



## COMPUTER INTERFACE FOR TUNING AND CONTROL (CITAC)

### GENERAL DESCRIPTION

The SAB3036 provides closed-loop digital tuning of TV receivers, with or without a.f.c., as required. It also controls 4 general purpose I/O ports and 4 high-current outputs for tuner band selection.

The IC is used in conjunction with a microcomputer from the MAB8400 family and is controlled via a two-wire, bidirectional I<sup>2</sup>C bus.

### Features

- Combined analogue and digital circuitry minimizes the number of additional interfacing components required
- Frequency measurement with resolution of 50 kHz
- Selectable prescaler divisor of 64 or 256
- 32 V tuning voltage amplifier
- 4 high-current outputs for direct band selection
- Four general purpose input/output (I/O) ports
- Tuning with control of speed and direction
- Tuning with or without a.f.c.
- Single-pin, 4 MHz on-chip oscillator
- I<sup>2</sup>C bus slave transceiver

### QUICK REFERENCE DATA

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Supply voltages			
(pin 5)	V <sub>P1</sub>	typ.	12 V
(pin 14)	V <sub>P2</sub>	typ.	13 V
(pin 9)	V <sub>P3</sub>	typ.	32 V
Supply currents (no outputs loaded)			
(pin 5)	I <sub>P1</sub>	typ.	23 mA
(pin 14)	I <sub>P2</sub>	typ.	0,1 mA
(pin 9)	I <sub>P3</sub>	typ.	0,6 mA
Total power dissipation	P <sub>tot</sub>	typ.	300 mW
Operating ambient temperature range	T <sub>amb</sub>		-20 to + 70 °C

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### PACKAGE OUTLINE

18-lead DIL; plastic (SOT102).



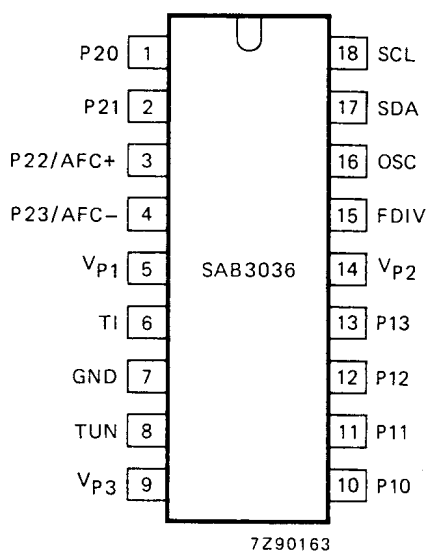
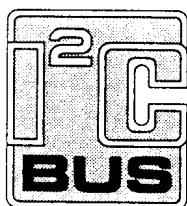


Fig. 2 Pinning diagram.

**PINNING**

1	P20	}	general purpose
2	P21		input/output ports
3	P22/AFC+	}	general purpose input/output
4	P23/AFC-		ports and a.f.c. inputs
5	V <sub>p1</sub>		+ 12 V supply voltage
6	TI		tuning voltage amplifier inverting input
7	GND		ground
8	TUN		tuning voltage amplifier output
9	V <sub>p3</sub>		+ 32 V supply for tuning voltage amplifier
10	P10	}	high-current band-selection output ports
11	P11		
12	P12		
13	P13		
14	V <sub>p2</sub>		positive supply for high-current band-selection output circuits
15	FDIV		input from prescaler
16	OSC		crystal oscillator input
17	SDA	}	I <sup>2</sup> C bus
18	SCL		



Purchase of Philips' I<sup>2</sup>C components conveys a license under the Philips' I<sup>2</sup>C patent to use the components in the I<sup>2</sup>C-system provided the system conforms to the I<sup>2</sup>C specifications defined by Philips.

## FUNCTIONAL DESCRIPTION

The SAB3036 is a monolithic computer interface which provides tuning and control functions and operates in conjunction with a microcomputer via an I<sup>2</sup>C bus.

### Tuning

This is performed using frequency-locked loop digital control. Data corresponding to the required tuner frequency is stored in a 15-bit frequency buffer. The actual tuner frequency, divided by a factor of 256 (or by 64) by a prescaler, is applied via a gate to a 15-bit frequency counter. This input (FDIV) is measured over a period controlled by a time reference counter and is compared with the contents of the frequency buffer. The result of the comparison is used to control the tuning voltage so that the tuner frequency equals the contents of the frequency buffer multiplied by 50 kHz within a programmable tuning window (TUV).

The system cycles over a period of 6,4 ms (or 2,56 ms), controlled by the time reference counter which is clocked by an on-chip 4 MHz reference oscillator. Regulation of the tuning voltage is performed by a charge pump frequency-locked loop system. The charge IT flowing into the tuning voltage amplifier is controlled by the tuning counter, 3-bit DAC and the charge pump circuit. The charge IT is linear with the frequency deviation  $\Delta f$  in steps of 50 kHz. For loop gain control, the relationship  $\Delta IT/\Delta f$  is programmable. In the normal mode (when control bits TUHNO and TUHN1 are both at logic 1, see OPERATION), the minimum charge IT at  $\Delta f = 50$  kHz equals  $250 \mu A \mu s$  (typical).

By programming the tuning sensitivity bits (TUS), the charge IT can be doubled up to 6 times. If correction-in-band (COIB) is programmed, the charge can be further doubled up to three times in relation to the tuning voltage level. From this, the maximum charge IT at  $\Delta f = 50$  kHz equals  $2^6 \times 2^3 \times 250 \mu A \mu s$  (typical).

The maximum tuning current I is  $875 \mu A$  (typical). In the tuning-hold (TUHN) mode (TUHN is active LOW), the tuning current I is reduced and as a consequence the charge into the tuning amplifier is also reduced.

An in-lock situation can be detected by reading FLOCK. When the tuner oscillator frequency is within the programmable tuning window (TUV), FLOCK is set to logic 1. If the frequency is also within the programmable a.f.c. hold range (AFCR), which always occurs if AFCR is wider than TUV, control bit AFCT can be set to logic 1. When set, digital tuning will be switched off, a.f.c. will be switched on and FLOCK will stay at logic 1 as long as the oscillator frequency is within AFCR. If the frequency of the tuning oscillator does not remain within AFCR, AFCT is cleared automatically and the system reverts to digital tuning. To be able to detect this situation, the occurrence of positive and negative transitions in the FLOCK signal can be read (FL/1N and FL/0N). AFCT can also be cleared by programming the AFCT bit to logic 0.

The a.f.c. has programmable polarity and transconductance; the latter can be doubled up to 3 times, depending on the tuning voltage level if correction-in-band is used.

The direction of tuning is programmable by using control bits TDIRD (tuning direction down) and TDIRU (tuning direction up). If a tuner enters a region in which oscillation stops, then, providing the prescaler remains stable, no FDIV signal is supplied to CITAC. In this situation the system will tune up, moving away from frequency lock-in. This situation is avoided by setting TDIRD which causes the system to tune down. In normal operation TDIRD must be cleared.

If a tuner stops oscillating and the prescaler becomes unstable by going into self-oscillation at a very high frequency, the system will react by tuning down, moving away from frequency lock-in. To overcome this, the system can be forced to tune up at the lowest sensitivity (TUS) value, by setting TDIRU.

Setting both TDIRD and TDIRU causes the digital tuning to be interrupted and a.f.c. to be switched on.

The minimum tuning voltage which can be generated during digital tuning is programmable by VTMI to prevent the tuner being driven into an unspecified low tuning voltage region.

**Control**

For tuner band selection there are four outputs P10 to P13 which are capable of sourcing up to 50 mA at a voltage drop of less than 600 mV with respect to the separate power supply input  $V_{p2}$ .

For additional digital control, four open collector I/O ports P20 to P23 are provided. Ports P22 and P23 are capable of detecting positive and negative transitions in their input signals and are connected with the AFC+ and AFC- inputs respectively. The a.f.c. amplifier must be switched off when P22 and/or P23 are used. When a.f.c. is used, P22 and P23 must be programmed HIGH (high impedance state). With the aid of port P20, up to three independent module addresses can be programmed.

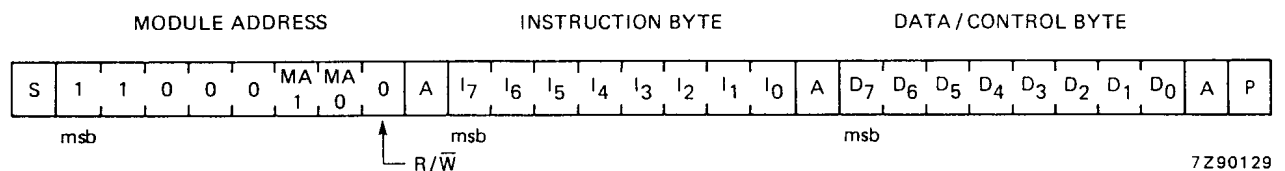
**Reset**

CITAC goes into the power-down-reset mode when  $V_{p1}$  is below 8,5 V (typical). In this mode all registers are set to a defined state. Reset can also be programmed.

**OPERATION**

**Write**

CITAC is controlled via a bidirectional two-wire I<sup>2</sup>C bus; the I<sup>2</sup>C bus is specified in our data handbook "ICs for digital systems in radio, audio, and video equipment". For programming, a module address, R/ $\bar{W}$  bit (logic 0), an instruction byte and a data/control byte are written into CITAC in the format shown in Fig. 3.



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Fig. 3 I<sup>2</sup>C bus write format.

The module address bits MA1, MA0 are used to give a 2-bit module address as a function of the voltage at port P20 as shown in Table 1.

Acknowledge (A) is generated by CITAC only when a valid address is received and the device is not in the power-down-reset mode ( $V_{p1} > 8,5$  V (typical)).

OPERATION (continued)

Table 1 Valid module addresses

MA1	MA0	P20
0	0	don't care
0	1	GND
1	0	½Vp1
1	1	Vp1

Tuning

Tuning is controlled by the instruction and data/control bytes as shown in Fig. 4.

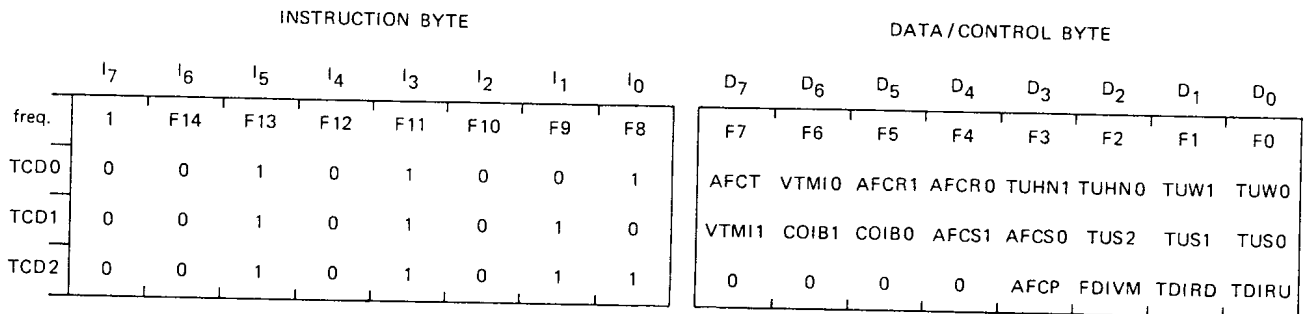


Fig. 4 Tuning control format.

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Frequency

Frequency is set when bit I7 of the instruction byte is set to logic 1; the remainder of this byte together with the data/control byte are loaded into the frequency buffer. The frequency to which the tuner oscillator is regulated equals the decimal representation of the 15-bit word multiplied by 50 kHz. All frequency bits are set to logic 1 at reset.

Tuning hold

The TUHN bits are used to decrease the maximum tuning current and, as a consequence, the minimum charge IT (at Δf = 50 kHz) into the tuning amplifier.

Table 2 Tuning current control

TUHN1	TUHN0	typ. I <sub>max</sub> μA	typ. IT <sub>min</sub> μA μs	typ. ΔVTUN <sub>min</sub> at C <sub>INT</sub> = 1 μF μV
0	0	3,5*	1*	1*
0	1	29	8	8
1	0	110	30	30
1	1	875	250	250

\* Values after reset.

During tuning but before lock-in, the highest current value should be selected. After lock-in the current may be reduced to decrease the tuning voltage ripple.

The lowest current value should not be used for tuning due to the input bias current of the tuning voltage amplifier (max. 5 nA). However it is good practice to program the lowest current value during tuner band switching.

*Tuning sensitivity*

To be able to program an optimum loop gain, the charge  $IT$  can be programmed by changing  $T$  using tuning sensitivity (TUS). Table 3 shows the minimum charge  $IT$  obtained by programming the TUS bits at  $\Delta f = 50$  kHz; TUHN0 and TUHN1 = logic 1.

**Table 3** Minimum charge  $IT$  as a function of TUS

$\Delta f = 50$  kHz; TUHN0 = logic 1; TUHN1 = logic 1

TUS2	TUS1	TUS0	typ. $IT_{\min}$ mA $\mu$ s	typ. $\Delta V_{TUN\min}$ at $C_{INT} = 1 \mu F$ mV
0	0	0	0,25*	0,25*
0	0	1	0,5	0,5
0	1	0	1	1
0	1	1	2	2
1	0	0	4	4
1	0	1	8	8
1	1	0	16	16

\* Values after reset.

*Correction-in-band*

This control is used to correct the loop gain of the tuning system to reduce in-band variations due to a non-linear voltage/frequency characteristic of the tuner. Correction-in-band (COIB) controls the time  $T$  of the charge equation  $IT$  and takes into account the tuning voltage  $V_{TUN}$  to give charge multiplying factors as shown in Table 4.

**Table 4** Programming correction-in-band

COIB1	COIB0	charge multiplying factors at typical values of $V_{TUN}$ at:			
		< 12 V	12 to 18 V	18 to 24 V	> 24 V
0	0	1*	1*	1*	1*
0	1	1	1	1	2
1	0	1	1	2	4
1	1	1	2	4	8

\* Values after reset.

The transconductance multiplying factor of the a.f.c. amplifier is similar when COIB is used, except for the lowest transconductance which is not affected.

*Tuning window*

Digital tuning is interrupted and FLOCK is set to logic 1 (in-lock) when the absolute deviation  $|\Delta f|$  between the tuner oscillator frequency and the programmed frequency is smaller than the programmed TUN value (see Table 5). If  $|\Delta f|$  is up to 50 kHz above the values listed in Table 5, it is possible for the system to be locked depending on the phase relationship between FDIV and the reference counter.

## OPERATION (continued)

Table 5 Tuning window programming

TUW1	TUW0	$ \Delta f $ (kHz)	tuning window (kHz)
0	0	0*	0*
0	1	50	100
1	0	150	300

\* Values after reset.

*A.F.C.*

When AFCT is set to logic 1 it will not be cleared and the a.f.c. will remain on as long as  $|\Delta f|$  is less than the value programmed for the a.f.c. hold range AFCR (see Table 6). It is possible for the a.f.c. to remain on for values of up to 50 kHz more than the programmed value depending on the phase relationship between FDIV and the reference counter.

Table 6 A.F.C. hold range programming

AFCR1	AFCR0	$ \Delta f $ (kHz)	a.f.c. hold range (kHz)
0	0	0*	0*
0	1	350	700
1	0	750	1500

\* Values after reset.

*Transconductance*

The transconductance (g) of the a.f.c. amplifier is programmed via the a.f.c. sensitivity bits AFCS as shown in Table 7.

Table 7 Transconductance programming

AFCS1	AFCS0	typ. transconductance ( $\mu\text{A/V}$ )
0	0	0,25*
0	1	25
1	0	50
1	1	100

\* Value after reset.

*A.F.C. polarity*

If a positive differential input voltage is applied to the (switched on) a.f.c. amplifier, the tuning voltage  $V_{TUN}$  falls when the a.f.c. polarity bit AFPC is at logic 0 (value after reset). At AFPC = logic 1,  $V_{TUN}$  rises.

*Minimum tuning voltage*

Both minimum tuning voltage control bits, VTMI1 and VTMI0, are at logic 0 after reset. Further details are given in CHARACTERISTICS.





OPERATION (continued)

Read

Information is read from CITAC when the R/W bit is set to logic 1. An acknowledge must be generated by the master after each data byte to allow transmission to continue. If no acknowledge is generated by the master the slave (CITAC) stops transmitting. The format of the information bytes is shown in Fig. 6.

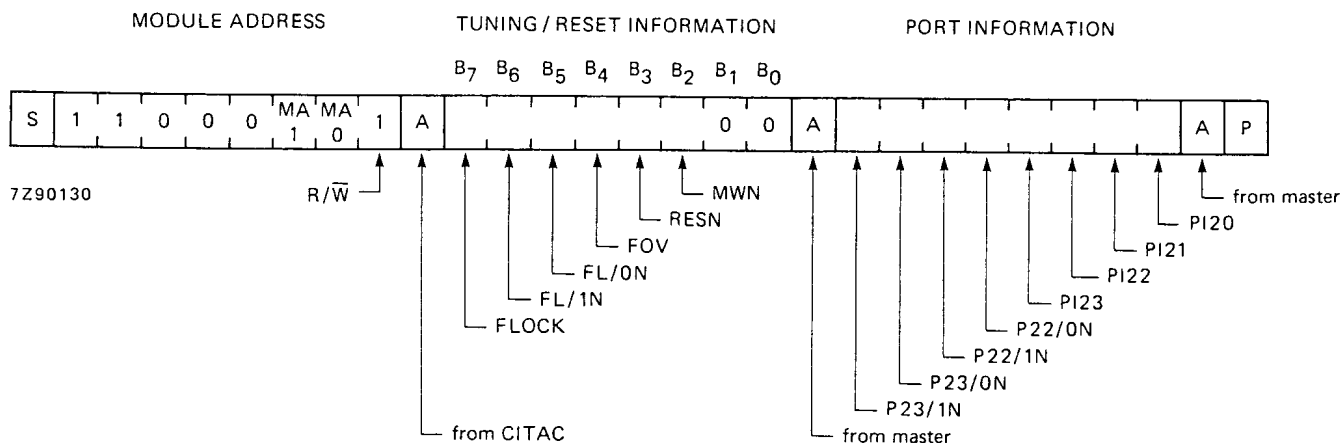


Fig. 6 Information byte format.

*Tuning/reset information bits*

- FLOCK** Set to logic 1 when the tuning oscillator frequency is within the programmed tuning window.
- FL/1N** Set to logic 0 (active LOW) when FLOCK changes from 0 to 1 and is reset to logic 1 automatically after tuning information has been read.
- FL/ON** As for FL/1N but is set to logic 0 when FLOCK changes from 1 to 0.
- FOV** Indicates frequency overflow. When the tuner oscillator frequency is too high with respect to the programmed frequency, FOV is at logic 1, and when too low, FOV is at logic 0. FOV is not valid when TDIRU and/or TDIRD are set to logic 1.
- RESN** Set to logic 0 (active LOW) by a programmed reset or a power-down-reset. It is reset to logic 1 automatically after tuning/reset information has been read.
- MWN** MWN (frequency measuring window, active LOW) is at logic 1 for a period of 1,28 ms, during which time the results of frequency measurement are processed. This time is independent of the cycle period. During the remaining time, MWN is at logic 0 and the received frequency is measured.

When slightly different frequencies are programmed repeatedly and a.f.c. is switched on, the received frequency can be measured using FOV and FLOCK. To prevent the frequency counter and frequency buffer being loaded at the same time, frequency should be programmed only during the period of MWN = logic 0.



## CHARACTERISTICS

$T_{amb} = 25\text{ }^{\circ}\text{C}$ ;  $V_{P1}$ ,  $V_{P2}$ ,  $V_{P3}$  at typical voltages, unless otherwise specified

parameter	symbol	min.	typ.	max.	unit
Supply voltages	$V_{P1}$	10,5	12	13,5	V
	$V_{P2}$	4,7	13	16	V
	$V_{P3}$	30	32	35	V
Supply currents (no outputs loaded)	$I_{P1}$	14	23	40	mA
	$I_{P2}$	0	—	0,1	mA
	$I_{P3}$	0,2	0,6	2	mA
Additional supply currents (A) (note 1)	$I_{P2A}$	—2	—	$I_{OHP1X}$	mA
	$I_{P3A}$	0,2	—	2	mA
Total power dissipation	$P_{tot}$	—	300	—	mW
Operating ambient temperature	$T_{amb}$	—20	—	+70	$^{\circ}\text{C}$
<b>I<sup>2</sup>C bus inputs/outputs</b>					
SDA input (pin 17); SCL input (pin 18)					
Input voltage HIGH (note 2)	$V_{IH}$	3	—	$V_{P1}-1$	V
Input voltage LOW	$V_{IL}$	—0,3	—	1,5	V
Input current HIGH (note 2)	$I_{IH}$	—	—	10	$\mu\text{A}$
Input current LOW (note 2)	$I_{IL}$	—	—	10	$\mu\text{A}$
SDA output (pin 17, open collector)					
Output voltage LOW at $I_{OL} = 3\text{ mA}$	$V_{OL}$	—	—	0,4	V
Maximum output sink current	$I_{OL}$	—	5	—	mA
<b>Open collector I/O ports</b>					
P20, P21, P22, P23 (pins 1 to 4, open collector)					
Input voltage HIGH (P20, P21)	$V_{IH}$	2	—	16	V
Input voltage HIGH (P22, P23) AFC switched off	$V_{IH}$	2	—	$V_{P1}-2$	V
Input voltage LOW	$V_{IL}$	—0,3	—	0,8	V
Input current HIGH	$I_{IH}$	—	—	25	$\mu\text{A}$
Input current LOW	$-I_{IL}$	—	—	25	$\mu\text{A}$
Output voltage LOW at $I_{OL} = 2\text{ mA}$	$V_{OL}$	—	—	0,4	V
Maximum output sink current	$I_{OL}$	—	4	—	mA

parameter	symbol	min.	typ.	max.	unit	
<b>A.F.C. amplifier</b>						
Inputs AFC+, AFC- (pins 3, 4)						
Transconductance for input voltages up to 1 V differential:						
AFCS1	AFCS2					
0	0	900	100	250	800	nA/V
0	1	901	15	25	35	$\mu$ A/V
1	0	910	30	50	70	$\mu$ A/V
1	1	911	60	100	140	$\mu$ A/V
Tolerance of transconductance multiplying factor (2, 4 or 8) when correction-in-band is used						
	$\Delta M_g$	-20	-	+20	%	
Input offset voltage						
	$V_{loff}$	-75	-	+75	mV	
Common mode input voltage						
	$V_{com}$	3	-	$V_{P1-2,5}$	V	
Common mode rejection ratio						
	CMRR	-	50	-	dB	
Power supply ( $V_{P1}$ ) rejection ratio						
	PSRR	-	50	-	dB	
Input current (P22 and P23 programmed HIGH)						
	$I_I$	-	-	500	nA	
<b>Tuning voltage amplifier</b>						
Input TI, output TUN (pins 6, 8)						
Maximum output voltage at $I_{load} = \pm 1,5$ mA						
	$V_{TUN}$	$V_{P3-1,6}$	-	$V_{P3-0,4}$	V	
Minimum output voltage at $I_{load} = \pm 1,5$ mA						
VTMI1	VTMI0					
0	0	$V_{TM00}$	300	-	500	mV
1	0	$V_{TM10}$	450	-	650	mV
1	1	$V_{TM11}$	650	-	900	mV
Maximum output source current						
	$-I_{TUNH}$	2,5	-	8	mA	
Maximum output sink current						
	$I_{TUNL}$	-	40	-	mA	
Input bias current						
	$I_{TI}$	-5	-	+5	nA	
Power supply ( $V_{P3}$ ) rejection ratio						
	PSRR	-	60	-	dB	

## CHARACTERISTICS (continued)

parameter	symbol	min.	typ.	max.	unit	
<b>Tuning voltage amplifier (continued)</b>						
Minimum charge IT to tuning voltage amplifier						
TUHN1	TUHN0					
0	0	CH00	0,4	1	1,7	$\mu\text{A } \mu\text{s}$
0	1	CH01	4	8	14	$\mu\text{A } \mu\text{s}$
1	0	CH10	15	30	48	$\mu\text{A } \mu\text{s}$
1	1	CH11	130	250	370	$\mu\text{A } \mu\text{s}$
Tolerance of charge (or $\Delta V_{\text{TUN}}$ ) multiplying factor when COIB and/or TUS are used						
		$\Delta\text{CH}$	-20	-	+20	%
Maximum current I into tuning amplifier						
TUHN1	TUHN0					
0	0	IT00	1,7	3,5	5,1	$\mu\text{A}$
0	1	IT01	15	29	41	$\mu\text{A}$
1	0	IT10	65	110	160	$\mu\text{A}$
1	1	IT11	530	875	1220	$\mu\text{A}$
<b>Correction-in-band</b>						
Tolerance of correction-in-band levels 12 V, 18 V and 24 V						
		$\Delta V_{\text{CIB}}$	-15	-	+15	%
<b>Band-select output ports</b>						
P10, P11, P12, P13 (pins 10 to 13)						
Output voltage HIGH at $-I_{\text{OH}} = 50 \text{ mA}$ (note 3)						
		$V_{\text{OH}}$	$V_{\text{P2}} - 0,6$	-	-	V
Output voltage LOW at $I_{\text{OL}} = 2 \text{ mA}$						
		$V_{\text{OL}}$	-	-	0,4	V
Maximum output source current (note 3)						
		$-I_{\text{OH}}$	-	130	200	mA
Maximum output sink current						
		$I_{\text{OL}}$	-	5	-	mA
<b>FDIV input (pin 15)</b>						
Input voltage (peak-to-peak value) ( $t_{\text{rise}}$ and $t_{\text{fall}} \leq 40 \text{ ns}$ )						
		$V_{\text{FDIV(p-p)}}$	0,1	-	2	V
Duty cycle						
		-	40	-	60	%
Maximum input frequency						
		$f_{\text{max}}$	16	-	-	MHz
Input impedance						
		$Z_{\text{i}}$	-	8	-	$\text{k}\Omega$
Input capacitance						
		$C_{\text{i}}$	-	5	-	pF

parameter	symbol	min.	typ.	max.	unit	
<b>OSC input (pin 24)</b>						
Crystal resistance at resonance (4 MHz)	$R_X$	—	—	150	$\Omega$	
<b>Power-down-reset</b>						
Maximum supply voltage $V_{P1}$ at which power-down-reset is active	$V_{PD}$	7,5	—	9,5	V	
$V_{P1}$ rise-time during power-up (up to $V_{PD}$ )	$t_r$	5	—	—	$\mu s$	
<b>Voltage level for valid module address</b>						
Voltage level at P20 (pin 1) for valid module address as a function of MA1, MA0						
MA1	MA0					
0	0	$V_{VA00}$	—0,3	—	16	V
0	1	$V_{VA01}$	—0,3	—	0,8	V
1	0	$V_{VA10}$	2,5	—	$V_{P1}-2$	V
1	1	$V_{VA11}$	$V_{P1}-0,3$	—	$V_{P1}$	V

**Notes to the characteristics**

1. For each band-select output which is programmed at logic 1, sourcing a current  $I_{OHP1X}$ , the additional supply currents (A) shown must be added to  $I_{P2}$  and  $I_{P3}$  respectively.
2. If  $V_{P1} < 1$  V, the input current is limited to 10  $\mu A$  at input voltages up to 16 V.
3. At continuous operation the output current should not exceed 50 mA. When the output is short-circuited to ground for several seconds the device may be damaged.
4. Values are proportional to  $V_{P1}$ .

I<sup>2</sup>C BUS TIMING (Fig. 8)

I<sup>2</sup>C bus load conditions are as follows:

4 kΩ pull-up resistor to +5 V; 200 pF capacitor to GND.

All values are referred to V<sub>IH</sub> = 3 V and V<sub>IL</sub> = 1,5 V.

parameter	symbol	min.	typ.	max.	unit
Bus free before start	t <sub>BUF</sub>	4	—	—	μs
Start condition set-up time	t <sub>SU,STA</sub>	4	—	—	μs
Start condition hold time	t <sub>HD,STA</sub>	4	—	—	μs
SCL, SDA LOW period	t <sub>LOW</sub>	4	—	—	μs
SCL HIGH period	t <sub>HIGH</sub>	4	—	—	μs
SCL, SDA rise time	t <sub>R</sub>	—	—	1	μs
SCL, SDA fall time	t <sub>F</sub>	—	—	0,3	μs
Data set-up time (write)	t <sub>SU,DAT</sub>	1	—	—	μs
Data hold time (write)	t <sub>HD,DAT</sub>	1	—	—	μs
Acknowledge (from CITAC) set-up time	t <sub>SU,CAC</sub>	—	—	2	μs
Acknowledge (from CITAC) hold time	t <sub>HD,CAC</sub>	0	—	—	μs
Stop condition set-up time	t <sub>SU,STO</sub>	4	—	—	μs
Data set-up time (read)	t <sub>SU,RDA</sub>	—	—	2	μs
Data hold time (read)	t <sub>HD,RDA</sub>	0	—	—	μs
Acknowledge (from master) set-up time	t <sub>SU,MAC</sub>	1	—	—	μs
Acknowledge (from master) hold time	t <sub>HD,MAC</sub>	2	—	—	μs

Note

Timings t<sub>SU,DAT</sub> and t<sub>HD,DAT</sub> deviate from the I<sup>2</sup>C bus specification .

After reset has been activated, transmission may only be started after a 50 μs delay.

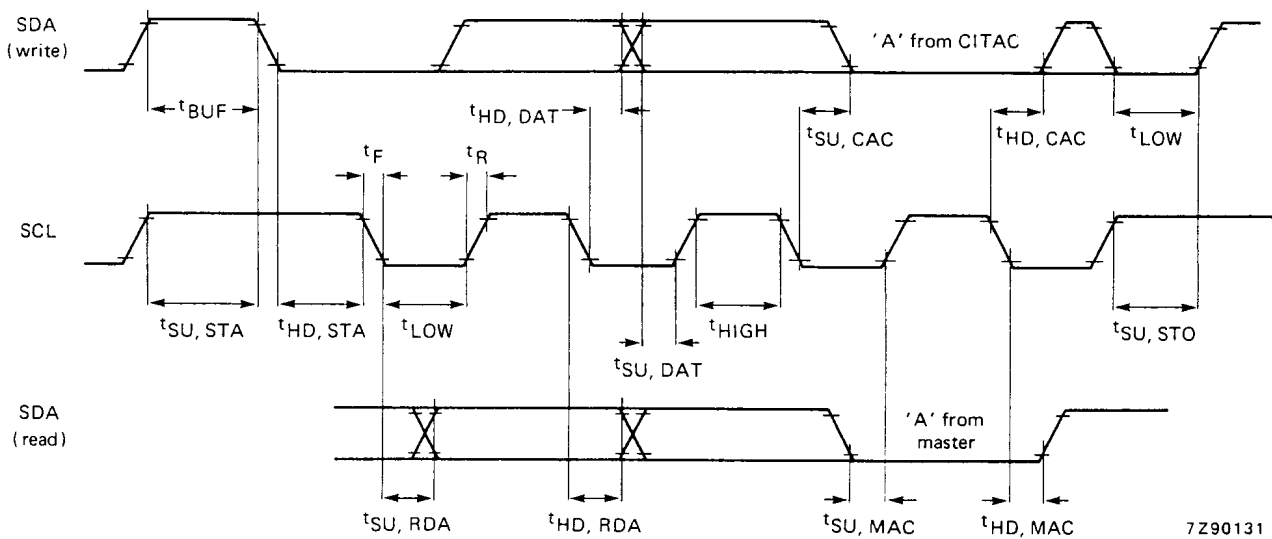


Fig. 8 I<sup>2</sup>C bus timing SAB3036.