Comprehensive Academic and Technical Science CAT-SCIENCE	# CAMTIMER ## TTL and LVDS (RS-644) timing input-output unit Version 1.1

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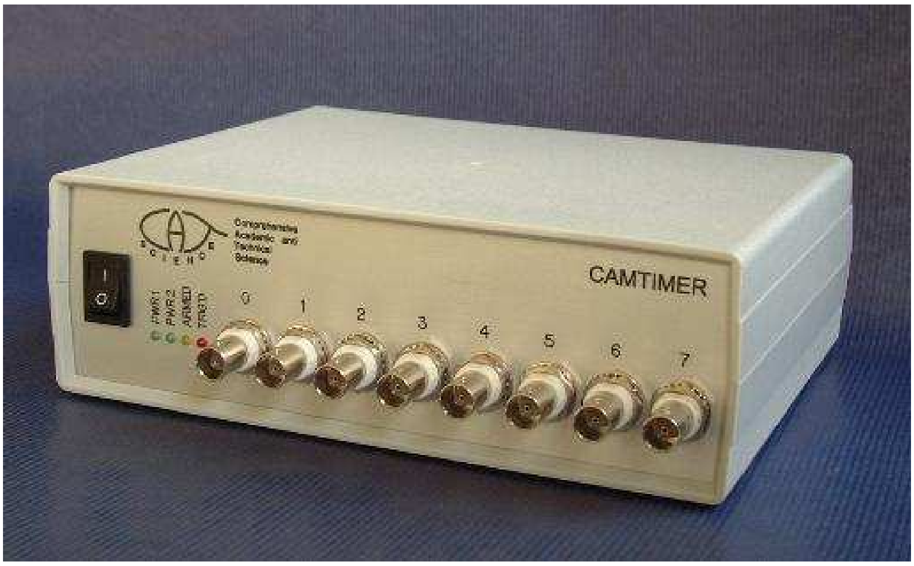
Overview

CAMTIMER is a standalone unit for generating and measuring 4-channel timing pulses in TTL and/or LVDS (RS-644) format. Although it is primarily designed for digital camera timing applications, CAMTIMER can be effectively used for many other purposes as well. Timing pulses are produced by 10 identical timers, each capable of generating a sequence of pulses. Each timer has 4 individually adjustable parameters: start time of the sequence, on-time, off-time and number of pulses. The output of these timers can be combined to form 4 output pulse sequences. The input section counts and measures pulses on 4 input lines. Additionally to timing an 8 bit digital I/O input register is also available. If operated from two power supplies the clock/trigger section of CAMTIMER can be made optically isolated from the timing module. External signal connections can be made via the jumper-configurable front BNC connectors and/or the two 9-pin D-sub connectors on the rear panel.



Features:

Number of timing inputs	4
Number of timing outputs	4
Number of timers	10
Digital inputs	8 bits
Digital outputs	8 bits
Digital output update	Synchronized with timers, 11 registers
Signal formats	TTL, LVDS, software selectable
Maximum clock frequency	10 MHz
Host communication	Serial line, max 115200 baud
Connectors	8×BNC, 2×D-sub 9, jumper configurable
Software	C develompent kit for Windows/Linux, CrossControl, IDL, script interpreter

Timing output

CAMTIMER has four timing outputs (TOUT0-TOUT3), each available in both TTL and LVDS format. (The two different format signals are always driven in parallel.) Each output can be synthesized from the output of ten internal timers (see Figure 1). Each timer can be OR connected to any of the four outputs and they can be enabled independently. The internal timers have four setup parameters: the delay (4 bytes), on-time (2 bytes), off-time (2 bytes) and number (4 bytes) of pulses as shown in Figure 2. All of these parameters are expressed in pulse counts of a common clock (see below). The timer output polarity can be set by software control as shown in Figure 1.

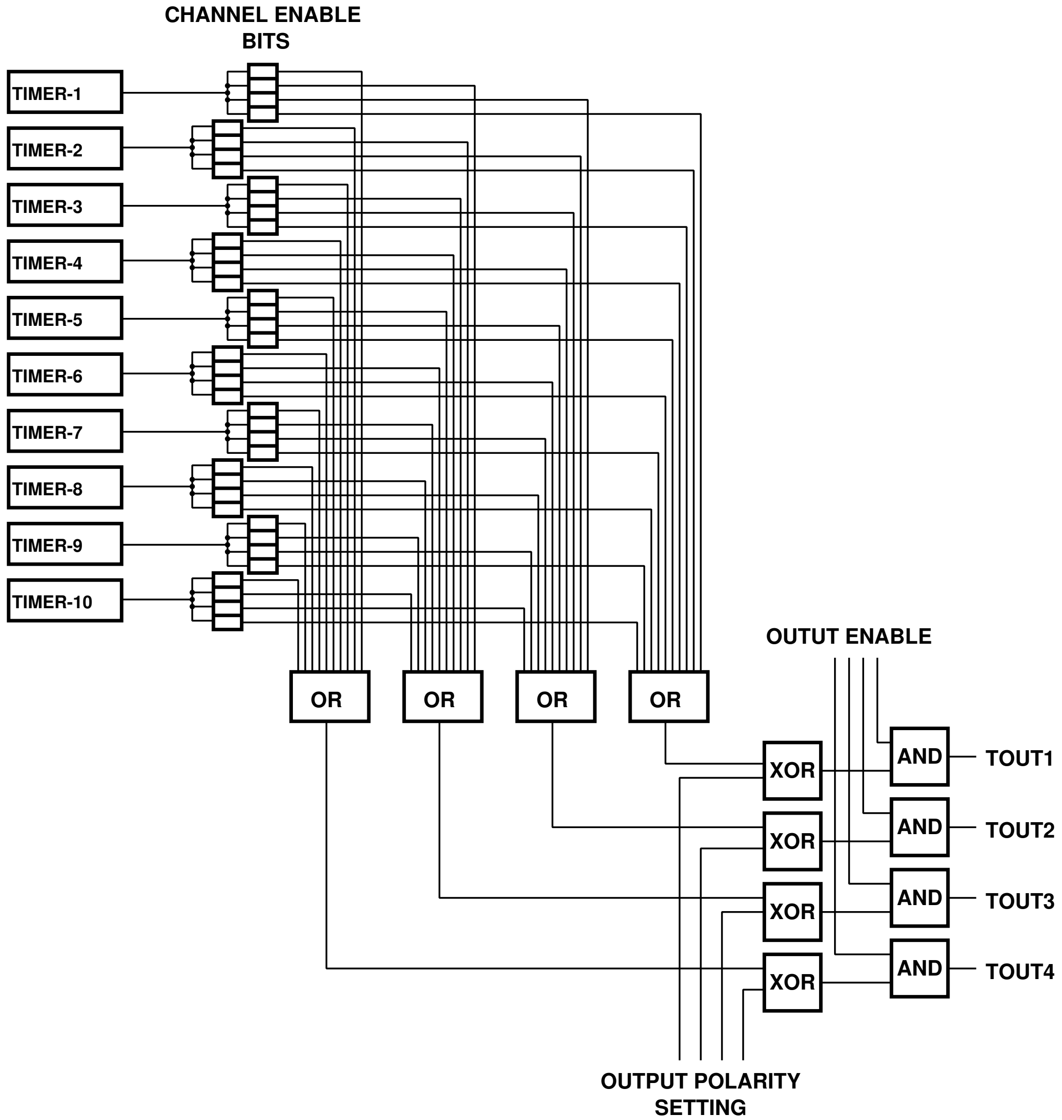


Figure 1: The four outputs of CAMTIMER are synthesized from the output of ten internal timers.

Two possibilities are available to produce clock signal for the timers: they can use a 10 MHz internal reference or the external clock input on the rear panel of the unit. Selection can be made via a control bit in the General Purpose Control Register (GPCR). The selected reference clock is output on the "CLOCK OUT" connector to enable synchronized operation of multiple units. The reference clock can be divided by a programmable divider (2 bytes giving a maximum division of 64K). This divided clock serves as the base clock for all the internal

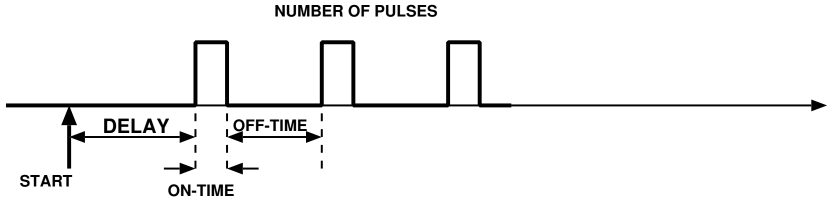


Figure 2: The parameters of one timer.

timers and time measurements..

Timing input

CAMTIMER has five time measuring channels. Four of them (TI0-TI3) measure the timing of edges in four input signals in time units of the base clock. The edges are also counted in a 13 bit register. These four channels are fed using the four timer inputs. The fifth time measuring channel can be activated by software command (setting bit 6 of the GPCR to 1) and can be used to measure the time of a software event. The measured time is a 4-byte time value representing the status of the base clock counter when the timer input edge was received. (That is the base clock time periods passed since the start trigger.) The timer status (the channel identification number, the measured time and the edge count) is sent to the computer via the RS-232 line. The four timer inputs can be driven from either TTL or LVDS signals, selection is made by bit 9 in the GPCR.

Digital I/O

CAMTIMER has 8 digital input and 8 bit digital output lines. The 8 digital input lines are mapped to bits 8-15 of the General Purpose Input-Output Register (GPIOR). A read operation on the register returns the actual input signal levels. The 8 input bits can be taken either from TTL or LVDS lines, a selection can be made by bit 8 of the GPCR. The 8 digital output lines are fed by a register file of 11 bytes. The outputs change state during the generation of output timing pulses as shown in Figure 3. Each of the 10 Timer Control Registers (TCR) contains one byte (bits 4-11) which are copied to the output when the timer finishes its operation (that is delay has passed and it has finished producing pulses). There is an additional one byte register (GPIOR bits 8-15) which will be output when the unit is in armed mode and before the first timer stops. The 8-bit digital output drives the 8 TTL and 8 LVDS outputs lines in parallel.

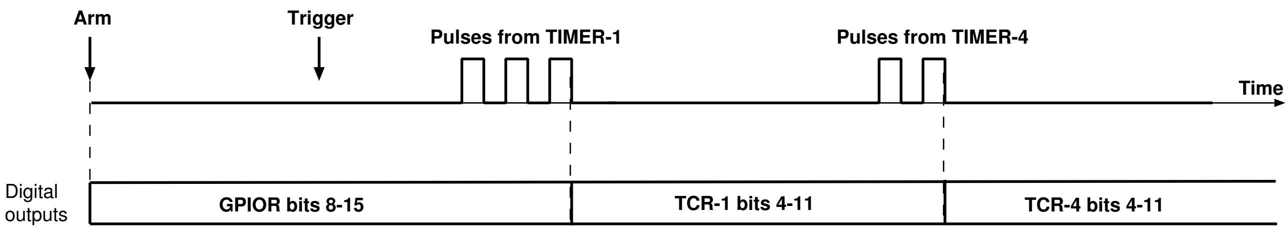


Figure 3: Timing of the 8 digital output lines.

Control and operating modes

CAMTIMER can be in one of three states: idle, armed or running. Idle is the default mode after power-up, when the unit does not respond to trigger or input pulses and does not produce output pulses. This mode is normally used for setting up operation parameters.

After programming is finished CAMTIMER is set to "armed" mode by setting bit 0 in the GPCR. In this mode the unit waits for trigger, still no timing pulses are generated or measured. The digital output lines will represent bits 8-15 of the GPIOR.

From "armed" mode "running" mode is entered on a trigger edge or when a start command is received (bit 1 of GPCR). Time measurement and pulse generation starts from this time instance, this is the 0 point for time measurements. Operation can be aborted by software command (resetting bit 0 in GPCR) or it ends when all 10 timers finished generating the requested number of pulses. Bits 2 and 3 in the GPCR control the action to be taken when all the timers finish pulse generation. In "restart" mode CAMTIMER immediately restarts operation with the previous setting. All internal counters will be reset and time measurement is restarted from a new 0 point. In "rearm" mode CAMTIMER is set to "armed" mode and will wait for the next trigger event. If none of these bits is set CAMTIMER will enter "idle" mode after finishing pulse generation. It has to be noted that time measurements are also stopped when "idle" mode is entered.

Signals and connectors

Two signal formats are available in CAMTIMER albeit not on all connectors: TTL and LVDS (RS-644). LVDS signals are also compatible with the RS-422 signal format. LVDS signals are bipolar and need two wires for transmitting one bit.

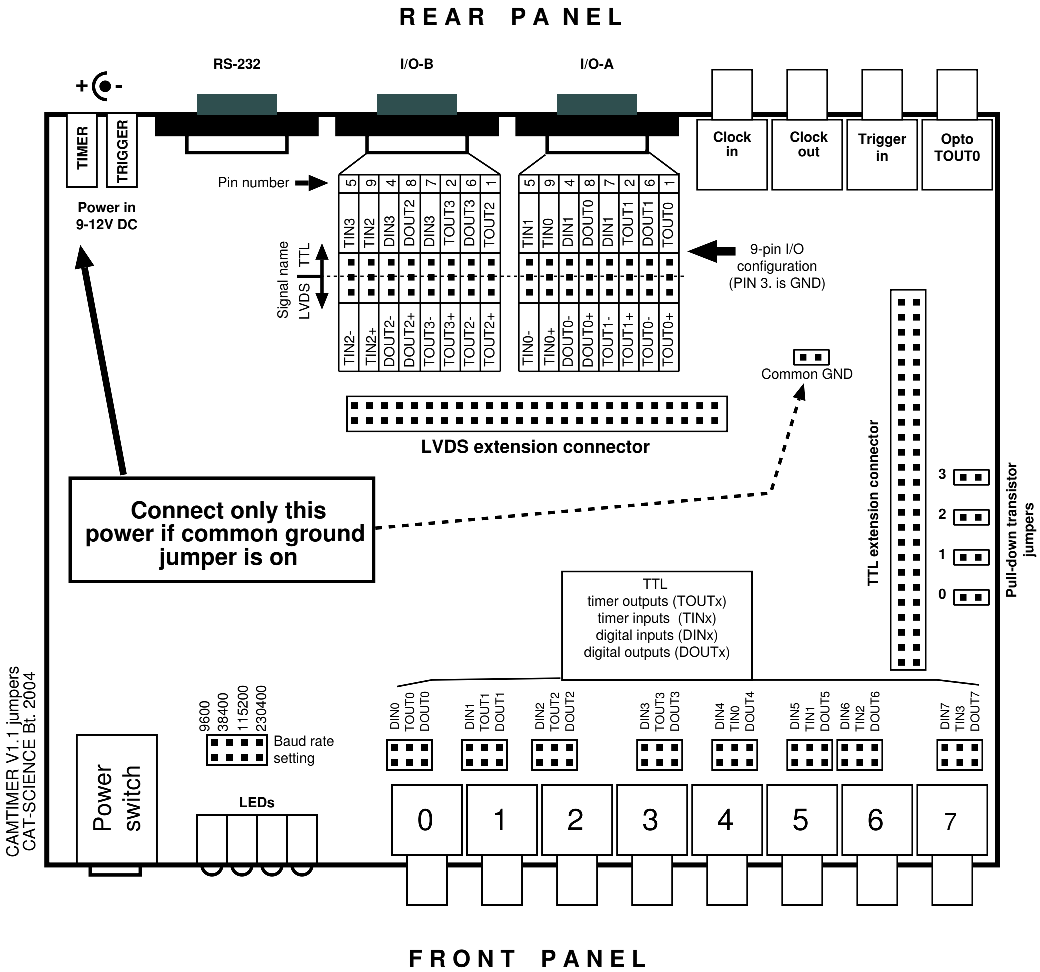


Figure 4: The location and use of jumpers on the CAMTIMER board.

The 8 BNC connectors on the front panel can accommodate only TTL signals, while the 2 rear male 9-pin D-sub connectors can be used for both TTL and LVDS signals. The pin-out of the connectors can be set using internal jumpers, Figure 4. shows the location of jumpers and their setting. (The same figure is attached to the inner side of the CAMTIMER box cover.) Signals are denoted as listed below. Signal names *without* a + or - at their end indicate a TTL signal. The same name *with* + and - is used for naming the corresponding pair of LVDS signals.

TOUTx: Timer outputs (0...3).

TINx: Time measurement inputs (0...3).

DOUTx: Digital output signals (0...7).

DINx: Digital input signals (0...7).

Please note that one of three signals can be connected to BNC connectors: a timing I/O, a digital input or a digital output. For timing output BNC 0...3 can be used, while for timing input BNC 4...7 are available. To configure a signal to the BNC connector place a jumper to connect the two pins next to the signal name. (That is the jumper will be placed at a right angle to the from panel.) Always place only one jumper for one BNC jumper block.

To set up the configuration of the two 9-pin D-sub connectors (I/O-A and I/O-B in Figure 4.) use the two jumper blocks close the rear panel. Pin 3 of both connectors is connected to GND. All other 8 pins can be used for either a TTL or an RS-644 signal. The jumper blocks are arranged in a way that 3 jumper pins belong to one pin in the D-sub connector. The pin number is indicated in Figure 4. next to the connector. To select a TTL signal place a jumper across the two jumper pins closer to the rear panel. To select an LVDS signal place the jumper across the two pins close to the front. The functionality of the two connectors is identical, only channel numbers are different.

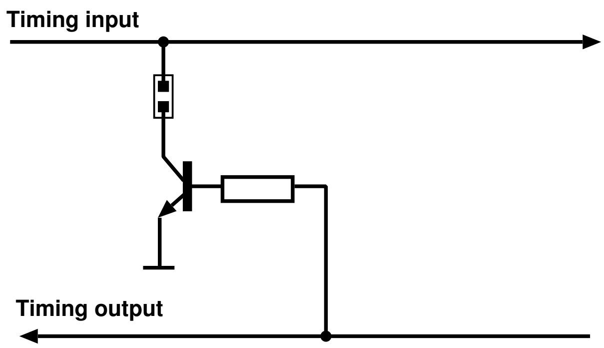


Figure 5: Pulldown transistor on the timing input line.

A special feature of CAMTIMER is that the TTL timing input signals can be pulled down with the timing output signals as shown in Figure 5. This is done to support communication with a SensiCam camera from PCO AG where trigger and exposure timing output is connected to a single TTL line.

Host connection, controls and indicators.

For communication with the host computer a female 9-pin Cannon connector is available on the rear panel. The pin-out follows the standard RS-232 signal connection. To connect to a serial port a straight connected RS-232 cable is necessary with female connector on one end and male on the other.

The following controls and indicators are available on the front panel (from left to right):

Power switch: Switches both power inputs.

Two green LEDs: Left indicates power for the timers, right one for the trigger unit.

The yellow LED is lit in ARMED state.

The red LED is lit when the unit is RUNNING state.

Power and grounding scheme

The trigger and clock subsystem can be operated in a ground-independent mode as shown in Fig. 6. For this purpose CAMTIMER has two independent power inputs (unregulated 9V DC each, central connector is negative). One operates the clock and trigger subsystem while the second feeds the rest of the unit. An internal jumper (see Figure 4.) serves for connecting grounds of the two power. If CAMTIMER is operated from a common ground it needs only one power input, which is connected to the connector closer to the corner. If grounds are separated, two power units must be used.

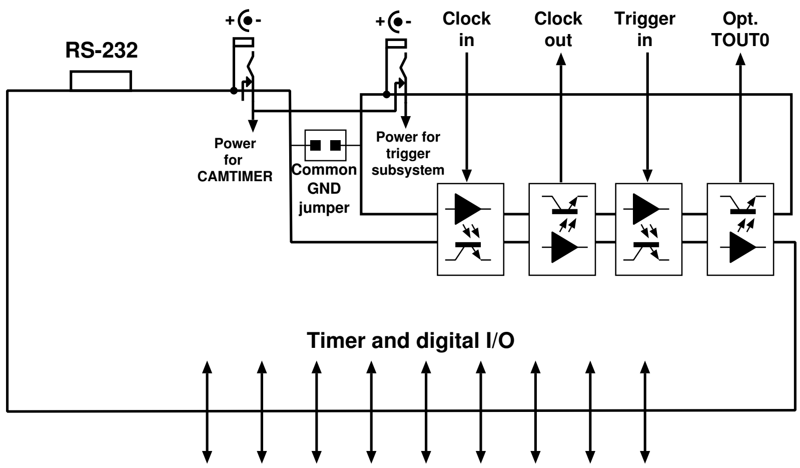


Figure 6: *Grounding scheme of* CAMTIMER.

An optocoupled TOUT0 signal is also available on the rear panel. It shares ground with the trigger and clock subsystem.

Trigger and clock input/output

An external TTL trigger pulse can be connected to the rear trigger connector. The active edge (positive or negative) can be selected in the GPCR. Pulse generation and time measurement starts from an active edge.

An external TTL clock input can be connected to the clock input BNC on the rear panel. If external clock source is selected in the GPCR this clock signal will be used instead of the internal 10 MHz reference. The maximum input frequency of the external clock input is 10 MHz. The selected reference clock signal (internal 10 MHz or external clock) is output on the "clock out" connector. This can be used to drive more than one CAMTIMERs from a single clock.

Host communication

Host communication is done through a standard RS-232 serial line with speeds up to 115200 baud. Baud rate can be set by a jumper inside CAMTIMER (see Figure 4. For communication

Character	*description*	*Hex code*
SOH	Start of header	0x01
ACK	Acknowledge (Frame accepted)	0x06
NAK	Not acknowledge (Frame not accepted)	0x15
XON	Transmission on	0x11
XOFF	Transmission off	0x13

Table 1: Control characters used in communication.

always 8 bits and 1 stop bit are used. Software flow control can be used, but no hardware flow control is available. Information between the host and CAMTIMER is sent in standardized 10 byte long frames in both directions. Each frame starts with a Start of Header (SOH, 0x01) character. The next 8 characters contain data, but to avoid undesired effects due to sending control characters only characters between 0x40 and 0x7f are used. This means 6 bits of data in each character, that is 48 bits in one frame. The last character of the frame contains checksum which is created by adding the eight 6-bit data words, keeping the last 6 bits and adding 0x40. Between the frames only control characters are transmitted, which are listed in Table 1. XON and XOFF characters are interpreted by CAMTIMER as transmission on and off and the data flow is stopped/started accordingly.

(a) HOST ⟶ CAMTIMER

47 44	43 12	11 4	3	2 0
reserved	Register value (32 bits)	Register address (8 bits)	$W/\overline{R}$	000

(b) CAMTIMER ⟶ HOST (register read)

47 44	43 12	11 4	3	2 0
reserved	Register value (32 bits)	Register address (8 bits)	0	000

(c) CAMTIMER ⟶ HOST (time measurement)

47 16	15 3	2 0
Time (32 bits)	Pulse counter(13 bits)	ID

Figure 7: Format of the 48 data bits in different frames. (a) Frames sent from the host to CAMTIMER. (b) Frames sent from CAMTIMER to the host with register contents. (c) Frames sent from CAMTIMER with time measurement data.

From the host CAMTIMER is controlled and its status is read by writing/reading its registers. Each read/write register operation is done by sending one 10-byte frame. If CAMTIMER accepts the frame it sends and ACK character as response, if the frame is rejected (due to e.g. checksum error or bad parameter) a NAK character is sent. After receiving a valid register read request CAMTIMER will send a 10-byte frame as a response, but does not expect any response from the host. CAMTIMER will also send a frame when it performs a time measurement in response to either a timing input edge or a software command. This means that the time measurement results are transmitted on the serial line during operation. Although CAMTIMER has an internal time measurement queue, if a lot of time measurements are done with short repetition time some data will be lost. For example in the case of 115200 baud communication speed the transmission of one frame takes about 1 ms. If several hundred time measurements occur with

Register	Address
General Purpose Control Register, GPCR (32 bits)	0
Reference Clock Divisor Register, RCDR (16 bits)	4
General Purpose Input Output Register, GPIOR (32 bits)	8
Version Identification Register, VIDR (32 bits)	12
Timer n Pulse Number Register, PNRn (32 bits)	$16n{+}16$
Timer n Delay Time Register, DTRn (32 bits)	$16n{+}20$
Timer n Off Time Register, OFFTRn (16 bits)	$16n{+}24$
Timer n On Time Register, ONTRn (32 bits)	$16n{+}26$
Timer n Control register, CTRn (32 bits)	$16n{+}28$

Table 2: CAMTIMER register addresses.

more than 1 kHz some data will be lost. However, this can be detected by checking the pulse counter field in the data transmission. This will reveal the number of lost time measurements.

As each frame consists of $8{\times}6{=}48$ data bits we consider each frame as a 48 bit data word. Always bit 0 is sent first on the serial line. The format of the different frames sent between the host and the timer is shown in Figure 7. The frames sent from the host to CAMTIMER request a read or write operation on a register. The register addresses are listed in Table 2. bit 3 determines whether read or write is desired: 1 causes write operation and the contents of the register value field is copied to the specified register.

The frames sent by CAMTIMER to the host can be either a response to a register read command or a time measurement. In the time measurement frame the ID field is 1...4 for the four timing inputs TIN0...TOUT3 and 5 for software initiated time measurement.

The address of the registers is shown in Table 2. GPCR contains a collection of bits, their interpretation is listed in Table 3. The value of RCDR is used for dividing the reference clock to set the timer base clock. The content of GPIOR is shown in Table 4. The VIDR can be read only and contains various information about the current version of the firmware operating the timer. Version 1.0 returns all 0 bits the contents returned from version 1.1 is shown in Table 6. The 5 last registers are repeated for each of the 4 timers. PNR gives the number of pulses the timer will generate, OFFTR and ONTR defines the off and on times of the pulse in base clock units, while CTR contains several bits as shown in Table. 5.

Software.

Different level software packages are available to control CAMTIMER. The most basic interface is to write/read its registers as described in the section above. As serial line drivers are part of all operating systems, this should be possible. To minimize the programming effort a C language subroutine package is supplied for Windows and Linux. A test program (`ct_test`) is available which enables the user to set up parameters of CAMTIMER using a simple menu interface. This test program can also be run using a scripting language, this way simple pulse generation tasks can be set up easily and run with a single command.

For users who wish to run their CAMTIMER from an IDL or Matlab program a CrossControl[1] server and associated IDL or Matlab interface can be purchased. Packages for easy controlling of a combination of CAMTIMER and digital cameras from PCO AG are also available. For details please check the webpages of CAT-SCIENCE: www.catscience.kfkipark.hu.

[1]CrossControl is a software communication scheme developed by CAT-SCIENCE for control and data acquisition in high-level languages in a heterogeneous network environment.

Bits	*Description*
0	**Arm.** This bit enables or disables operation. When this bit is set to 1 CAMTIMER goes to ARMED mode. Setting this bit to 0 will put CAMTIMER in IDLE mode. *Care must be taken that this bit returns 0 when GPCR is read.*
1	**Start/Stop.** Setting this bit to 1 will put CAMTIMER from ARMED to RUNNING state, i.e. it is a software trigger. Please note that bit 0 has to be set prior to starting operation.
2	**Rearm.** Setting this bit to 1 will cause CAMTIMER to automatically enter ARMED mode when the pulse generation is finished.
3	**Restart.** Setting this bit to 1 will cause CAMTIMER to automatically enter RUNNING mode when the pulse generation is finished.
4	**Trigger enable.** 1: Enable hardware trigger, 0: disable hardware trigger
5	**Trigger polarity.** 1: Positive edge (L→H), 0: negative edge (H→L)
6	**Software time measurement.** Writing 1 into this bit will trigger a time measurement if CAMTIMER is in RUNNING mode. The measured data will be sent to the host in a standard time measurement frame with channel ID 5.
7	**Clock divider disable.** 1: Base clock will be identical to the selected reference clock. 0: The reference clock is divided by the RCDR.
8	**DIN source.** Source of the digital inputs. 1: LVDS signals, 0: TTL signals,
9	**TIN source.** Source of the timing inputs. 1: LVDS signals, 0: TTL signals,
10	**Reference clock source.** Source of the reference clock. 1: External clock input, 0: Internal 10 MHz,
11-15	**Unused.**
16-19	**Output enable.** These four bits enable the 4 timing outputs 1-4. 1:Enable, 0: Disable.
20-23	**Output polarity.** These four bits set the polarity of the 4 timing outputs 1-4. 0:Normal , 1: Inverted.
24-27	**Input enable.** These four bits enable the 4 timing inputs 1-4. 1:Enable, 0: Disable.
28-31	**Input polarity.** These four bits set the polarity of the 4 timing inputs 1-4. 0:L→H is sensed , 1:H→L is sensed .

Table 3: Usage of GPCR bits.

Bits	*Description*
0-7	**DIN.** On read these bits return the current state of the digital input lines. Depending on bit 8 of the GPCR the LVDS or TTL lines are sampled.
8-15	**DOUT on ARMED.** The bits written here will be present on the digital output lines when CAMTIMER goes to ARMED state.

Table 4: Usage of GPIOR bits.

Bits	*Description*
0-3	**Output mask.** These four bits mask the output of the timer to the four timing outputs. Bit 0 masks output 1. When a bit is set the output of this timer will be OR-ed to the output.
4-11	**DOUT on ARMED.** The bits written here will be set to the digital output lines when this timer finishes pulse generation.

Table 5: Usage of bits in the Timer Control Registers.

Bits	*Description*
0-3	**Minor version number.** The BCD encoded minor version number.
4-7	**Major version number.** The BCD encoded major version number.
8-15	**Unused.** These bits are set to 0 on read.
16-20	**Day.** Day of firmware date.
21-24	**Month.** Month of firmware date.
25-31	**Year.** Year of firmware date after 2000.

Table 6: Contents of the Version ID Register.

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