



## CBIC Programmable FIR Filter

### AT76C001

## Features

- 4 Multiplier-Accumulators
- 40 Bits Accuracy
- 16 Bit Data and Coefficients
- 4-tap Filter With 27 MHz Sample Rate
- Programmable to Give up to 256 Taps With Sampling Reducing Proportionally to 421,875 kHz
- Programmable Rounding and Truncation to 16 Bit
- 8 Bit Standard Microprocessor Interface
- 64-pin PQFP, 68-pin PGA68 or 68-pin LCC68 Packaging

## Description

The AT76C001 Programmable Finite Impulse Response (FIR) Filter implements a 4th order FIR cell built around 4 multiplier-accumulators. It contains a dual-port RAM and a RAM which are used to implement FIR filters of up to 256 taps. High order filters are achieved by multiplexing the 4th order cell and accumulating the intermediate results up to 40 bits, so that there is no loss of accuracy.

The maximum frequency of the AT76C001 is 27 MHz. For 4-tap FIR filter, the incoming sample rate can be as high as 27 MHz. For higher order FIR filters, the sample rate can be as high as the circuit frequency divided by the 4th order cell multiplexing factor.

A programmable normalization block allows the choice of the 16 significant bits from the 40 bit internal result which can be previously rounded by adding 0.5 LSB according to the 16 significant bit locations. The AT76C001 has a microprocessor interface which can be configured to be Intel or Motorola compatible.

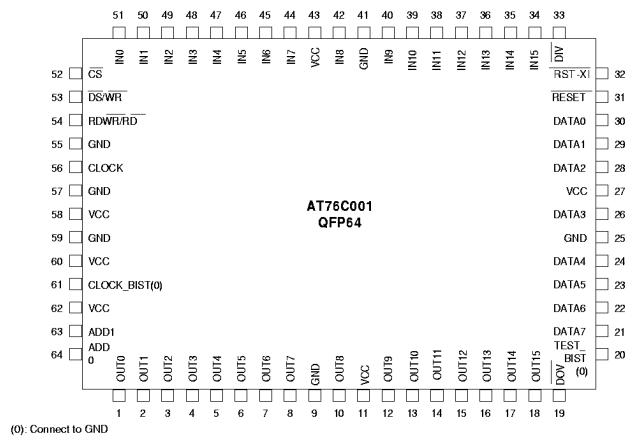
## Applications

- Digital Filters (video, audio, etc.)
- Correlation
- Image Processing

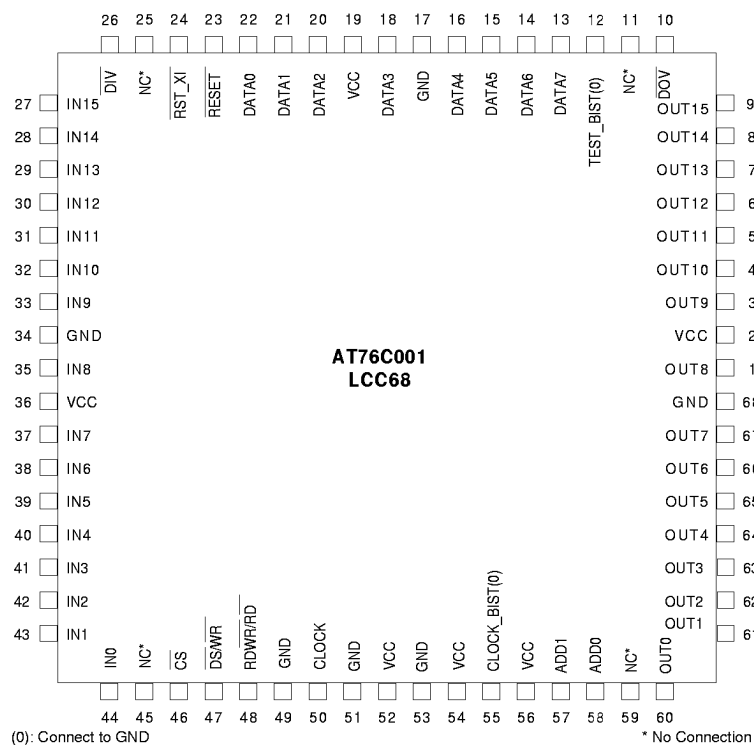


## Pin Description

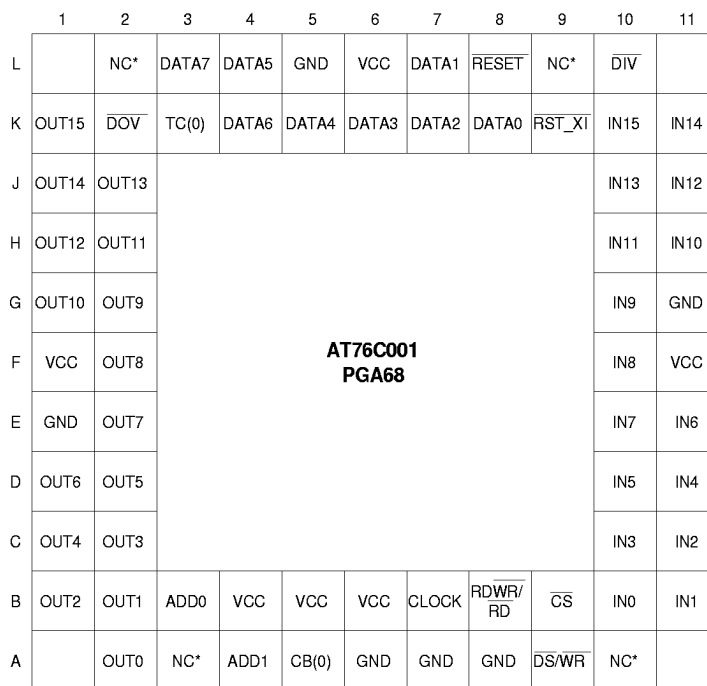
Name	Pin Number			Type	Function
	QFP64 Packaging	LCC68 Packaging	PGA68 Packaging		
IN<15:0>	34-40, 42, 44-51	27-33, 35, 37-44	K10-11, J10-11, H10-11, G10, F10, E10-11, D10-11, C10-11, B11-10	I	Input sample
DIV	33	26	L10	I	Input sample valid. Active low
RST_X1	32	24	K9	I	Force input sample to 0. Useful for interpolation implementation
OUT<15:0>	18-12, 10, 8-1	9-3, 1, 67-60	K1, J1-2, H1-2, G1-2, F2, E2, D1-2, C1-2, B1-2, A2	O	Output filtered sample
DOV	19	10	K2	O	Output filtered sample valid. Active low
DATA<7:0>	21-24, 26, 28-30	13-16, 18, 20-22	L3, K4, L4, K5-7, L7, K8	I/O	Microprocessor interface data bus. Used for accessing internal registers and to write the coefficients of the filter
CS	52	46	B9	I	Chip select. Active low
DS/WR	53	47	A9	I	Microprocessor interface data strobe (Motorola mode) or Write signal (Intel mode). Active low
RDWR/RD	54	48	B8	I	Microprocessor interface Read/Write signal (Motorola mode) or Read signal (Intel mode). Active low
ADD<1:0>	63-64	57-58	A4, B3	I	Microprocessor interface address bus
RESET	31	23	L8	I	Circuit master reset. Active low
CLOCK	56	50	B7	I	Circuit clock (27 MHz max)
CLOCK_BIST	61	55	A5	I	For internal use. Connect to ground
TEST_BIST	20	12	K3	I	For internal use. Connect to ground
VCC	11, 27, 43, 58, 60, 62	2, 19, 36, 52, 54, 56	B4-6, F1, F11, L6		Power supply (+5V)
GND	9, 25, 41, 55, 57, 59	17, 34, 49, 51, 53	A6-8, E1, G11, L5		Ground
NC		11, 25, 45, 59	A3, A10, L2, L9		No connection



Plan View of AT76C001 in QFP64 Package



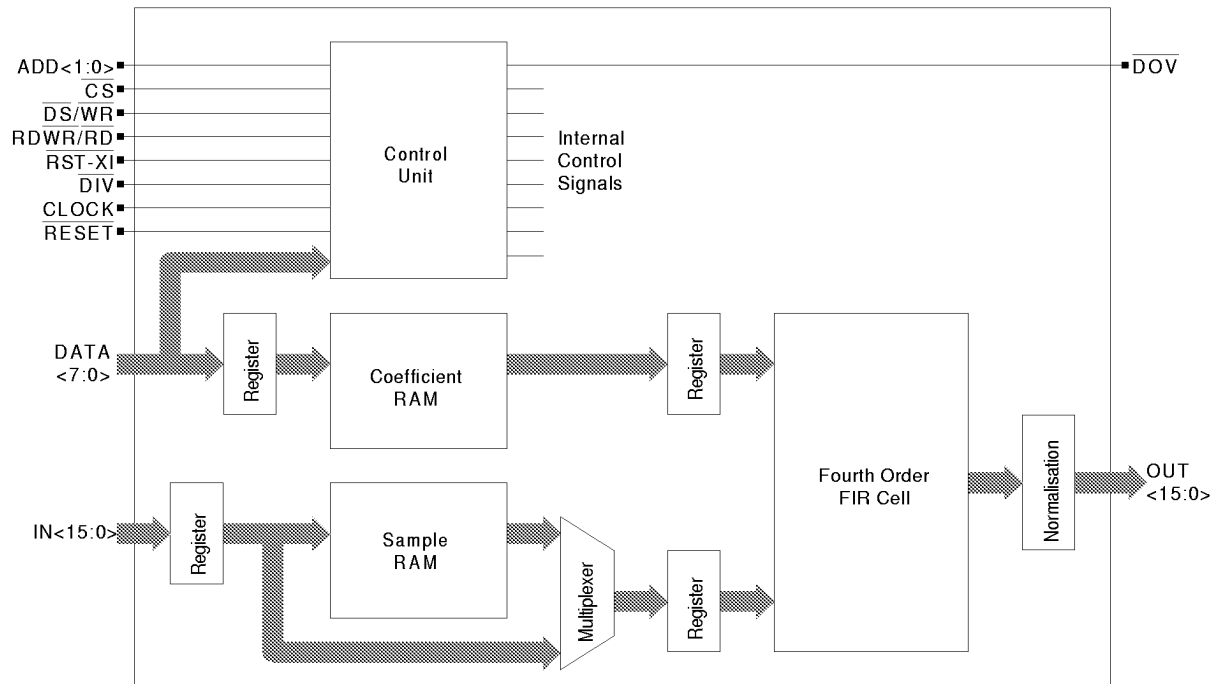
Plan view of AT76C001 in LCC68 package



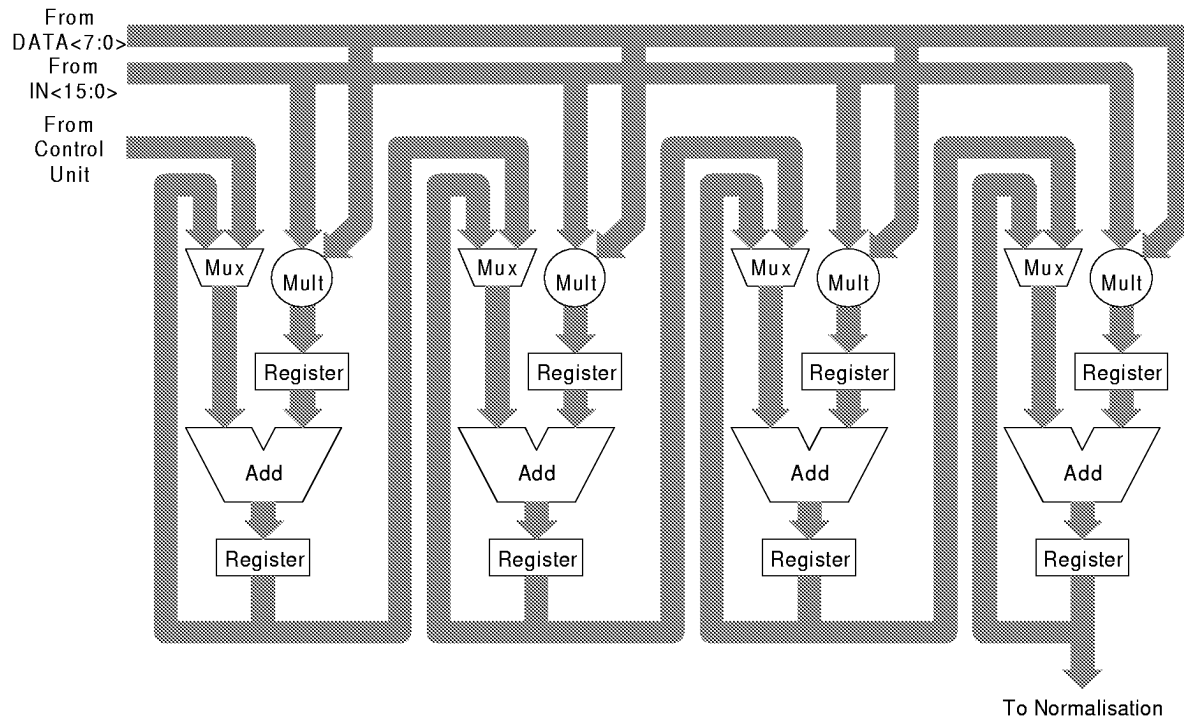
Plan view of AT76C001 in PGA68 package



## Block Diagram



## Fourth Order FIR Cell



## Functional Description

The AT76C001 has an architecture built around a 4-tap non-recursive filter cell. This allows a 4-tap filter to be implemented, e.g.

$$y(n) = a(0)x(n) + a(1)x(n-1) + a(2)x(n-2) + a(3)x(n-3)$$

where  $x$  = 16 bit incoming sample

$y$  = 16 bit filtered sample

$a$  = 16 bit coefficient

This operating mode is called 'single mode'.

The AT76C001 can implement up to 256-tap filters by multiplexing the 4th order structure, using internal RAMs. Nth order FIR filters can be divided into P 4th-order FIR sub-filters where P is the integer part of  $(N+3)/4$ . Thus the complete filter is evaluated by accumulating the contributions of each elementary 4th order sub-filter:

$$y(n) = y(n,0) + y(n,1) + \dots + y(n,P-1)$$

where  $y(n,j) = a(4j)x(n-4j) + a(4j+1)x(n-4j-1)$

$$+ a(4j+2)x(n-4j-2) + a(4j+3)x(n-4j-3)$$

$j$  = number of the sub-filter

This operating mode is called 'sequential mode'.

If  $(N+3)/4$  is greater than P, then some coefficients of the last sub-filter will be set to zero automatically by the circuit.

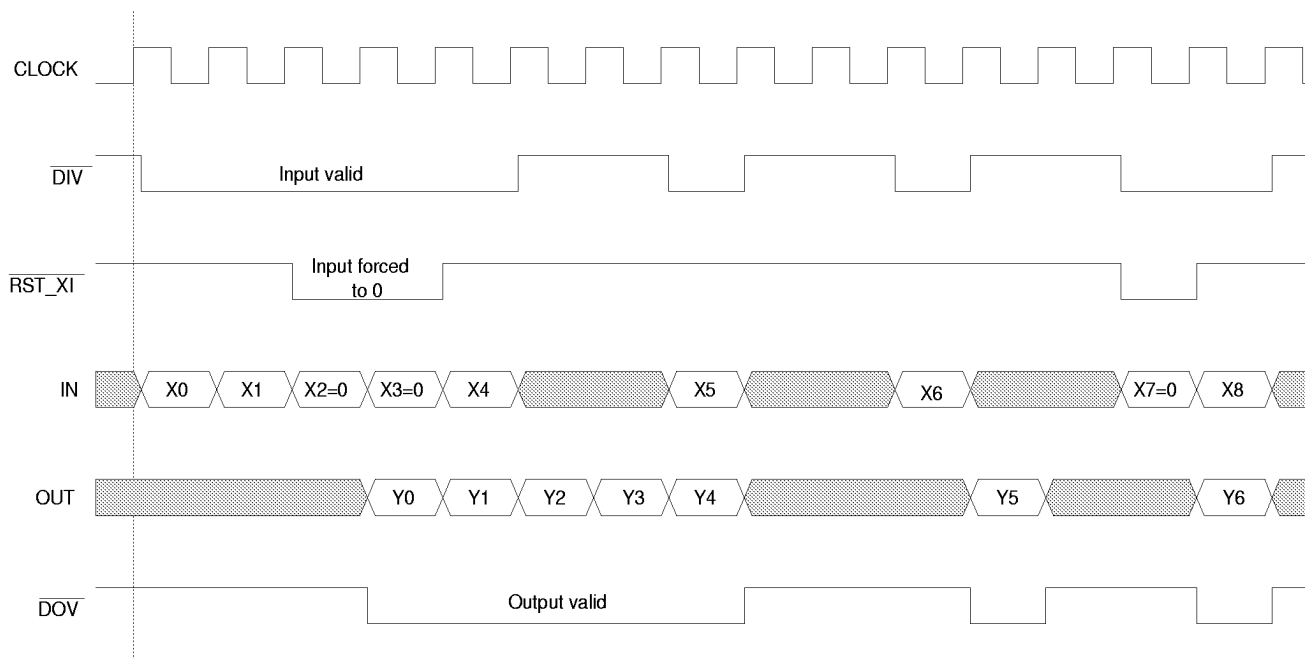
In single mode, the incoming sample rate can be as high as the circuit frequency (27 MHz). A new incoming sample is notified by a low level on DIV input signal and clocked by the rising edge of the circuit clock CLOCK.

If there is a low level set on DIV and then a low level is set on RST\_XI input, then a 'zero' sample is fed internally into the circuit.

For each new sample, a filtered sample is calculated. Valid output filtered samples are notified by a low level on DOV output signal. The timing diagram below illustrates the single mode operation.

In sequential mode, an N-tap filter is divided into P 4-tap filters. Consequently, the incoming sample rate must be at least P times slower than the circuit rate. As in single mode, a new incoming sample is notified by a low level on DIV input signal and clocked by the rising edge of CLOCK. But here, DIV defines a temporal window where XIN is valid and whose width must be at least one CLOCK period and at most P-1 clock periods. The timing diagrams below illustrate the case for an N-tap filter, where N is greater than 4 but less than 9, i.e., DIV must go to high level between two incoming signals.

## Timing Diagram for Single Mode Operation



## Microprocessor Interface

The AT76C001 has an 8 bit configurable microprocessor interface comprising the following signals:

DATA <7:0>	8 bit data bus
AD- <1:0>	2 bit address bus
CS	Chip Select
DS/WR	Data Strobe or Write signal
RDWR/RD	Read/Write signal or Read signal

By setting bit 1 of the configuration interface (INTEL/MOTO), it is possible to configure the microprocessor interface to be Motorola or Intel compatible. When chosen, the configuration must be locked by setting bit LOCK\_CFG of the configuration register. This must be done first of all otherwise the circuit will not function properly.

Configuration	Motorola Mode	Intel Mode
Intel/Moto bit	Bit set to 0	Bit set to 1
Signals	DATA<7:0> ADD<1:0> CS DS RD/WR	DATA<7:0> ADD<1:0> CS WR RD

## Internal Registers

The AT76C001 contains three internal registers accessible in Read and Write via the microprocessor interface, as soon as it is configured and locked. They are:

- Configuration register (CFGR)
- Normalization and Rounding Register (NORR)
- Filter Order Register (FILR)

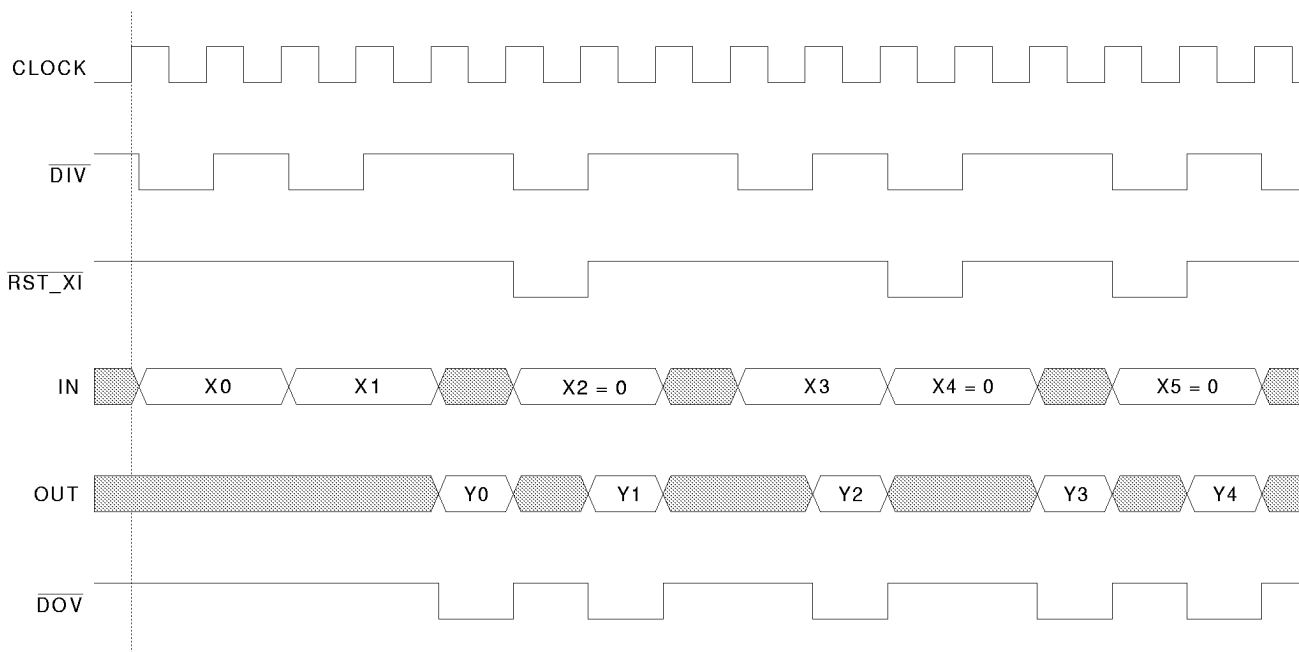
### Configuration Register

It is an 8 bit register mapped at address 1hex = 01bin

- Bit 0 = START/STOP Activates/deactivates filtering
- Bit 1 = INTEL/MOTO Configures microprocessor interface to be Intel or Motorola.
- Bit 2 = MSB/LSB Indicates if 16 bit coefficients are written with Most Significant Byte or Least Significant Byte ahead.
- Bit 3 = LOCK\_CFG Locks the microprocessor interface configuration.
- Bit 4 = SING/SEQ Indicates the operating mode of the 4th order cell, i.e. Single Mode or Sequential Mode.
- Bit 5 = BUFF\_FULL Indicates that the sample input buffer contains N samples when implementing an N-tap FIR filter.

(continued)

## Timing Diagram for N-tap Filter where $4 < N < 9$



## Internal Registers (Continued)

Bit 6 = LAST\_SFILT Indicates that the last sub-filter is accessed.

Bit 7 = END\_INCOEFF Indicates that the last coefficient of the last sub-filter is being accessed.

Bit No	7	6	5	4	3	2	1	0
Bit Name	END_IN COEFF	LAST_S FILT	BUFF_ FULL	SING/ SEQ	CFG LOCK	INT/ MOTO	MSB/LSB	START/ STOP
Acc. Mode	R	R	R	R	R/W	R/W	R/W	R/W
Reset Value	1	0	1	0	0	0	1	0

### Normalization and Rounding Register

The normalization and rounding register is a 5 bit register mapped at address 2h = 10b allows the selection of the 16 bit significant part of the internal 40 bit result; also defines the number of bits rounding value if rounding is desired.

Bit <3:0>= SEL <3:0> Selects the 16 bit part and defines the number of bits rounding value as illustrated in the following table:

Bit 3:0	OUT<15:0>	Rounding Value (Hex)
0000	RES<31:16>	00 0000 8000
0001	RES<32:17>	00 0001 0000
0010	RES<33:18>	00 0002 0000
0011	RES<34:19>	00 0004 0000
0100	RES<35:20>	00 0008 0000
0101	RES<36:21>	00 0010 0000
0110	RES<37:22>	00 0020 0000
0111	RES<38:23>	00 0040 0000
1XXX	RES<39:24>	00 0080 0000

Bit 4 = ROUNDEN Enables/disables rounding of the 40 bit result before normalization.

Bit No	4	3	2	1	0
Bit Name	ROUNDEN	SEL3	SEL2	SEL1	SEL0
Access Mode	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0

### Filter Order Register

The filter order register is an 8 bit register mapped at address 3h=11b. It contains the number of the order of the filter to be implemented **minus 1**.

#### Reset Values

Bit No	7	6	5	4	3	2	1	0
Bit Name	FILT7	FILT6	FILT5	FILT4	FILT3	FILT2	FILT1	FILT0
Acc. Mode	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0

## Coefficient Writing

Filter coefficients are stored internally by writing to address 0hex = 00bin. The bit MSB/LSB of the configuration register indicates if the MSB is sent before the LSB and vice versa. Stored coefficients are not readable via the microprocessor interface. For an N-tap filter, 2xN writing is necessary. If N is not a multiple of 4, the remaining coefficients of the last sub-filter are set automatically to zero.

## Application Examples

### A 4-Tap FIR Filter in Motorola Mode

Example with coefficient MSB ahead and rounding enabled.

$$y_n = c_0x_n + c_1x_{n-1} + c_2x_{n-2} + c_3x_{n-3}$$

Where  $y_n$  is the output filtered sample,  $c$  is the coefficient and  $x$  is the incoming samples.

1. Firstly, unlock the microprocessor interface by writing a zero to bit 3 (this is normally performed by applying a Master reset).
2. Write 1100bin in the configuration register. This sets the configuration with bit 0 selecting stop mode, bit 1 selecting Motorola mode, bit 2 selecting MSB ahead, and bit 3 locks the configuration.
3. Write the Filter Order-1 in the FILT\_ORD register, i.e. 03hex.
4. Write the 4 coefficients starting with the Most Significant Byte of  $c_0$ , then the LSB of  $c_0$ , etc.
5. Write 00010bin in the NORM register to enable rounding, and to select range of bits, for example bits 33 to 18 of the 40 bit internal result.
6. Write 1101bin in the Configuration register to start the filter. At each new incoming sample,  $XIN$ , specified by a low level on DIV. The filtered sample  $XOUT$  is calculated and is notified by a low level on DOV. The

(continued)



## Application Examples (Continued)

filtered XOUT is output 4 clock cycles after the sampling of the corresponding XIN input.

### A 130-Tap FIR Filter in Intel Mode

Example with coefficient LSB ahead and rounding disabled.

$$Y_n = C_0X_n + C_1X_{n-1} + \dots + C_{128}X_{n-128} + C_{129}X_{n-129}$$

1. Firstly, unlock the microprocessor interface by writing a zero to bit 3 (this is normally performed by applying a Master reset).
2. Write 1010bin in the configuration register. This sets the configuration with bit 0 selecting stop mode, bit 1 selecting Intel mode, bit 2 selecting LSB ahead, and bit 3 locks the configuration.
3. Write the Filter Order-1 in the FILT\_ORD register, i.e. 81hex
4. Write the 130 coefficients beginning with the LSB of  $c_0$ , then the MSB of  $c_0$ , etc.
5. Write 11xxx in the NORM register to disable rounding and to select bits 39 to 24 of the 40 bit internal result..
6. Write 1011bin in the Configuration register to start the filter. At each new transition high to low on DIV input signal, a new sample is fed into the filter. The corresponding filtered sample is output 4+33 clock cycles later and specified by a low level on DOV output signal. Here the incoming sample rate must at most be 33 times less than the circuit clock rate, where 33 represents the number of times the 4th order cell is multiplexed.

## Electrical Specifications

### Absolute Maximum Ratings

Symbol	Parameter	Min	Max	Unit	Conditions
$V_{DD}$	DC supply voltage	-0.5	5.5	V	
$V_I$	DC input voltage	-0.5	$V_{DD} + 0.5V$	V	or see $\pm I_{lk}$
$V_O$	DC output voltage	-0.5	$V_{DD} + 0.5V$	V	or see $\pm I_{Ok}$
$\pm I_{lk}$	DC input diode current		10	mA	$V_I < -0.5V$ $V_I > V_{DD} + 0.5V$
$\pm I_{Ok}$	DC output diode current		20	mA	$V_O < -0.5V$ $V_O > V_{DD} + 0.5V$
$I_{OLMAX}$	Continuous output current		10	mA	Industrial
$I_{OHMAX}$	Continuous output current		10	mA	Industrial
$T_{SH}$	Time of outputs shorted		5	sec	

(continued)

### Absolute Maximum Ratings (Continued)

$T_A$	Temperature range	-40	+85	C	Industrial
$T_{SG}$	Storage temperature	-65	+150	C	

### Recommended Operating Conditions

Symbol	Parameter	Min	Typ	Max	Unit	Conditions
$V_{DD}$	DC supply voltage	4.5	5.0	5.5	V	
$V_I$	DC input voltage	0	5.0	$V_{DD}$	V	
$V_O$	DC output voltage	0	5.0	$V_{DD}$	V	
$T_A$	Temperature range	-40		+85	C	Ind
$T_R$	Input rise time			15	ns	10%-90% CMOS
$T_F$	Input fall time			15	ns	10%-90% CMOS

### DC Characteristics

Symbol	Parameter	Min	Max	Unit	Conditions
$I_{IH}$	Input leakage, no pullup	-1.0	+1.0	$\mu A$	$V_{IN} = V_{DD} = 5.5V$
$I_{IL}$	Input leakage, no pullup	-1.0	+1.0	$\mu A$	$V_{IN} = 0$ $V_{DD} = 5.5V$
$I_{OZ}$	High-impedance output current bi-directional pins	-1.0	+1.0	$\mu A$	$V_{DD} = 5.5V$
$V_{IL}$	Low level input voltage		30% $V_{DD}$	V	CMOS inputs and bi-dir
$V_{IH}$	High level input voltage	70% $V_{DD}$		V	CMOS inputs and bi-dir
$V_{OL}$	Low level output voltage		0.5	V	$I_{OL} = 5.0mA$
$V_{OH}$	High level output voltage	$V_{DD} - 0.5$		V	$I_{OH} = 5.0mA$
$C_{IN}$	Input capacitance		7	pF	



# AC Characteristics

Code	Description	Min	Max	Units
TCPH	Clock period	37		ns
TCLH	Clock high	15		ns
TCLL	Clock low	15		ns
TWRP	Write/read period	37		ns
TWRH	Write/read high	15		ns
TWRL	Write/read low	15		ns
TSIS	Synchronous signals to rising clock setup	5		ns
TSIH	Synchronous inputs to rising clock hold	5		ns
TSOD	Synchronous outputs to rising clock delay		10	ns
TWRCLD	Write/read to clock high	5		ns
TACWS	Asynchronous input setup	20		ns
TACWH	Asynchronous inputs hold	5		ns
TAOE	Asynchronous output enable		12	ns
TAOD	Asynchronous output disable		7	ns

See the illustration below for the interpretations of these characteristics.

## AC Characteristics for Single Mode Operation

