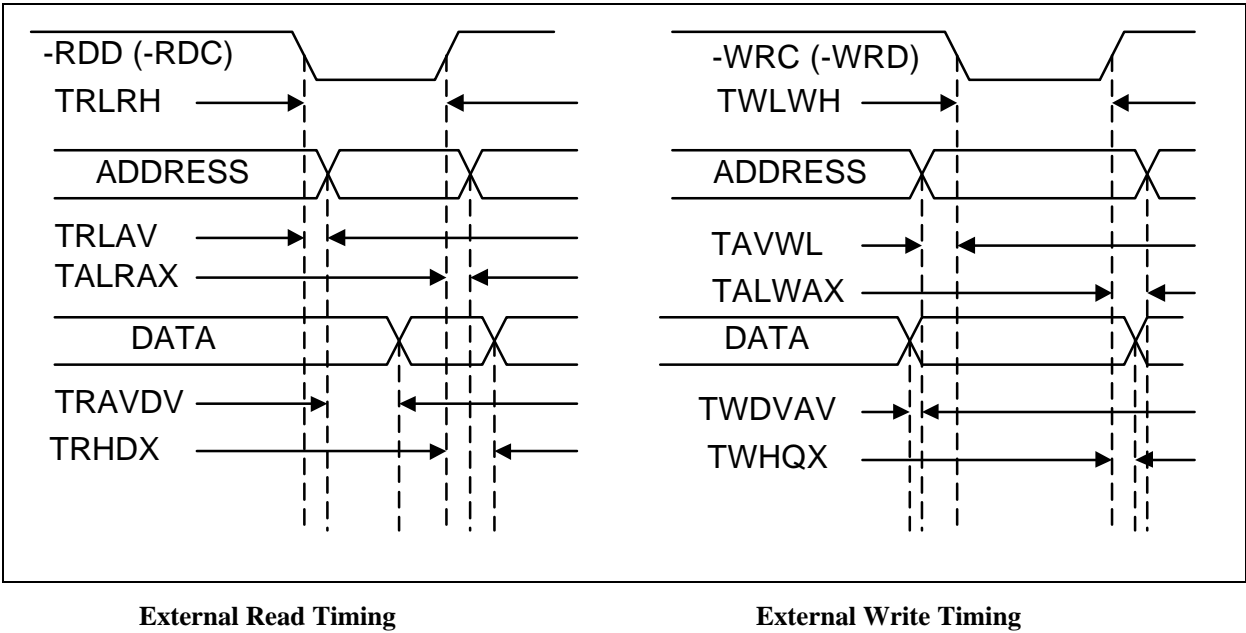
ABSOLUTE MAXIMUM RATINGS

Any pin to GND	-0.1V to +6.5V
Operating temperature (T_O)	0°C to +70°C
Soldering temperature	260°C for 10 sec
Power dissipation	1 W
Operating Conditions	0°C to +70°C;
	V_{DD}=2.4 - 5.25V
	V_{SS}=0V

WARNING: *Stressing the RSC-200/264T beyond the "Absolute Maximum Ratings" may cause permanent damage. These are stress ratings only. Operation beyond the "Operating Conditions" is not recommended and extended exposure beyond the "Operating Conditions" may affect device reliability.*

ORDERING INFORMATION

Part	Marketing #	Description
RSC-264T DWF	C264XS1P	Tested die in wafer form
RSC-264T Die	C264XD1B	Tested, singulated die in waffle pack
RSC-200T DWF	C200XS1P	Tested die in wafer form
RSC-200T Die	C200XD1B	Tested, singulated die in waffle pack

THE INTERACTIVE SPEECH™ PRODUCT LINE

The Interactive Speech line of ICs and software was developed to *"bring life to products"* through advanced speech recognition and audio technology. The Interactive Speech Product Line was designed for consumer telephony products and cost-sensitive consumer electronic applications such as home electronics, personal security, and personal communication. The product line includes award-winning RSC-series general purpose microcontrollers plus a line of easy-to-implement chips which can be pin-configured or controlled by an external host microcontroller. Sensory's software technologies run on a variety of microcontrollers and DSPs.

RSC Microcontrollers
The RSC family of microcontrollers (RSC-164, RSC-200/264T, RSC-300/364) are low-cost 8-bit microcontrollers designed for use in consumer electronics. All members of the RSC family are fully integrated and include a speech processor, A/D, D/A, ROM (except RSC-200/300), and RAM circuitry on chip. The RSC-200/264T and RSC-300/364 also include on chip pre-amplification. The RSC family of microcontrollers can perform a full range of speech/audio functions including speech recognition, speaker verification, speech and music synthesis, and voice record/playback.

Voice Direct™ TSSP
The Voice Direct™ TSSP provides cost-sensitive products with speaker-dependent speech recognition and speech. This easy-to-use, pin-configurable chip requires no custom programming and can recognize up to 60 trained words in slave mode, and 15 words in stand-alone mode. The Voice Direct™ TSSP is ideal for speaker-dependent command and control of household consumer products, and is part of a complete product line that includes the IC, module, Development Kit Voice Direct™ Speech Recognition Kit. For product developers with limited time and unlimited imagination!

Voice Dialer™ ASSP
The Voice Dialer™ ASSP delivers speech recognition technology that allows users to dial phone numbers by saying the name of the person they wish to call. Voice dialing and phone directory management through speech recognition can be easily integrated into existing products. This IC is designed for use as a slave chip controlled by an external host processor.

Voice Activation™ Software
Sensory's Voice Activation™ software provides advanced speech technology on a variety of microcontroller and DSP platforms. A complete speech API and flexible design allows manufacturers to easily integrate speech functionality into telephony products.

IMPORTANT NOTICES

S E N S O R Y ®

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From the *Interactive Speech*™ Line of Products