



## Scientific instrumentation SiPM read-out chip

**Citiroc 1A is a 32-channel front-end ASIC designed to readout silicon photo-multipliers (SiPM) for scientific instrumentation application.**

**Citiroc 1A allows triggering down to 1/3 pe and provides the charge measurement with a good noise rejection. Citiroc 1A outputs the 32-channel triggers with a high accuracy (better than 100 ps).**

**An adjustment of the SiPM high-voltage is possible using a channel-by-channel DAC connected to the ASIC inputs. That allows a fine SiPM gain and dark noise adjustment at the system level to correct for the non-uniformity of SiPMs. CITIROC 1A can be calibrated using a unique calibration signal.**

**Timing measurement better than 100 ps RMS jitter is possible along with 1% linearity energy measurement up to 2500 p.e. The power consumption is about 7mW/channel with all features ON.**



<b>Detector Read-Out</b>	SiPM, SiPM array
<b>Number of Channels</b>	32
<b>Signal Polarity</b>	Positive
<b>Sensitivity</b>	Trigger on 1/3 of photo-electron
<b>Timing Resolution</b>	Better than 100 ps RMS on single photo-electron
<b>Dynamic Range</b>	0-400 pC i.e. 2500 photo-electrons @ $10^6$ SiPM gain
<b>Packaging &amp; Dimension</b>	TQFP 160 – TFBGA353
<b>Power Consumption</b>	225mW – Supply voltage : 3.3V
<b>Inputs</b>	32 voltage inputs with independent SiPM HV adjustments
<b>Outputs</b>	32 trigger outputs 2 multiplexed charge output, 1 multiplexed hit register 2 ASIC trigger output (Trigger OR)
<b>Internal Programmable Features</b>	32 HV adjustment for SiPM (32x8bits), Trigger Threshold Adjustment (10bits), channel by channel gain tuning, 32 Trigger Masks, Trigger Latch, internal temperature sensor

**Table 1 – ASIC main parameters**

### Learn more about Citiroc 1A

<b>Contact</b>	Jean-Baptiste Cizel
<b>Web</b>	<a href="http://www.weeroc.com/en/products/citiroc-1">http://www.weeroc.com/en/products/citiroc-1</a>
<b>Email</b>	<a href="mailto:citiroc@weeroc.com">citiroc@weeroc.com</a>
<b>Phone</b>	+33 1 69 59 69 27

## Table of content

1	General description .....	4	9	Performances .....	28
1.1	SiPM Gain trimming .....	4	10	I/Os connection .....	29
1.2	Charge measurement .....	4	10.1	SiPM connection .....	29
1.3	Trigger line .....	4	10.2	Trigger output connection .....	30
1.4	Service blocks .....	4	10.3	Digital control & read-out connection .....	31
2	Maximum ratings .....	6	10.4	Power connection & bias or reference decoupling .....	32
3	Operating modes .....	7	10.5	Bias and references values .....	34
3.1	Analogue charge integration .....	7	11	Pinout & mechanics .....	36
3.2	Photon counting .....	8	11.1	Pin type description .....	36
4	SiPM high voltage trimming .....	9	11.2	LQFP 160 packaging .....	37
4.1	Program the input DACs .....	9	11.2.1	Package layout & mechanics .....	37
5	Trigger scheme .....	10	11.2.2	Pin list .....	38
5.1	Trigger mode .....	10	11.3	TFBGA 353 package .....	41
5.2	Trigger chain .....	10	11.3.1	Package layout & mechanics .....	41
5.2.1	Fast shaper .....	10	12	Bug list & log .....	46
5.2.2	Discriminators, trigger outputs .....	11	13	Document version .....	47
5.2.3	Time windowing, channel mask and trigger latch .....	11			
6	Charge measurement scheme .....	14			
6.1	Preamplifiers .....	14			
6.2	Slow Shaper .....	15			
6.3	Peak sampling: Track and hold or peak detector 16				
6.3.1	Track & hold .....	16			
6.3.2	Peak detector .....	17			
7	Data outing - analogue chip multiplexed read out 20				
8	Programmable parameters, internal probing and power pulsing .....	23			
8.1	General description of slow control shift-register .....	23			
8.2	Slow control register parameters .....	24			
8.3	General description of probe shift-register 25				
8.4	Probe register parameters .....	26			
8.5	Power pulsing and ON/OFF functions .....	27			

## Table of figures

Figure 1 - General ASIC block scheme.....	5
Figure 2 - Block scheme of the trigger chain.....	10
Figure 3 - Fast shaper block scheme.....	11
Figure 4 - Trigger logic of charge discriminator .....	12
Figure 5 – Val Evt signal effect .....	12
Figure 6 - – Trigger output using Latch.....	12
Figure 7 – Trigger output in direct discriminator mode	13
Figure 8 – High gain and low gain voltage sensitive preamplifier.....	14
Figure 9 - Ctest schematic.....	15
Figure 10 – Slow shaper schematic.....	15
Figure 11 – Schematic of track and hold cell .....	16
Figure 12– Standard Track & Hold working mode.....	17
Figure 13– Peak detector working mode.....	18
Figure 14 - Peak detector chronogram.....	19
Figure 15 – Peak detector block scheme .....	19
Figure 16 - Read register description scheme.....	20
Figure 17- Read Register high impedance output.....	21
Figure 18 – Read Register Chronogram .....	22
Figure 19 - Select bit for Citiroc 1A programming.....	23
Figure 20: Slow control chronogram and explanation.	23
Figure 21 - Scheme block of internal probing system.	26
Figure 22 - SiPM connection scheme - DC bias .....	29
Figure 23 - SiPM charge transfer scheme - Fast signal .....	30
Figure 24 - Trigger output connection.....	30
Figure 25 - Citiroc 1A shift register connection to controller.....	31
Figure 26 - Citiroc 1A analog and digital output signals connection.....	32
Figure 27 – Citiroc 1A direct digital control signal connection to controller.....	32
Figure 28 – North-west Citiroc 1A ball out .....	41
Figure 29 – North-east Citiroc 1A ball-out.....	42
Figure 30 – South-west Citiroc 1A ball-out .....	43
Figure 31 – South-east Citiroc1A ball-out.....	44
Figure 32 - Citiroc1A TFBGA353 mechanics.....	45

Table 1 – ASIC main parameters .....	1
Table 2 - Maximum rating operation condition.....	6
Table 3 - Preamplifier Gain versus slow control program .....	14
Table 4– Slow shaper peaking time value vs slow control parameters.....	16
Table 5 – slow control register parameters.....	25
Table 6 – Probe register parameters.....	27
Table 7 – Power mode truth table .....	27
Table 8 - Bias point list & values .....	34
Table 9 - Reference voltage list and values.....	35
Table 10 – pin type description.....	36
Table 11 – LQFP 160 pinout .....	40

## 1 General description

Citiroc 1A is a 32-channel analogue front end ASIC dedicated to the **gain-trimming and read-out of SiPM detectors**.

### 1.1 SiPM Gain trimming

Each of the 32 inputs features a low power 4.5V-range 8-bit DAC to easily **adjust the SiPM high-voltage channel by channel** to correct for the gain and noise non-uniformity of system using several SiPM. The virtual ground of each SiPM can be adjusted to fine tune each SiPM high voltage that are all connected to a same high voltage source.

### 1.2 Charge measurement

Citiroc 1A is compatible **with positive-charge SiPM signals**. Two measurement lines with different gain (1 to 10 ratio) are working in parallel in order to maximize the dynamic range of Citiroc 1A. The two measurement lines have a significant overlap to help user for gain inter-calibration.

For each channel, **two parallel AC coupled voltage preamplifiers** are embedded to ensure a dynamic range from 160fC to 400pC<sup>1</sup>. Each preamplifier is followed by a **variable shaper** with an adjustable time constant<sup>2</sup> to filter the signal bandwidth and optimize the signal-to-noise ratio.

The signal from the two shapers can be sampled using either a **sample & hold** controlled by an external signal<sup>3</sup> or by a **peak-detector** disabled by an external signal<sup>4</sup>.

The stored charge information is read-out in serial using two **analogue multiplexed outputs**, one for low gain and one for high gain. The multiplexed outputs are controlled by a **read shift-register**. Both information of low gain and high gain of a same channel are present at the same time. Along the two charge measurement information, a hit-register provides a trigger status information described in chapter 1.3.

### 1.3 Trigger line

Citiroc 1A features a programmable trigger line that can be connected either to the high-gain or low gain preamplifier. It embeds a 15 ns peaking time fast shaper followed by two discriminators.

- The first provides the **trigger of the chip** (one unmask channel at least has triggered – OR of the 32 channels) and is also used for the hit register storing channel by channel if a channel has triggered for **sequential read-out**.
- The second provides **accurate trigger time flag** on each channel. The 32 trigger are outed.

The two discriminators thresholds are common for the 32 channels and are set by two 10-bit DAC. A 4-bit DAC on each discriminator allows adjusting each of the 2x32 thresholds channel by channel to compensate non-uniformities.

### 1.4 Service blocks

Citiroc 1A can be programmed using a shift register described in chapter 2 of that datasheet. A probe register allow probing internal analogue points of the chip for debug or study purpose. The power can be switched of using the power pulsing mode and each stage can be switched off if not used by the user to save power. A bandgap set the different reference voltage for good temperature stability and a temperature sensor is embedded.

<sup>1</sup> 1 to 2500 photoelectrons with SiPM Gain =  $10^6$ , with a photoelectron to noise ratio of 10

<sup>2</sup> from 12.5 ns to 87.5 ns with a 12.5ns pitch

<sup>3</sup> All the 32 channels are hold at the same time

<sup>4</sup> The maximum of each channel is memorized until the peak detector is set blind by external signal

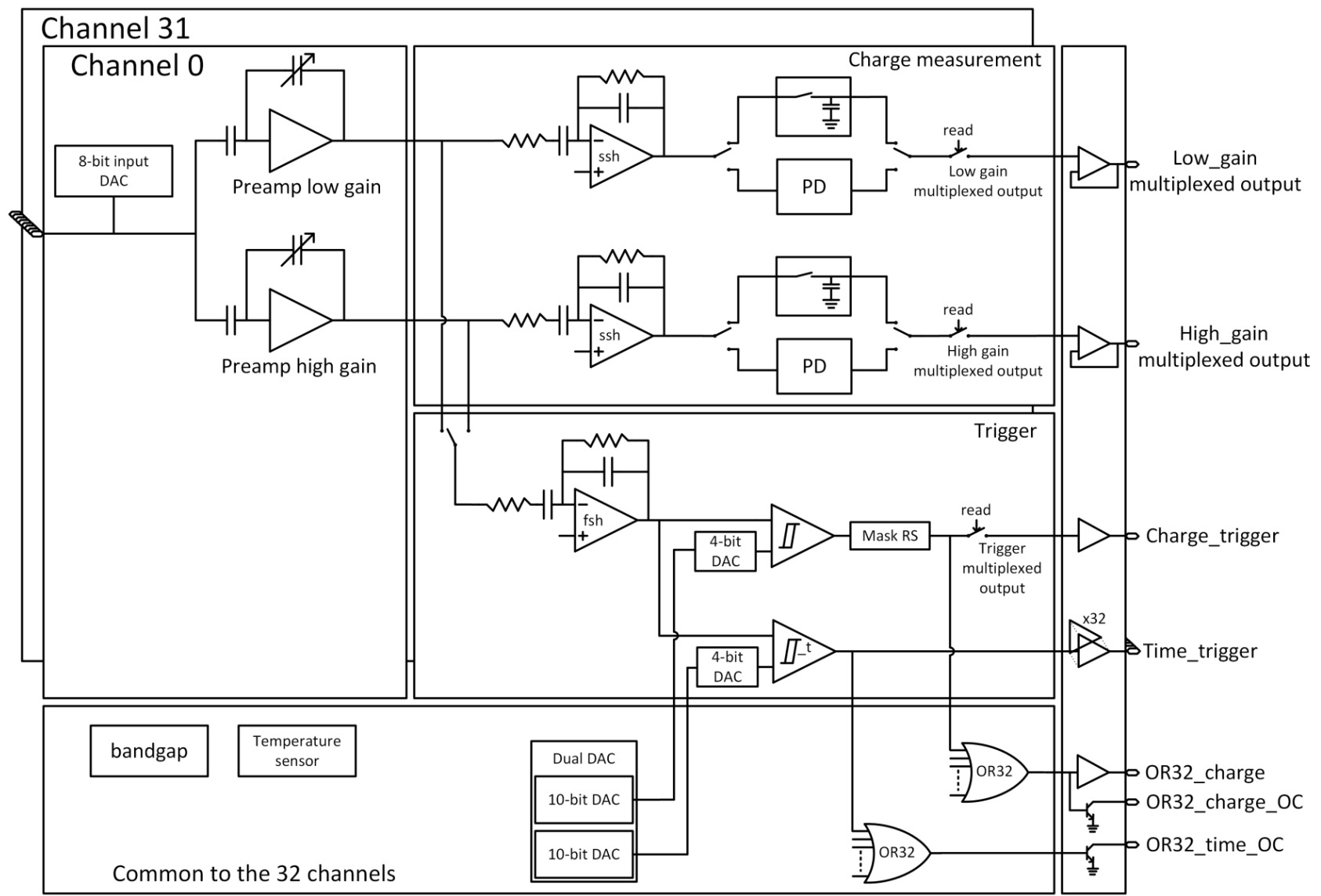


Figure 1 - General ASIC block scheme

## 2 Maximum ratings

The operating condition of Citiroc 1A should not exceed the parameters listed in Table 2.

Parameter	Note	Minimum	Maximum	Unit
Storage temperature range		-40	125	°C
Operating temperature range		-20	110	°C
Power pin	All power pins	0	3.5	V
Ground pin	All ground (gnd_xx) and vss pins	0	0	V
Analogue input		-0.5	VDD+0.3	V
Digital input TTL		-0.5	VDD+0.3	V
Digital input LVDS		-0.5	VDD+0.3	V

**Table 2 - Maximum rating operation condition**

Citiroc 1A electrostatic discharge (ESD) protection is HBM (Human Body Model) compatible on every pin.

### 3 Operating modes

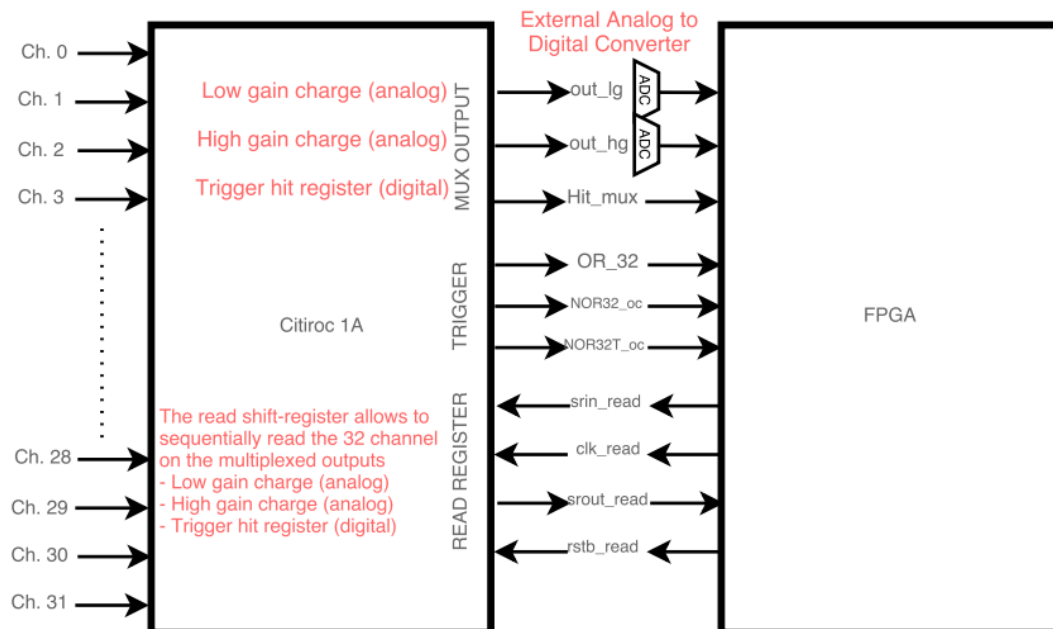
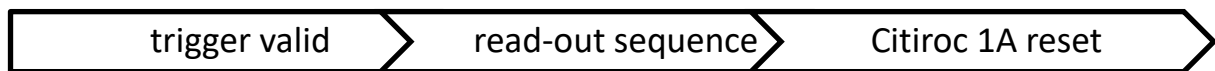
Citiroc 1A is an analogue chip that can operate in two different modes.

- Analogue charge integration where the number of photon of each channel is measured in an analogue way, integrating the total energy in two shapers. The two gains allow a large dynamic range. Both gains are outed in parallel to choose offline which gain to use and build easy gain inter-calibration.
- Photon counting mode where the total amount of light is measured by counting the photons channel-by-channel using the 32 trigger outputs. Because photon counting is limited by the fast shaper peaking time, that mode can only be used for low light environment, below 20M photons per second.

These two modes can be combined to get all the single photons out of each channel using the 32 trigger outputs and the analogue charge integration upon specific trigger or photon counting calibration.

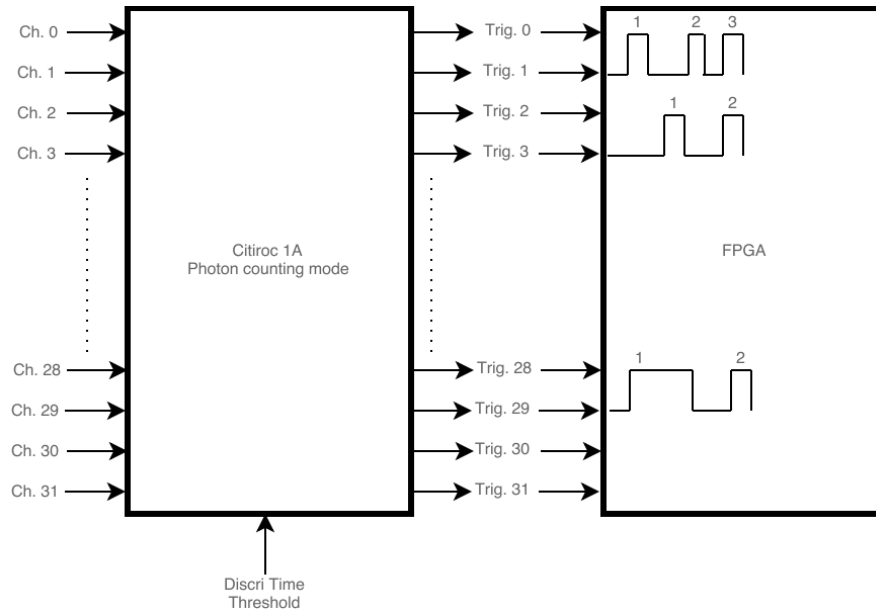
#### 3.1 Analogue charge integration

In analogue charge injection mode, the use of the 32 trigger output is not required. The general trigger of the chip is given by one of the OR signal and validate the acquisition of the event. Upon validation of the event, the FPGA will start the read-out sequence using the serial output read-out providing in parallel the low gain analog value, high gain analog value and trigger status of each channel sequentially. **Citiroc1A will be blind during that read-out sequence.**



### 3.2 Photon counting

In photon counting mode, Citiroc 1A will provide a trigger for each channel upon each threshold crossing. The trigger threshold is set on the time discriminators that are connected to the 32 trigger outputs. Threshold can be set lower than one photon to get all photon or to any value decided by the user. Citiroc 1A will be blind at a channel level if threshold is crossed twice within a short time of 50ns. That value depends on the threshold value. Maximum photon counting rate is 20MHz per channel.





## 4 SiPM high voltage trimming

### 4.1 Program the input DACs

Connection of the SiPM to Citiroc 1A is described in section 10.1 of this datasheet.

The chip is foreseen to be connected to an external power supply and to provide a common forward high voltage to all connected 32 SiPM. Tuning of the applied voltage, channel by channel, is achieved using a high impedance output 8-bit DAC dedicated to each detector power line. A slow control bit permits to use either the 2.5V internal reference or a 4.5V external reference as dynamic range for this High Voltage tuning. Input DACs have 9 control bits:

- 1 to enable/disable the DAC
- 8 to set voltage.

Note: to perform a linearity test of these input DACs, a very high impedance multimeter is required ( $\sim 1\text{Gohm}$ ) to keep the DAC biased.

## 5 Trigger scheme

### 5.1 Trigger mode

Citiroc 1A is an analogue ASIC and there is no auto-trigger capability with Citiroc 1A. The trigger going out of Citiroc 1A must be sent to a data acquisition system where a decision to convert the event in digital or not can be taken.

However, Citiroc 1A can easily be used in a synchronous system by holding the analogue memory when a machine trigger occurs, considering that the shaping time is well known.

Using the Citiroc 1A trigger to build a trigger is easy. User has access to channel level trigger as well as ASIC trigger with 2 threshold.

The peak detector can be armed (switching from track to peak sensing mode) either with the internal trigger of a channel or with an external signal (PS\_global\_trig).

### 5.2 Trigger chain

Citiroc trigger chain can be connected either to the low gain or the high gain preamplifier depending on the requested level of trigger. The chain is composed of a fast shaper followed by two discriminators.

- The first defined as “**charge discriminator**” provides the trigger (OR32) and is also used for the “hit register”. Discriminator outputs provide an ASIC level trigger (OR32) which is a logic OR of the 32 channels. The OR32 signal toggle at the first charge discriminator trigger. Charge discriminator outputs can be latched by slow control command (“RS\_or\_discri”). The reset of the latched (if used) triggers is performed by the LVDS signal “Raz\_Chn”.
- The second defined as “**time discriminator**” provides the event time information on each channel. The 32 discriminators outputs are available on the trigb[0-31] digital outputs. The logic NOR of the 32 time discriminator is available as an open collector digital output on pin NOR32t\_oc.

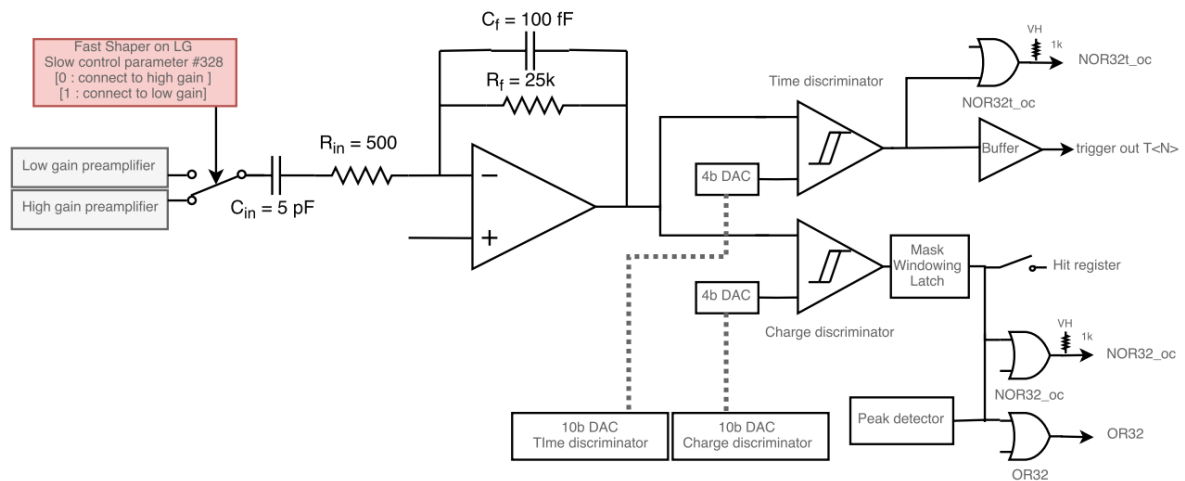


Figure 2 - Block scheme of the trigger chain

#### 5.2.1 Fast shaper

A 15ns peaking-time fast shaper can either be connected to the high gain preamplifier or to the low gain. That connection is set by slow control. **The fast shaper peaking time and gain are not programmable.**

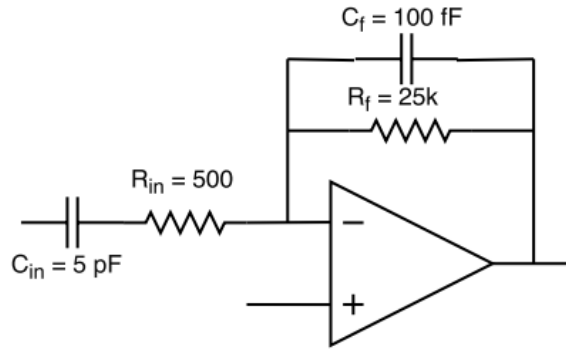


Figure 3 - Fast shaper block scheme

### 5.2.2 Discriminators, trigger outputs

Two discriminators are connected to the output of the fast shaper. The time discriminator is outed on a trigger out pin, channel by channel. That discriminator cannot be neither masked nor time windowed. It is always active and the digital treatment of time windowing, channel masking, trigger decision making is to be taken in the data acquisition system.

The charge discriminator is followed by a programmable logic system allowing simple validation operation.

**Each time discriminator** connects to:

- A direct trigger output (pin T<N<sub>ch</sub>>) buffered with a user-level defined high level (pin V<sub>Hi</sub>)
- A 32-NOR logic outing the ASIC with an open collector output (NOR32t\_oc)

**Each charge discriminator** is followed by a trigger validation logic (see 5.2.3) connecting to:

- A OR-32 logic (pin OR32) buffered with a user-level defined high level (pin V<sub>Hi</sub>)
- A NOR-32 logic outing the ASIC with an open collector output (NOR32\_oc)
- The hit register that can be read out sequentially (require the trigger to be latched)
- The peak sensing arming system ( that toggle the peak detector from track to peak sensing)

### 5.2.3 Time windowing, channel mask and trigger latch

The charge discriminator is followed by a logic system as shown in. That logic system allows the following choice:

- **Mask a channel:** allows inhibiting a charge discriminator channel by channel to quiet a noisy channel for example. That parameter is programmed by slow control. The slow control parameter is discriminator mask ch. N (slow control parameter #265+N)
- **Enable/inhibit trigger during a specific period of time:** that LVDS signal allows enabling all the triggers during a specific time window only if the user know when an event is supposed to occur for example. The signal name on the pin list is ValEvt [ValEvt\_p / ValEvt\_n]
- **Latch the discriminator output:** allows latching the discriminators output to memorize the trigger status. Triggers can be reset with the RazChn LVDS signal to be ready for the next event(RazChn\_p / RazChn\_n). Charge discriminators must be latched to use the hit register and shall only be reset after the read sequence.

The output of the trigger logic can be used to arm the peak detector. **It is not mandatory to latch the discriminator output to use the peak detector.**

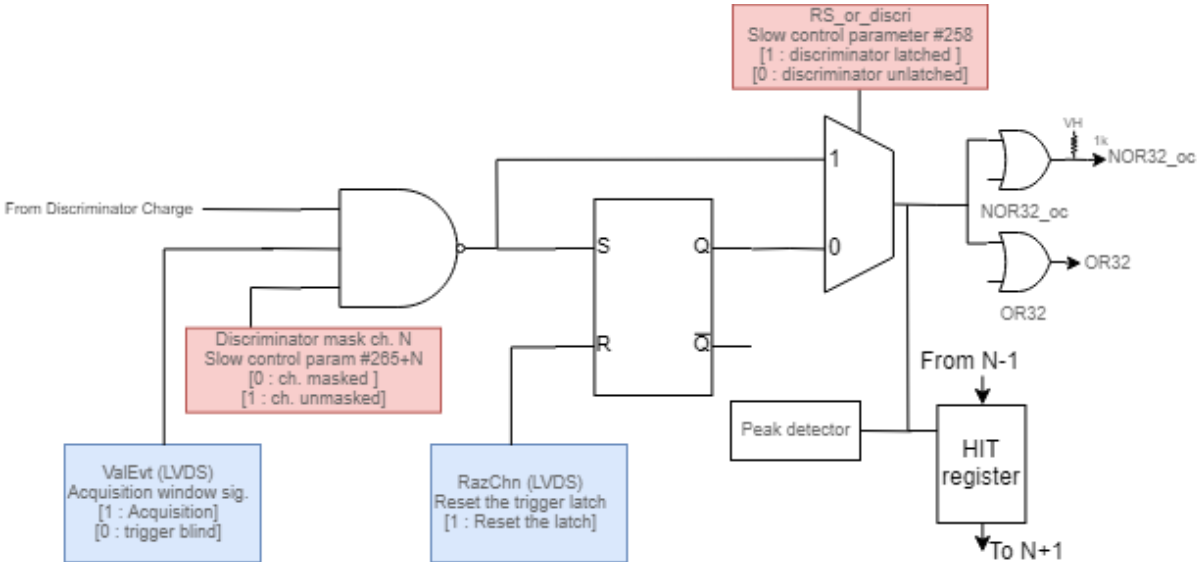


Figure 4 – Trigger logic of charge discriminator

The different parameters described above allow the user to set the ASIC in a correct configuration for its specific use. The figure below shows chronogram examples of different modes.

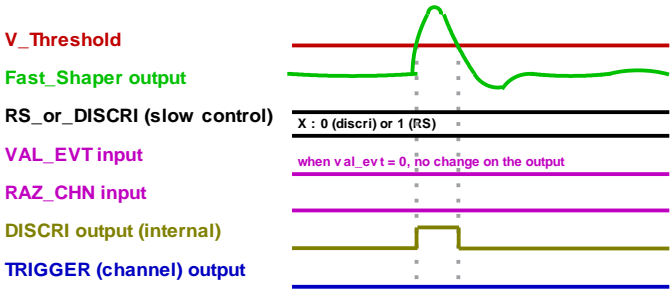


Figure 5 – Val Evt signal effect

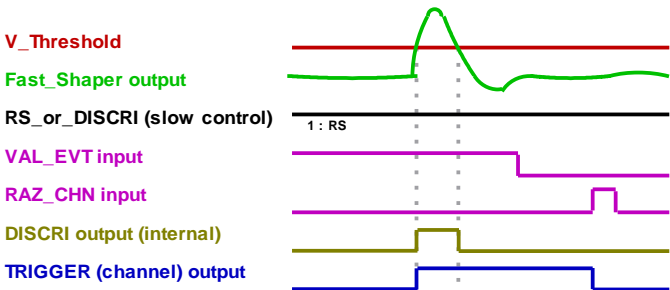


Figure 6 – Trigger output using Latch

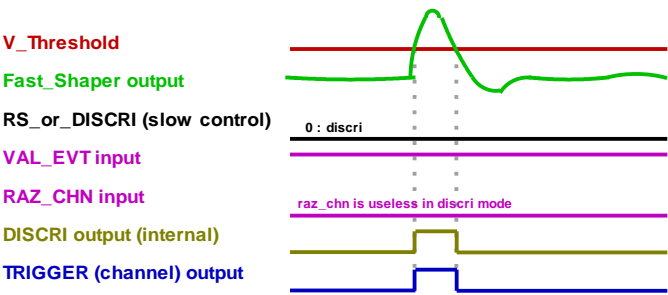


Figure 7 – Trigger output in direct discriminator mode

## 6 Charge measurement scheme

### 6.1 Preamplifiers

Each channel of Citiroc 1A embeds two **channel-by-channel independent programmable variable-gain preamplifiers** ensuring a wide coverage of the dynamic range depending on the application. Both low gain and high gain preamplifier can be tuned on 6 bits ( $C_f$  can be tuned from 0 to 1575fF with a step of 25fF). The voltage gain is given by  $C_{in}/C_f$ ,  $C_{in}=15pF$  for high gain and 1.5pF for low gain. The slow control bits are active low as shown in Table 3.

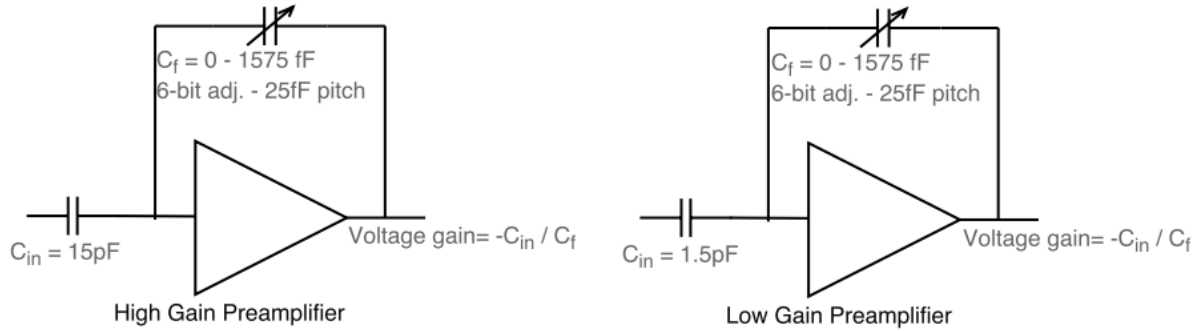


Figure 8 – High gain and low gain voltage sensitive preamplifier

6-bit feedback config	Feedback capacitance	Low gain preamp gain	High gain preamp gain
111110 [62]	25 fF	60 V/V	600 V/V
111101 [61]	50 fF	30 V/V	300 V/V
....			
011111 [31]	800 fF	1.875 V/V	18.75 V/V
....			
000001 [1]	1550 fF	0.97 V/V	9.7 V/V
000000 [0]	1575 fF	0.95 V/V	9.5 V/V

Table 3 – Preamplifier Gain versus slow control program

Any channel preamplifier can be shut down by slow control bit ("disable PA"), to disconnect any noisy channel from the measurement chain.

A calibration input is included in each channel and can be enabled individually by slow control parameters ("In\_calib enabled"). In order to have a good precision, only one calibration input should be allowed at the same time. The injection calibration capacitance value is about 3pF.

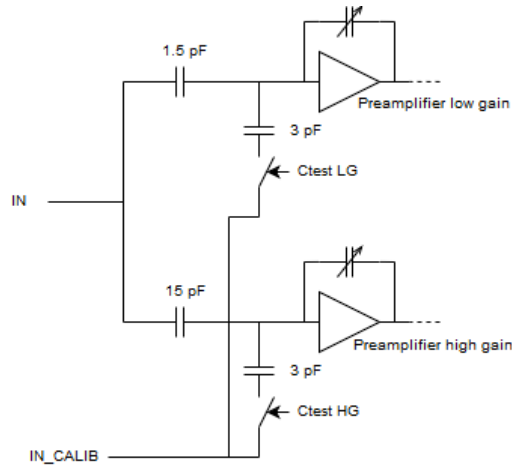


Figure 9 – Ctest schematic.

Linearity of Low Gain preamplifier can be improved by increasing its current consumption. The slow control bit “Low Gain PreAmp Bias” controls that feature.

## 6.2 Slow Shaper

Two CRRC<sup>2</sup> slow shapers are connected on the two preamplifiers outputs for each channel. The peaking time of each slow shaper can be tuned from 12.5 ns to 87.5 ns with a 12.5ns pitch. The peaking time is set commonly for all the 32 channels, however it can be different between low gain shaper [slow control bits 315-317] and high gain shaper [slow control bits 318-320]. The slow control bits for shaping time selection are active low, see Table 4 for details.

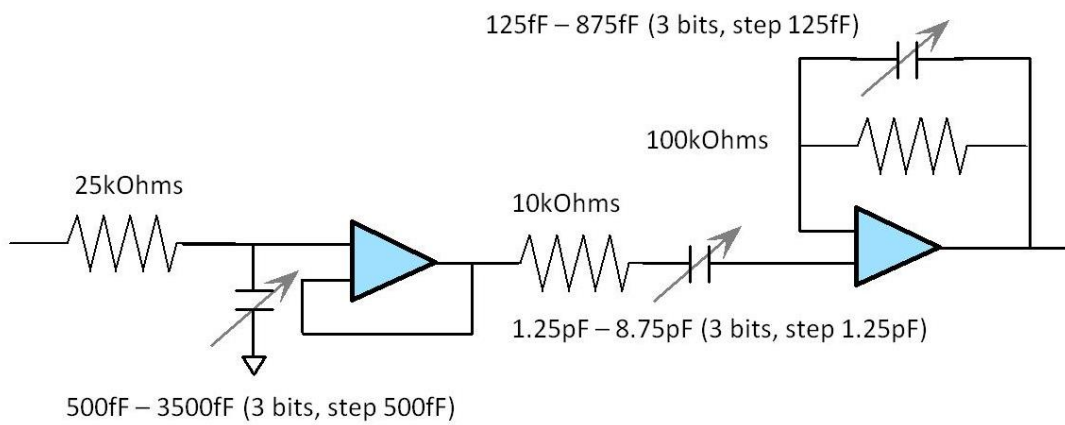


Figure 10 – Slow shaper schematic

Slow control value	Peaking time value
6 (110)	12.5 ns
5 (101)	25.0 ns
4 (100)	37.5 ns
3 (011)	50.0 ns
2 (010)	62.5 ns
1 (001)	75.0 ns
0 (000)	87.5 ns

Table 4– Slow shaper peaking time value vs slow control parameters

### 6.3 Peak sampling: Track and hold or peak detector

Two peak sensing systems are embedded for each shaper. A peak detector that automatically stores the highest value of the slow shaper after being armed, and a track and hold that requires an external hold signal at the peaking time. They cannot run concurrently and a slow control bit allows choosing between the two. The selection of the peak sampling solution is independent between low gain and high gain and is common for the 32 channel of each gain.

- Slow control bit #306 selects high gain peak sampling system [0: peak sensing – 1: track&hold]
- Slow control bit #307 selects low gain peak sampling system [0: peak sensing – 1: track&hold]

The choice of the best peak sampling solution depends on the final application.

- Track & hold is more suitable for events where photons are all detected at the same time (few ns spread)
- Peak detector is more suitable for events where photons are spread in time (several 10 or 100ns)

#### 6.3.1 Track & hold

The track & hold cell of each gain is controlled by a hold signal - hold\_lg for low gain, hold\_hg for high gain (both are 0: track – 1: hold). The hold signals must remain high (in hold mode) until the read-out sequence has been completed. The hold signal is active on level.

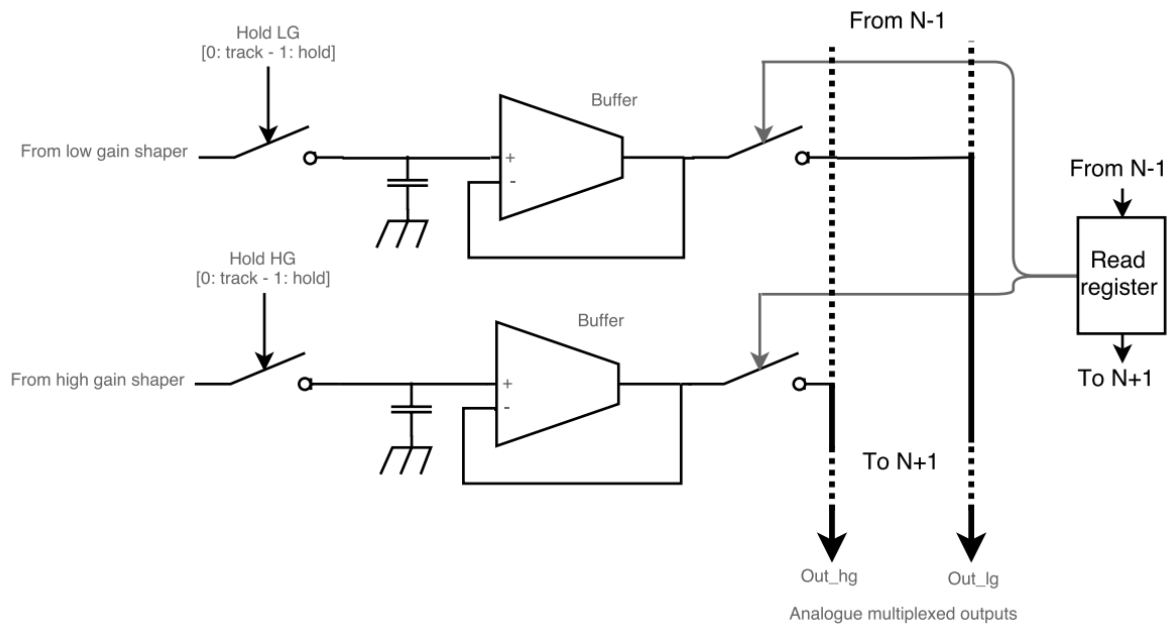


Figure 11 – Schematic of track and hold cell



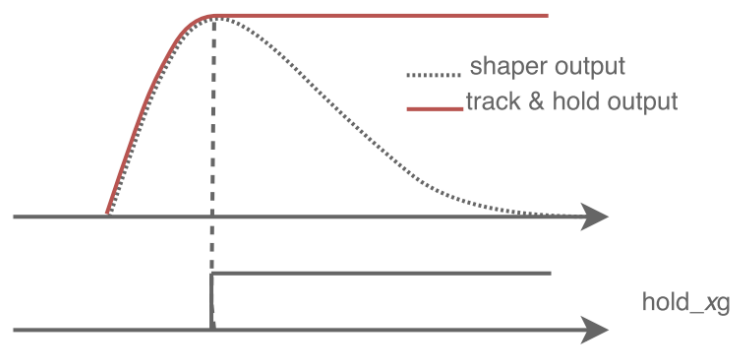


Figure 12– Standard Track & Hold working mode

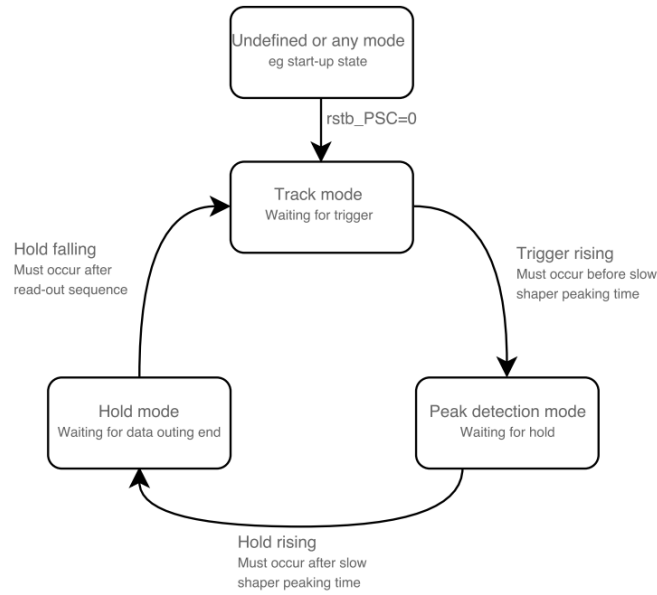
The readout of these analogue memories is controlled by the read register as detailed in chapter 7.

### 6.3.2 Peak detector

User can use a peak detector to sample the maximum of the shaped signal instead of the track and hold. The peak detector allow to get the maximum of the peak even if that peak is not precisely defined in time – for example if incident photons come with a delay from channel to channel or if photon are spread in time in a single channel.

The peak detector acquisition sequence works in 3 phases:

- Track phase: before any trigger, the peak detector is in track mode to avoid noise pile-up. Upon trigger, the peak detector switch to peak detection phase
- Peak detection phase: in that mode, the peak detector memorizes the maximum of the input signal. That mode is kept until user provides a rising edge on the hold\_xg (hold\_lg for low gain and hold\_hg for high gain). The peak detector switch to hold phase when that signal occurs.
- Hold phase: disconnect the input of the peak detector from the shaper and ensure that any input signal will not be memorized. That phase is used during serial read-out of the ASIC. Falling edge on hold\_xg will release the hold phase and switch back to track phase for the next acquisition



**Figure 13– Peak detector working mode**

A reset pin (rstb\_PSC) reset the peak detector to track mode on low level. The reset doesn't need to be used at each acquisition, the system get back to track mode automatically as shown in Figure 13 and Figure 14.

The trig signal shown on Figure 14 can be either internal by using the channel charge trigger or external by using the PS\_global\_trig signal. In the first case, the trigger can occur at different timing channel by channel (auto-trigger). In the second case, the trigger is external and global to the 32 channels. Slow control bit Sel TrigExt PSC allows to choose between internal and external trigger [0: internal trigger – 1: external trigger].

The peak sensing control cell can be bypassed and the hold/track and peak detection / track signal can be controlled externally by setting the Bypass PSC slow control parameter to 1 [0: peak sensing cell used – 1: peak sensing cell bypassed]. When the cell is bypassed, the peak detection track signal is connected to pin PS\_modeb\_ext [0: track – 1: peak detection]. Hold signal keep the same behavior [0:track – 1: hold].

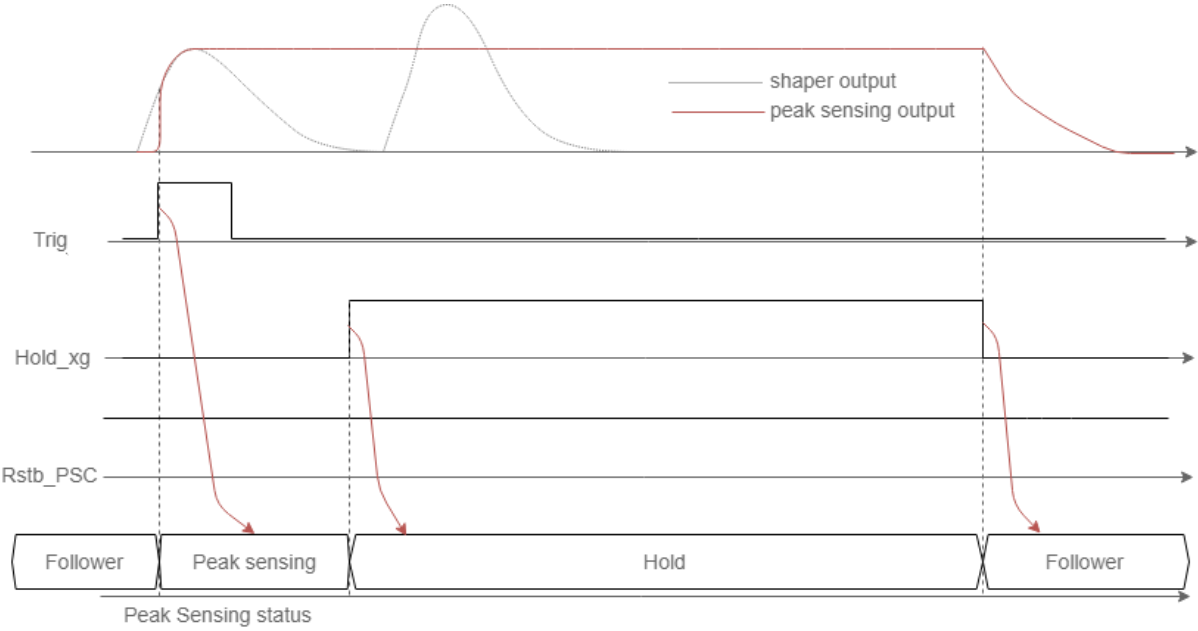


Figure 14 - Peak detector chronogram

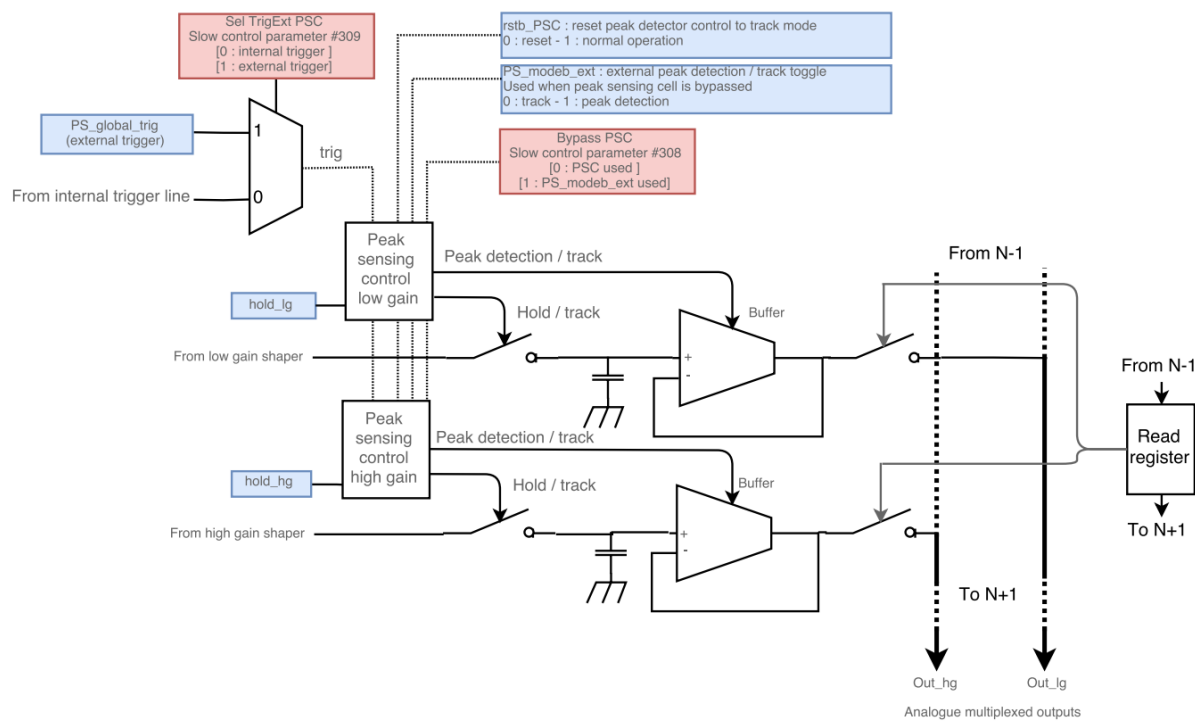


Figure 15 - Peak detector block scheme

## 7 Data outing - analogue chip multiplexed read out

The two analogue charge measurement can be read in serial using a multiplexed output providing sequentially the 32 charge measurement as well as the charge trigger status (if the charge trigger is latched). These three signals are provided concomitantly for each channel. The channel selection is done with a shift register equivalent to the slow control register and the probe register and work the same way.

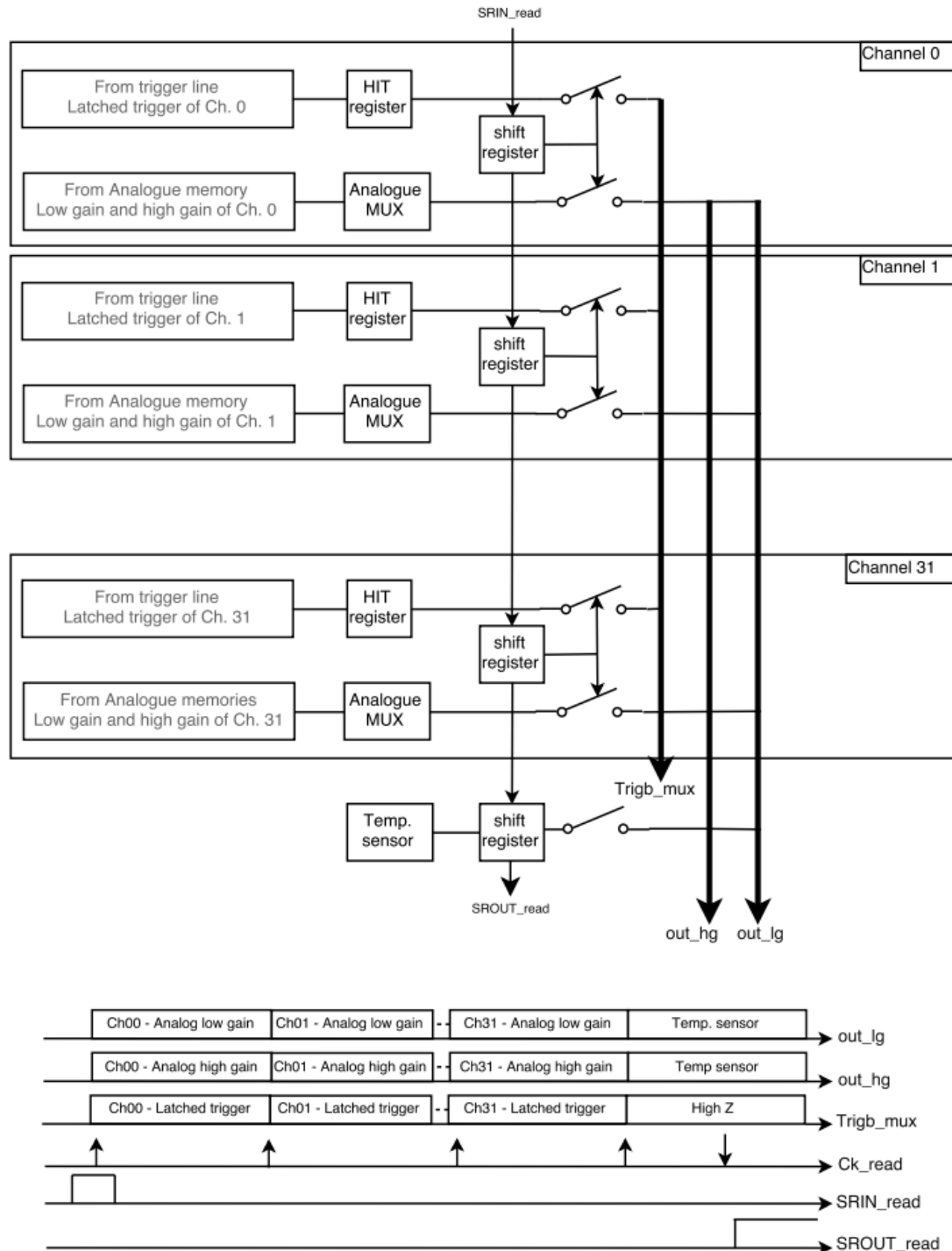
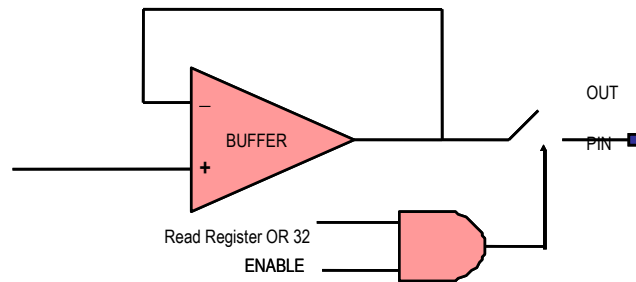


Figure 16 - Read register description scheme

A single 1 must be presented at the input of the shift register (srin\_read) then propagated along the register to sequentially connect the 32 channels to the multiplexed output at the shift register clock pace (ck\_read). The clock should not be faster

than 5MHz to get a 10-bit resolution on the energy. The temperature sensor is connected on that read register as a 33<sup>rd</sup> channel. However, the temperature information should not be read at the same pace as the 32 channel and a 1 ms timing is required to stabilize that analogue information prior to conversion. **A temperature measurement should then be considered as an independent and specific slow measurement.** If the power consumption is a critical parameter and the read-out speed does not require to be fast, it is possible to reduce the biasing current of the back-end stages along with a read register clock speed reduction to 600KHz maximum ( slow control bit #301 SCA bias [0: weak bias – 1: strong bias]).

When no channel is selected, an OR function of the contents of this “read” register ensures high impedance the 3 outputs (low gain, high gain and digital output).



**Figure 17– Read Register high impedance output**

That high impedance features allow using only three lines (High gain, Low gain, Hit register) to read several daisy-chained Citiroc 1A.

A chronogram in Figure 18 show the different signal and timing to be used to read-out Citiroc 1A through the serial output register.

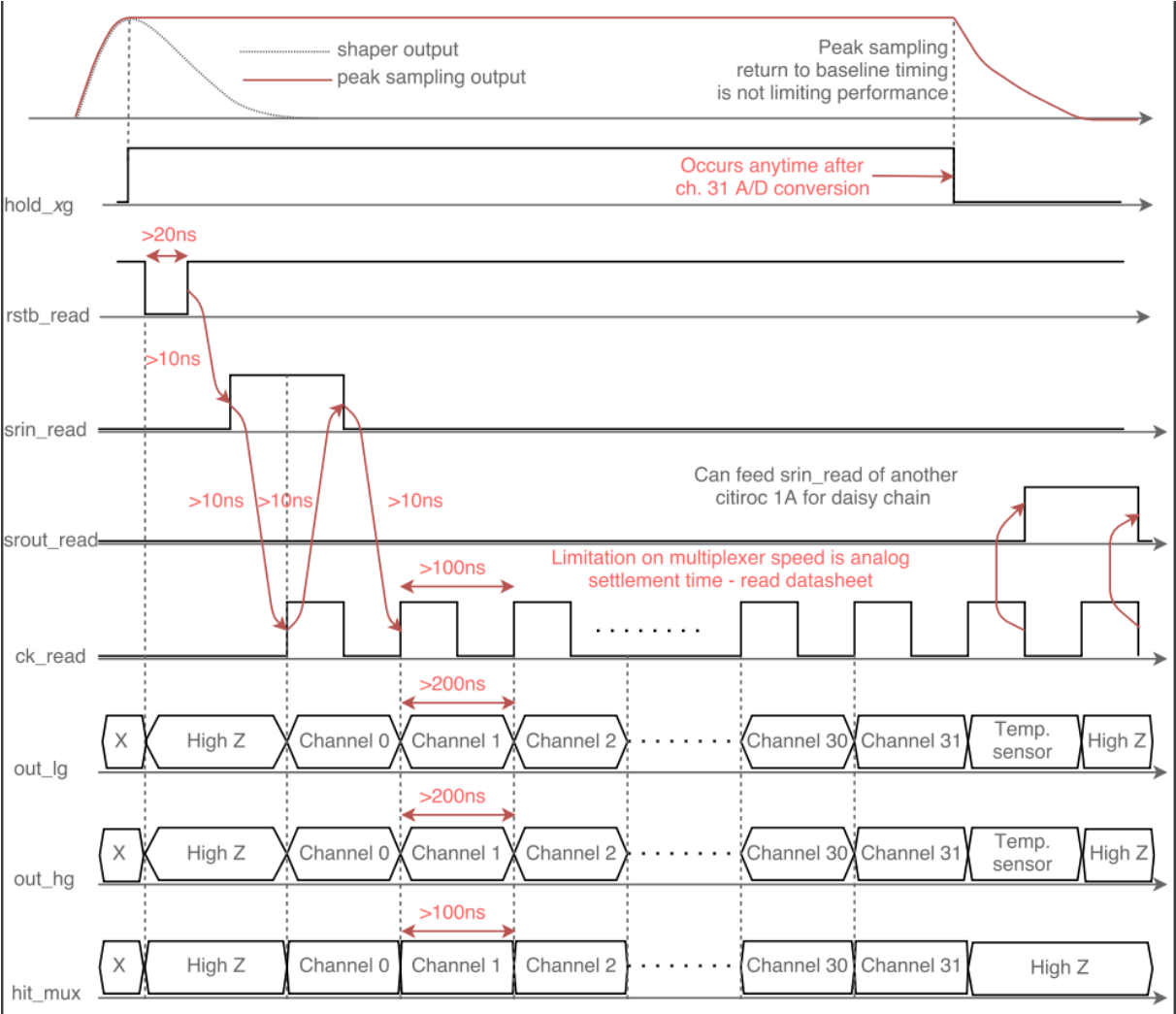


Figure 18 – Read Register Chronogram

## 8 Programmable parameters, internal probing and power pulsing

The slow control and probe registers are using the same programming pin and a select signal allows choosing between the two registers as shown in Figure 19.

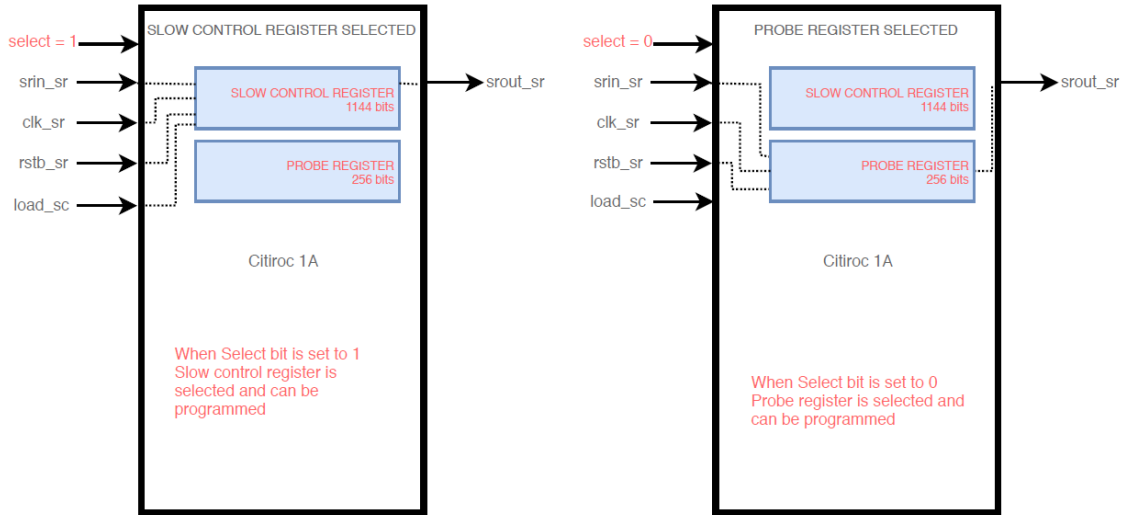


Figure 19 – Select bit for Citiroc 1A programming

### 8.1 General description of slow control shift-register

The slow control register allows programming Citiroc 1A with all required parameters such as:

- switching on or off the different stages of the ASIC
- setting the signal polarities and threshold values
- activating or bypassing latches
- routing triggers, etc.

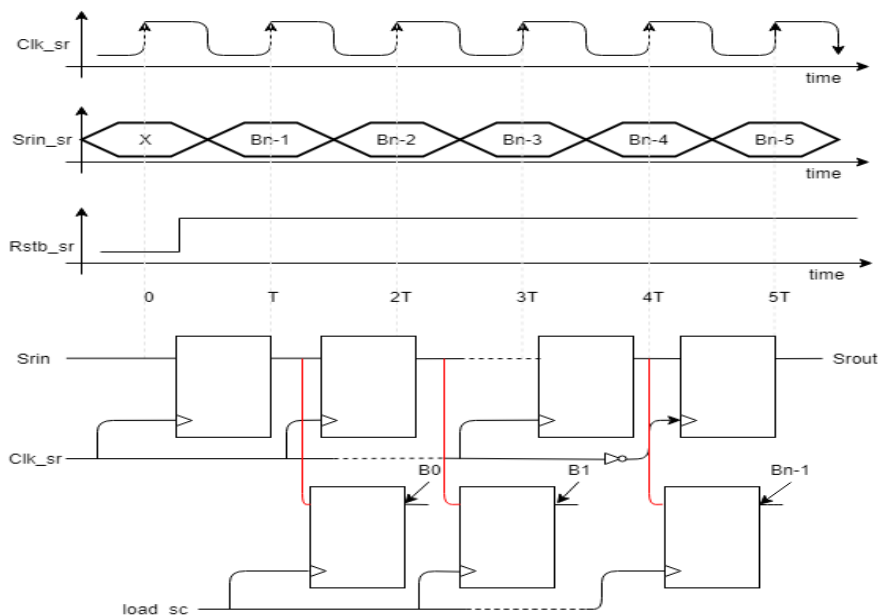
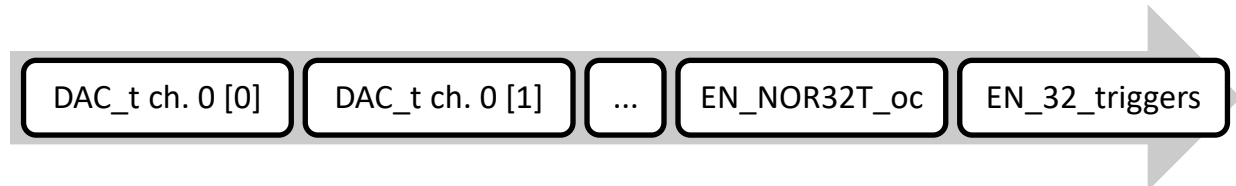


Figure 20: Slow control chronogram and explanation.

The slow control is a shift register composed of 1144 flip flops (first bit is  $B_0 = \text{DAC\_t} \langle 0 \rangle$  and last is  $B_{1143} = \text{EN\_32\_triggers}$ ). Data are stored in flip-flops on leading edge of the clock. The data are shifted at each clock cycle as seen on Figure 20. Between srout and the output of the last slow control register's flip flop, there is another flip flop clocked on lclk so an additional falling edge is needed to send the data out on Srout. **In order to load the slow control parameter into the ASIC, it is needed to apply a rising edge on load\_sc after bit shift of the configuration of the configuration.**

## 8.2 Slow control register parameters

The **first bit of the slow control register is the last bit to enter the register** as the data are pushed on a forward path regarding the slow control register.



Register Name	bits	Register description	Subadd
Channel 0 to 31 4-bit_t	128	Ch0 to 31 4-bit DAC_t ([0..3])	0
Channel 0 to 31 4-bit	128	Ch0 to 31 4-bit DAC ([0..3])	128
EN_discr	1	Enable Discriminator Charge [0 : disabled, force off – 1 : Enabled] – see Table 7	256
Discriminator	1	discriminator Charge power pulsing mode [0: power pin – 1 : force on] – see Table 7	257
RS_or_discr	1	Select latched (RS : 1) or direct output (trigger : 0) on charge discriminator	258
EN_discr_t	1	Enable Discriminator Time [0 : disabled, force off – 1 : Enabled] – see Table 7	259
Discriminator_t	1	discriminator Time power pulsing mode [0: power pin – 1 : force on] – see Table 7	260
EN_4b_dac	1	Enable 4-bit DAC charge [0 : disabled, force off – 1 : Enabled] – see Table 7	261
4b_dac	1	4-bit DAC charge power pulsing mode [0: power pin – 1 : force on] – see Table 7	262
EN_4b_dac_t	1	Enable 4-bit DAC time [0 : disabled, force off – 1 : Enabled] – see Table 7	263
4b_dac_t	1	4-bit DAC time power pulsing mode [0: power pin – 1 : force on] – see Table 7	264
Discriminator Mask	32	Discriminator mask (channel 0 to 31) [0: Masked – 1 : unmasked]	265
HG T&H (Widlar SCA)	1	High Gain Track & Hold power pulsing mode [0: power pin – 1 : force on] – see Table 7	297
EN_HG_T&H (Widlar SCA)	1	Enable High Gain Track & Hold [0 : disabled, force off – 1 : Enabled] – see Table 7	298
LG T&H (Widlar SCA)	1	Low Gain Track & Hold power pulsing mode [0: power pin – 1 : force on] – see Table 7	299
EN_LG_T&H (Widlar SCA)	1	Enable Low Gain Track & Hold [0 : disabled, force off – 1 : Enabled] – see Table 7	300
SCA bias	1	SCA bias (1 = weak bias, 0 = high bias 5MHz ReadOut Speed)	301
HG Pdet	1	High Gain Peak detector power pulsing mode [0: power pin – 1 : force on] – see Table 7	302
EN_HG_Pdet	1	Enable High Gain Peak detector [0 : disabled, force off – 1 : Enabled] – see Table 7	303
LG Pdet	1	Low Gain Peak detector power pulsing mode [0: power pin – 1 : force on] – see Table 7	304
EN_LG_Pdet	1	Enable Low Gain Peak detector [0 : disabled, force off – 1 : Enabled] – see Table 7	305
Sel SCA or PeakD HG	1	Select Track & Hold or Peak Detector – High Gain [0: peak detector – 1 : T&H]	306
Sel SCA or PeakD LG	1	Select Track & Hold or Peak Detector – Low Gain [0: peak detector – 1 : T&H]	307
bypass PSC	1	Bypass Peak Sensing Cell [0 : cell active – 1 : cell bypassed]	308
Sel Trig Ext PSC	1	Select peak sensing cell trigger [0 : internal trigger – 1 : external trigger]	309
Fast Shapers Follower	1	fast shaper follower power pulsing mode [0: power pin – 1 : force on] – see Table 7	310
EN_Fast Shaper	1	Enable fast shaper [0 : disabled, force off – 1 : Enabled] – see Table 7	311
Fast Shaper	1	fast shaper power pulsing mode [0: power pin – 1 : force on] – see Table 7	312
Low Gain Slow Shaper	1	low gain slow shaper power pulsing mode [0: power pin – 1 : force on] – see Table 7	313
EN_Low_Gain_Slow Shaper	1	Enable Low Gain Slow Shaper [0 : disabled, force off – 1 : Enabled] – see Table 7	314
Time Constant LG Shaper	3	Low gain shaper time constant commands (0..2) [active low] – see Table 4	315
High Gain Slow Shaper	1	high gain slow shaper power pulsing mode [0: power pin – 1 : force on] – see Table 7	318
EN_High_Gain_Slow Shaper	1	Enable high gain Slow Shaper [0 : disabled, force off – 1 : Enabled] – see Table 7	319
Time Constant HG Shaper	3	High gain shaper time constant commands (0..2) [active low] – see Table 4	320



LG PA bias	1	Low Gain PreAmp bias [0: normal bias - 1: weak bias]	323
High Gain PreAmplifier	1	High Gain preamp power pulsing mode [0: power pin - 1: force on] – see Table 7	324
EN_High_Gain_PA	1	Enable High Gain preamp [0: disabled, force off - 1: Enabled] – see Table 7	325
Low Gain PreAmplifier	1	Low Gain preamp power pulsing mode [0: power pin - 1: force on] – see Table 7	326
EN_Low_Gain_PA	1	Enable Low Gain preamp [0: disabled, force off - 1: Enabled] – see Table 7	327
Fast Shaper on LG	1	Select preamp to connect to Fast Shaper [0: fast shaper on HG preamp - 1: fast shaper on LG preamp]	328
EN_input_dac	1	Enable 32 input 8-bit DACs [0: disabled, force off - 1: Enabled] – see Table 7	329
8-bit DAC reference	1	8-bit input DAC Voltage Reference (1 = internal 4,5V, 0 = internal 2,5V)	330
Input 8-bit DAC	288	Input 8-bit DAC Data from channel 0 to 31 – (DAC7...DAC0 + DAC ON)	331
Channel 0 to 31 PA	480	Ch0 to 31 Preamps config 15 bit * 32 channels [HG gain[5..0], LG gain [5..0], CtestHG, CtestLG, PA disabled] HG gain and LG gain are active low – see Table 3 CtestHG, CtestLG : connect injection capacitance to preamp [0: Cinj disconnected - 1: Cinj connected] PA disabled : disable preamplifier [0: preamplifier enabled - 1: preamplifier disabled]	619
Temp	1	Temperature Sensor power pulsing mode [0: power pin - 1: force on] – see Table 7	1099
EN_Temp	1	Enable Temperature Sensor [0: disabled, force off - 1: Enabled] – see Table 7	1100
BandGap	1	BandGap power pulsing mode [0: power pin - 1: force on] – see Table 7	1101
EN_BandGap	1	Enable BandGap [0: disabled, force off - 1: Enabled] – see Table 7	1102
EN_DAC1	1	Enable DAC charge [0: disabled, force off - 1: Enabled] – see Table 7	1103
DAC1	1	DAC charge power pulsing mode [0: power pin - 1: force on] – see Table 7	1104
EN_DAC2	1	Enable DAC time [0: disabled, force off - 1: Enabled] – see Table 7	1105
DAC2	1	DAC time power pulsing mode [0: power pin - 1: force on] – see Table 7	1106
DAC1 code	10	10-bit DAC1 (MSB-LSB) – Charge discriminator threshold	1107
DAC2 code	10	10-bit DAC2 (MSB-LSB) – Time discriminator threshold	1117
EN_High Gain OTAq	1	Enable High Gain OTA [0: disabled, force off - 1: Enabled] – see Table 7	1127
High Gain OTAq	1	High Gain OTA power pulsing mode [0: power pin - 1: force on] – see Table 7	1128
EN_Low Gain OTAq	1	Enable Low Gain OTA [0: disabled, force off - 1: Enabled] – see Table 7	1129
Low Gain OTAq	1	Low Gain OTA power pulsing mode [0: power pin - 1: force on] – see Table 7	1130
EN_Probe OTAq	1	Enable Probe OTA [0: disabled, force off - 1: Enabled] – see Table 7	1131
Probe OTAq	1	Probe OTA power pulsing mode [0: power pin - 1: force on] – see Table 7	1132
Testb_OTaq	1	Output OTA buffer bias automatic off [0: auto-bias - 1: force on]	1133
EN_Val_Evt receiver	1	Enable Val_Evt receiver [0: disabled, force off - 1: Enabled] – see Table 7	1134
Val_Evt receiver	1	Val_Evt receiver power pulsing mode [0: power pin - 1: force on] – see Table 7	1135
EN_Raz_Chn receiver	1	Enable Raz_Chn receiver [0: disabled, force off - 1: Enabled] – see Table 7	1136
Raz_Chn receiver	1	Raz_Chn receiver power pulsing mode [0: power pin - 1: force on] – see Table 7	1137
EN_out_dig	1	Enable digital multiplexed output (hit mux out) [0: disabled, force off - 1: Enabled] – see Table 7	1138
EN_OR32	1	Enable digital OR32 output [0: disabled, force off - 1: Enabled] – see Table 7	1139
EN_NOR32_oc	1	Enable digital OR32 Open Collector output [0: disabled, force off - 1: Enabled] – see Table 7	1140
Trigger Polarity	1	Output trigger polarity choice [0: positive (rising edge) - 1: negative (falling edge)] <sup>5</sup>	1141
EN_NOR32T_oc	1	Enable digital OR32_T Open Collector output [0: disabled, force off - 1: Enabled] – see Table 7	1142
EN_32 triggers	1	Enable 32 channels triggers outputs [0: disabled, force off - 1: Enabled] – see Table 7	1143
<b>Total</b>	<b>1144</b>		<b>1144</b>

**Table 5 – slow control register parameters**

### 8.3 General description of probe shift-register

A probing system is embedded in Citiroc 1A. It routes internal points of the ASIC to specific probe pins in order to measure internal point in case of debug need. Three dedicated pins are available for probing:

- Digital\_probe: for digital signal giving peak detector real time status
- Out\_probe: for analog signals such as shaper or preamplifiers outputs

<sup>5</sup> It is recommended to use negative polarity for EMC consideration

- Input\_DAC: for input 5V DAC output, that pin can be used for DAC intercalibration

The probing points are set by the probe register. This “probe” register shares the same I/O with the “slow control” register as both are multiplexed. Selection of either “probe” or “slow control” is done by the “Select” pin as shown in Figure 19.

For each of the 32 channels, output of low and high gain preamplifier, of low gain and high gain slow shaper, of fast shaper and the internal signals “PeakSensing\_modeb\_LG” and “PeakSensing\_modeb\_HG” can be monitored.

Only one analogue, one digital output and one input DAC can be routed at the same time. **Connecting several point to the same probe induce CMOS short inside Citiroc 1A.**

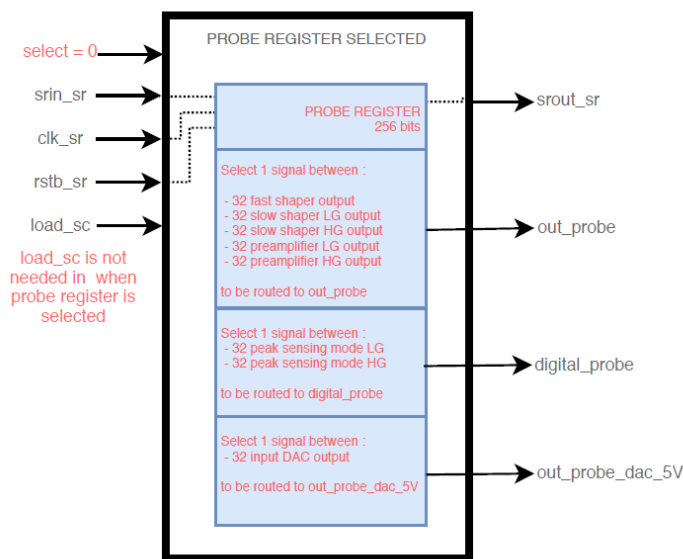


Figure 21 - Scheme block of internal probing system

In normal use, this probe output should be disabled by Slow Control to save power. The probe can be useful for debug or calibration purpose.

#### 8.4 Probe register parameters

Signal name	Probe	Comments	Type	Subadd	Routed to
Out_fs	32	Fast shaper output channel 0 to 31	Analog	0	Out_probe
Out_ssh_LG	32	Low gain slow shaper, output channel 0 to 31	Analog	32	Out_probe
PeakSensing_modeb_LG	32	Low gain peak detector status (follower or peak sensing) channel 0 to 31	Digital	64	Digital_probe
Out_ssh_HG	32	High gain slow shaper output channel 0 to 31	Analog	96	Out_probe
PeakSensing_modeb_HG	32	High gain peak detector status (follower or peak sensing) channel 0 to 31	Digital	128	Digital_probe
Out_PA_HG/Out_PA_LG	64	High gain preamp output Low gain preamp output channel 0 to 31	Analog	160	Out_probe
Input DAC	32	Input DAC output channel 0 to 31	Analog	224	Out_probe_dac_5V
Total	256				

Table 6 – Probe register parameters

### 8.5 Power pulsing and ON/OFF functions

Each unused stage can be disabled to reduce power consumption. This is controlled by the slow control bits Enable (EN\_xxxx). Moreover, in order to save more power, chosen chip stages can be switched off dynamically thanks to the "pwr\_on" command (provided by a pin). This mode is the power pulsing function.

Caution, for each stage, the slow control bit Power Pulsing (PP\_xxxx) allows to bypass this feature by forcing it ON. Refer to the Table 7.

Note that turning OFF a stage has the highest priority.

Slow Control : EN_xxxx	Slow Control : PP_xxxx	Power PIN : pwr_on	Comments
0	X	X	Stage disabled
1	0	0 (OFF)	Power pulsing mode : Stage shut down
1	0	1 (ON)	Power pulsing mode : Stage powered
1	1	X	Stage powered

Table 7 – Power mode truth table

## **9 Performances**

That section is under validation and will be released in next version of Datasheet.

## 10 I/Os connection

### 10.1 SiPM connection

The 32 SiPM must be connected to the 32 inputs named **in<0>** to **in<31>**. The SiPM must be connected to provide a positive charge to Citiroc 1A. The SiPM anode must be connected to the Citiroc 1A input with the shortest possible cable length for good timing resolution (few cm). **The capacitance on the SiPM anode must be minimized (few pC)**. The line shall be terminated with a 50 Ohm & 100nF load in series. The 50 Ohm resistor is for RF signal termination (can be anything else matching the input line) and the 100nF is for DC block to allow the input DAC adjusting the DC value on the input point. The SiPM cathode should be connected to the common high voltage. Connection scheme is shown in Figure 22.

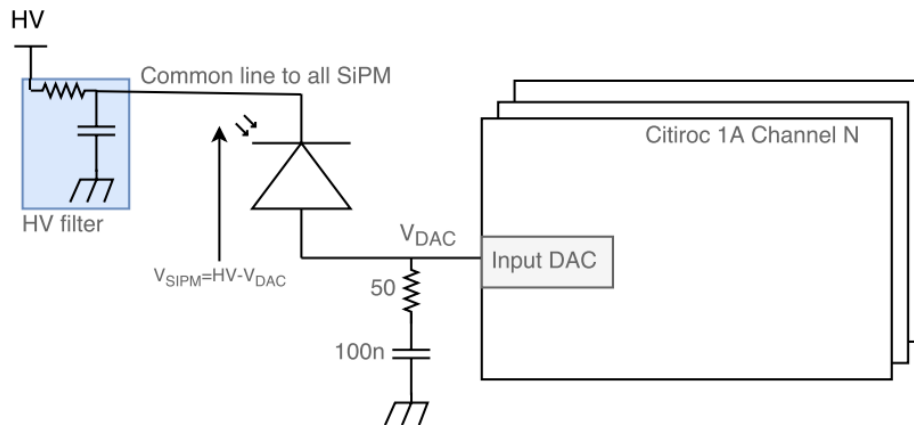


Figure 22 – SiPM connection scheme – DC bias

The SiPM bias voltage must be equal to the recommended voltage by the SiPM manufacturer according to the specified breakdown voltage ( $V_{BR}$ ) and the required overvoltage ( $V_{OV}$ ). The SiPM bias is equal to the High Voltage (HV) supply minus the input DAC voltage ( $V_{DAC}$ ). The input DAC voltage can be adjusted channel by channel to correct non uniformity in the breakdown voltage of the different SiPM connected to Citiroc 1A.

$$V_{SiPM} = V_{BD} + V_{OV} = V_{HV} - V_{DAC}$$

**Ramp-up of high voltage SiPM power should be no faster than 10V/ms to avoid excessive discharge at the input of the Citiroc 1A.** Once correctly biased, the SiPM will provide a positive charge upon incident photon. The input DAC is high impedance on fast signal and the fast charge generated by the SiPM will be injected in the Citiroc 1A preamplifier as shown on Figure 23.

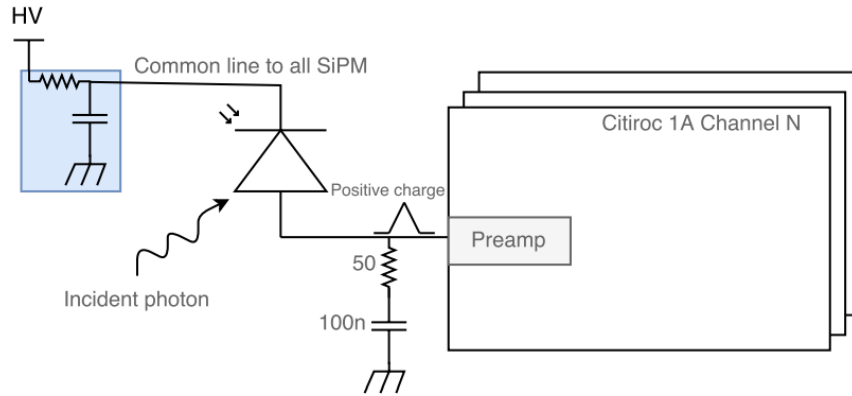


Figure 23 – SiPM charge transfer scheme - Fast signal

The input DAC can be connected to get a 4.5V dynamic range or a 2.5V dynamic range.

- 4.5V dynamic range
  - Connect Vdd\_dac\_5V to a 5V power supply
  - Slow control bit "8-bit DAC reference" must be set to 1
- 2.5V dynamic range
  - Connect Vdd\_dac\_5V to a 3.3V power supply
  - Slow control bit "8-bit DAC reference" must be set to 0

## 10.2 Trigger output connection

The Citiroc 1A 32 trigger output and OR32 general chip trigger have a user-defined voltage swing. The open collector signals of general trigger for each discriminator (discriminator Q and discriminator T) have the same user-defined voltage swing but requires external pull-up resistor/ The power supply pins VH (V high) and VL (V low) define the digital high level and digital low level of these pins. It is strongly recommended to set VL to zero volt (GND) to get better and faster signal.

**VH can be set to 1.8V – 2.5V or 3.3V** depending on user needs. The higher the voltage swing, the faster the signal. However, the EMC is better for low VH. That choice will be a design trade-off depending on the application and the timing performance required. The trigger signal receiving device (FPGA, microcontroller, etc.) must have a consistent voltage swing to operate correctly as shown in Figure 24.

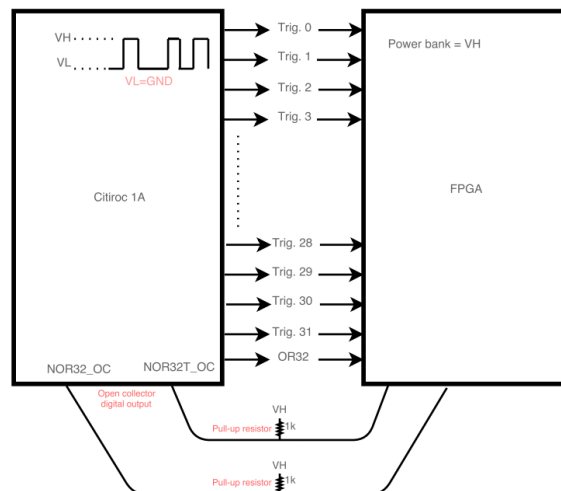


Figure 24 – Trigger output connection

The pull-up resistor for the open collector signal must have a value between 1k and 10k. The larger the resistance, the slower the signal will be to get back to baseline after a trigger. This is dependent on the line capacitance that should be minimized to have fast trigger count if Citiroc 1A is used in photon counting mode. **It is possible to connect several Citiroc 1A NOR32\_OC and NOR32T\_OC together to build a general trigger of several chips with a cabled OR.**

### 10.3 Digital control & read-out connection

The digital control of Citiroc 1A can be break down into two categories. The first category is the control of the different shift registers in Citiroc 1A. The slow control and probe register and the read register must be connected to a 3.3V power bank on the driving device (FPGA, microcontroller, etc.) as shown in Figure 25.

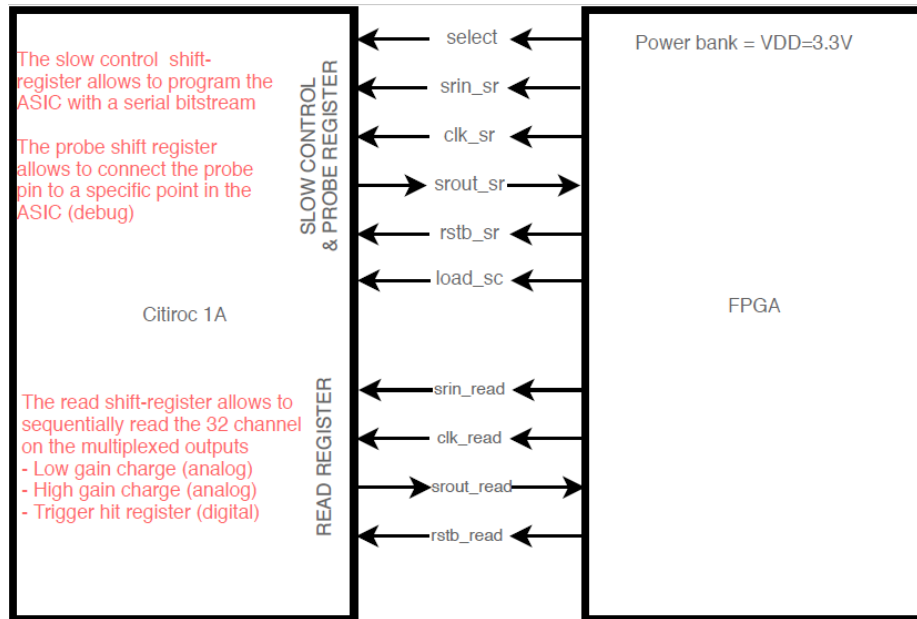


Figure 25 - Citiroc 1A shift register connection to controller

The two slow control register allow programming the ASIC parameters and the probing for debug for the slow control/probe shift register (the select bit allow to choose as described in) and drive the multiplexed outputs for the read register as described in Figure 26. The analog output signals must be connected to an ADC or an analog buffer with impedance higher than 1k. **The analog output should not be 50 Ohm terminated.** The hit multiplexer must be connected to a controller with a VH power bank as for the trigger outputs. The connection of the analog and digital output signals is described in Figure 26.

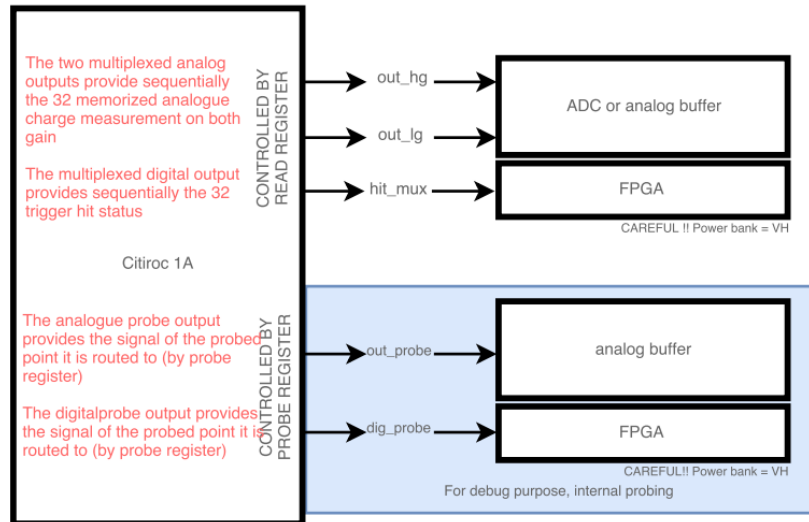


Figure 26 – Citiroc 1A analog and digital output signals connection

The second category is the direct connection signals. Two signals (RAZ\_chn and Val\_Evt) are LVDS. It is recommended to terminate the line with a 100 Ohm resistance between the plus and minus branch at the Citiroc 1A receiver level for these two signals. However this is not mandatory. Please refer to your FPGA or microcontroller datasheet for further information on how to handle LVDS signals from the transmitter point of view. **There is no 100 Ohm termination resistance inside the Citiroc 1A LVDS receiver.**

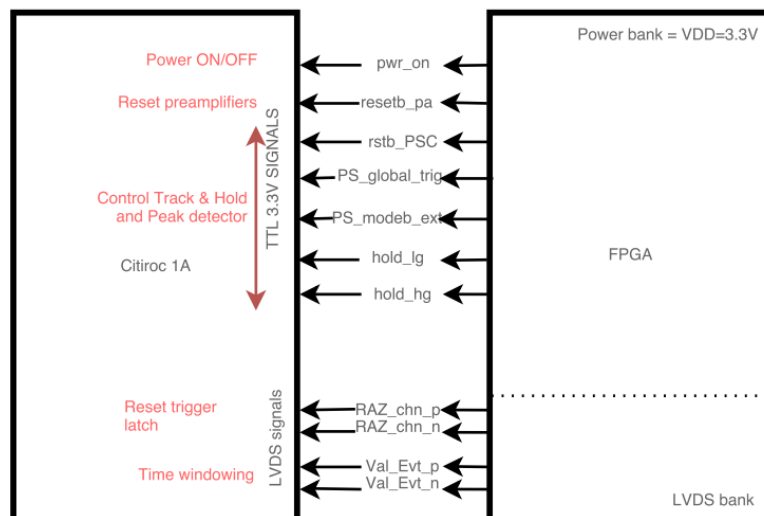


Figure 27 – Citiroc 1A direct digital control signal connection to controller

Other signals are standard 3.3V and should be connected to a same voltage power bank on the controller as shown in Figure 27.

#### 10.4 Power connection & bias or reference decoupling

**All the ground (gnd\_XXX) and substrate reference (vss) must be connected to the ground of the board** or system to ensure good signal integrity. Indeed that ground must be built out of a plane on the hosting PCB and cannot be only wired.



The different supply voltage must be carefully decoupled and should not be build out of a DC-DC converter. Prefer a LDO in your design to have a cleaner power supply. **The VDDA power supply is the most critical in term of noise** because it powers the preamplifiers. Bad decoupling on VDDA will induce coherent noise in your system.

The most critical point to decouple is the bandgap reference ( $V_{bg}$ ). 100nF on that point is useful and strongly recommended. If possible, decouple as well the shaper references:

- Vref\_ssh\_lg : Low gain slow shaper reference
- Vref\_ssh\_hg : High gain slow shaper reference
- Vref\_fs : Fast shaper reference

## 10.5 Bias and references values

All references and bias point of Citiroc 1A are described in that section. References are bias point are not to be changed unless specifically required by Weeroc. Contact us if you have specific request concerning fine tuning.

Reference bias name	LQFP160	TFBGA353	Value (V)	Description
ib_1nA_dac	NC	A1	0,8	Input DAC bias - referenced to ground
ib_1nA_peak	146	B9	2,75	Peak detector bias - referenced to VDD
ib_dac_4b	3	D2	2,6	4bit DAC bias - referenced to VDD
ib_dac_5V	159	B3	3	Input DAC bias - referenced to VDD
ib_ota_bg	NC	AC1	0,65	Bandgap buffer bias - referenced to GND
ib_otaq	64	AB13	0,85	Output analogue buffer bias - referenced to GND
ib_rec	69	AB15	0,8	LVDS receiver bias – referenced to GND
ib_sca	144	B10	1,6	SCA bias - referenced to GND
ib_suiv_fs	NC	B13	0,9	Fast shaper input follower - referenced to GND
ib_suiv_rc_hg	NC	A11	0,85	High gain slow shaper follower bias - referenced to GND
ib_suiv_rc_lg	NC	A8	0,85	Low gain slow shaper follower bias - referenced to GND
ib_temp	39	Y2	0,52	Temperature sensor bias - referenced to GND
ibfol_discr_i_t	NC	B12	0,8	Time discriminator follower bias - referenced to GND
ibi_dac	NC	AB5	0,75	10b DAC input stage bias - referenced to GND
ibi_discr_i	NC	E16	0,8	Charge discriminator input stage bias - referenced to GND
ibi_discr_i_t	160	B17	0,7	Time discriminator input stage bias - referenced to GND
ibi_fs	NC	E12	0,7	Fast shaper input stage bias - referenced to GND
ibi_ota_dac	NC	A3	0,7	10b DAC buffer input stage bias - referenced to GND
ibi_pa_hg	NC	A4	1,1	High gain preamplifier input stage bias - referenced to GND
ibi_pa_lg	NC	B8	1,1	Low gain preamplifier input stage bias - referenced to GND
ibi_peak	148	E10	0,65	Peak detector input stage bias - referenced to GND
ibi_ssh_hg	NC	B11	0,7	High gain slow shaper input stage bias - referenced to GND
ibi_ssh_lg	NC	A9	0,75	Low gain slow shaper input stage bias - referenced to GND
ibm_discr_i	NC	B15	2,5	Charge discriminator medium stage bias - referenced to VDD
ibm_discr_i_t	NC	B14	0,6	Time discriminator medium stage bias - referenced to GND
ibm_pa_hg	NC	B6	2,4	High gain preamplifier medium stage bias - referenced to VDD
ibm_pa_lg	NC	B7	2,1	Low gain preamplifier medium stage bias - referenced to VDD
ibmin_discr_i	NC	B16	3	Power-off discriminator quiescent current bias - referenced to VDD
ibmin_pa	NC	A6	0,65	Power-off preamplifier quiescent current bias - referenced to GND
ibo_dac	NC	AC6	0,62	10b DAC output stage bias - referenced to GND
ibo_discr_i	NC	A16	0,77	Charge discriminator output stage bias - referenced to GND
ibo_discr_i_t	NC	B2	0,95	Time discriminator output stage bias - referenced to GND
ibo_fs	NC	A13	0,7	Fast shaper output stage bias - referenced to GND
ibo_ota_dac	NC	A2	0,85	10b DAC buffer output stage bias - referenced to GND
ibo_pa_hg	NC	A5	2,5	High gain preamplifier output stage bias - referenced to VDD
ibo_pa_lg	NC	A7	2,5	Low gain preamplifier output stage bias - referenced to VDD
ibo_peak	147	E11	2,15	Peak detector output stage bias - referenced to VDD
ibo_ssh_hg	NC	A12	0,75	High gain slow shaper output stage bias - referenced to GND
ibo_ssh_lg	NC	A10	0,75	Low gain slow shaper output stage bias - referenced to GND

Table 8 – Bias point list & values

These bias points may be useful to finely tune some parameter. Please **do not connect these pins** unless specifically required by Weeroc team. Contact [citiroc@weeroc.com](mailto:citiroc@weeroc.com) in case you need specific ASIC tuning.

Voltage reference name	LQFP160	TFBGA353	Value	Description
v_bg	45	AC3	2,5	Bandgap reference output - do not change
va_pa	NC	AC4	1,25	Feedback resistor reference - do not change
vg_pa_hg	NC	AB3	1,25	folded cascode reference - do not change
vg_pa_lg	NC	AC2	0,66	folded cascode reference - do not change
vref_dac	NC	AB4	0,82	10b DAC reference (value #000) - adjust pedestal of 10b DACs
vref_dac_5V	157	B4	4,5	90% of VDD_5V - input DACs reference (value #00)
vref_fs	53	AC8	1,2	Fast shaper quiescent voltage
vref_iGen_dac_5V	2	C2	0,6 0,3	Input DACs slope reference 0,6 if input DACs reference is 4,5 (SC bit #330=0) 0,3 if input DACs reference is 2,5 (SC bit #330=0)
vref_ssh_hg	52	AB8	1,25	High gain slow shaper quiescent voltage
vref_ssh_lg	50	AB7	1,25	Low gain slow shaper quiescent voltage
iref_dac	49	AB6	1,85	Threshold DACs slope reference

**Table 9 – Reference voltage list and values**

Reference points may be decoupled with 100nF capacitance. V\_bg decoupling is mandatory. Shapers reference decoupling is highly recommended. Other decoupling are advised but not necessary. Please **do not change the reference values** unless specifically asked by Weeroc team.

## 11 Pinout & mechanics

Citiroc is available in a LQFP 160 or TFBGA 353 package.

### 11.1 Pin type description

Pin type	Description	Connection
Power	Power or Ground pin	Decoupling advised
Analogue input	Analogue signal input	See specifics
Analogue output	Analogue signal output	External buffering required if cable driving
Analogue bias	Analogue bias connection. Bias is internal and can be tuned externally through these pins	Not mandatory if not specifically specified
Digital input	Digital input connection	TTL levels
Digital output	Digital output connection	TTL levels
Digital output OC	Open Collector digital output connection	External pull-up resistor required
Digital input LVDS	LVDS pair connection	See LVDS norm, matching resistor outside ASIC
Digital output LVDS	LVDS pair connection	See LVDS norm, matching resistor outside ASIC

**Table 10 – pin type description**

SYMBOL	LEAD COUNT; FOOT PRINT			NOTE
	160; 2.0 FP			
	MIN.	NOM.	MAX.	
A	== ==	== ==	1.60	
A1	0.05	== ==	0.15	
A2	1.35	1.40	1.45	
D	30.00 BSC			
D1	28.00 BSC			
E	30.00 BSC			
E1	28.00 BSC			
L	0.45	0.60	0.75	
e	0.65 BSC			
b	0.22	== ==	0.38	
b1	0.22	0.28	0.33	
c	0.09	== ==	0.20	
c1	0.09	== ==	0.16	
Tolerances of form and position				
aaa	0.20			
bbb	0.20			
ccc	0.12			
ddd	0.08			

### 11.2.2 Pin list

Pin #	Pin name	Pin type	Description	Connection
1	vssi	Power	Analogue part Bulk	to GND
2	vref_iGen_dac_5V	Analogue Bias	8-bit DAC reference bias voltage (for 4,5V dynamic range)	100nF decoupling
3	ib_dac_4b	Analogue Bias		
4	in<0>	Analogue Input	Channel 0 input	See Figure 22
5	in<1>	Analogue Input	Channel 1 input	See Figure 22
6	in<2>	Analogue Input	Channel 2 input	See Figure 22
7	in<3>	Analogue Input	Channel 3 input	See Figure 22
8	in<4>	Analogue Input	Channel 4 input	See Figure 22
9	in<5>	Analogue Input	Channel 5 input	See Figure 22
10	in<6>	Analogue Input	Channel 6 input	See Figure 22
11	in<7>	Analogue Input	Channel 7 input	See Figure 22
12	vdda_pa	Power	Analogue (PreAmplifier) Power Supply	to 3.3V
13	in<8>	Analogue Input	Channel 8 input	See Figure 22
14	in<9>	Analogue Input	Channel 9 input	See Figure 22
15	in<10>	Analogue Input	Channel 10 input	See Figure 22
16	in<11>	Analogue Input	Channel 11 input	See Figure 22
17	in<12>	Analogue Input	Channel 12 input	See Figure 22
18	in<13>	Analogue Input	Channel 13 input	See Figure 22
19	in<14>	Analogue Input	Channel 14 input	See Figure 22
20	in<15>	Analogue Input	Channel 15 input	See Figure 22
21	vssi	Power	Analogue part Bulk	to GND
22	in<16>	Analogue Input	Channel 16 input	See Figure 22
23	in<17>	Analogue Input	Channel 17 input	See Figure 22
24	in<18>	Analogue Input	Channel 18 input	See Figure 22
25	in<19>	Analogue Input	Channel 19 input	See Figure 22
26	in<20>	Analogue Input	Channel 20 input	See Figure 22
27	in<21>	Analogue Input	Channel 21 input	See Figure 22
28	in<22>	Analogue Input	Channel 22 input	See Figure 22
29	in<23>	Analogue Input	Channel 23 input	See Figure 22
30	vdda_pa	Power	Analogue (PreAmplifier) Power Supply	to 3.3V
31	in<24>	Analogue Input	Channel 24 input	See Figure 22
32	in<25>	Analogue Input	Channel 25 input	See Figure 22
33	in<26>	Analogue Input	Channel 26 input	See Figure 22
34	in<27>	Analogue Input	Channel 27 input	See Figure 22
35	in<28>	Analogue Input	Channel 28 input	See Figure 22
36	in<29>	Analogue Input	Channel 29 input	See Figure 22
37	in<30>	Analogue Input	Channel 30 input	See Figure 22
38	in<31>	Analogue Input	Channel 31 input	See Figure 22
39	ib_temp	Analogue Bias		
40	out_temp	Analogue Output		
41	vssi	Power	Analogue part Bulk	to GND
42	Out_probe_dac_5V	Analogue output	Input DAC probe (5V pad)	
43	vdda_pa	Power	Analogue (PreAmplifier) Power Supply	to 3.3V
44	vssa	Power	Analogue part Bulk	to GND
45	v_bg	Analogue Output	BandGap output	
46	vdd_dac	Power	Analogue (10-bit DAC) Power Supply	to 3.3V
47	gnd_dac	Power	Analogue (10-bit DAC) Ground	to GND
48	vth	Analogue Output	10-bit DAC output (Trigger Discriminator Threshold)	
49	iref_dac	Analogue Bias	10-bit DAC bias current	
50	vref_ssh_lg	Analogue Bias	Low Gain Slow Shapers bias voltage	
51	vth_t	Analogue Output	10-bit DAC output (2nd Trigger Discriminator Threshold)	
52	vref_ssh_hg	Analogue Bias	High Gain Slow Shapers bias voltage	
53	vref_fs	Analogue Bias	Fast Shapers bias voltage	
54	vdd_fs	Power	Analogue (Fast Shaper) Power Supply	to 3.3V
55	vdd_sca	Power	Analogue (Switched Capacitor Array) Power Supply	to 3.3V
56	gnd_fs	Power	Analogue (Fast Shaper) Ground	to GND
57	gnd_capa_sca_hg	Power	Analogue SCA capacitors Ground (High Gain)	to GND
58	gnd_capa_sca_lg	Power	Analogue SCA capacitors Ground (Low Gain)	to GND
59	gnd_sca	Power	Analogue (Switched Capacitor Array) Ground	to GND
60	vssa	Power	Analogue part Bulk	to GND

	vssm	Power	Mixed part Bulk	to GND
61	out_hg	Analogue Output	High Gain Slow Shaper Multiplexed Output (Hi Z when not Ch. selected)	
62	out_lg	Analogue Output	Low Gain Slow Shaper Multiplexed Output (Hi Z when not Ch. selected)	
63	out_probe	Analogue Output	Analogue Probe Output	
64	ib_otaq	Analogue Bias	Analogue outputs OTA bias	
65	vssm	Power	Mixed part Bulk	to GND
66	vssd	Power	Digital part Bulk	to GND
67	gndd	Power	Digital (LVDS receivers & digital parts) Ground	to GND
68	vddd	Power	Digital (LVDS receivers & digital parts) Power Supply	to 3.3V
69	ib_rec	Analogue Bias	LVDS receiver bias current	
70	resetb_pa	Digital Input	Charge PreAmp Reset Signal	Active L
71	rstb_PSC	Digital Input	Peak Detector Cell reset	Active L
72	pwr_on	Digital Input	Power Pulsing Control	Active H
73	Raz_Ch_n_p	Digital (LVDS) Input	Erase RS cell	Active H
74	Raz_Ch_n_n			
75	Val_Evt_p	Digital (LVDS) Input	Acquisition window (valid events)	Active H
76	Val_Evt_n			
77	digital_output/hit_mux	Digital Output	Digital (Triggers) Multiplexed Output (Hi Z when not Ch. selected)	
78	OR32	Digital Output	OR of the 32 triggers	
79	select	Digital Input	Select Slow Control Register (1) or Probe Register (0)	
80	NOR32_oc	OC Digital Output	NOR of the 32 triggers (Open Collector Output)	
81	vssd	Power	Digital part Bulk	to GND
82	PS_global_trig	Digital Input		
83	NOR32T_oc	OC Digital Output	NOR of the 2nd threshold 32 triggers (Open Collector Output)	
84	T<31>	Digital Output	Channel 31 Trigger Output	
85	T<30>	Digital Output	Channel 30 Trigger Output	
86	T<29>	Digital Output	Channel 29 Trigger Output	
87	T<28>	Digital Output	Channel 28 Trigger Output	
88	T<27>	Digital Output	Channel 27 Trigger Output	
89	T<26>	Digital Output	Channel 26 Trigger Output	
90	T<25>	Digital Output	Channel 25 Trigger Output	
91	T<24>	Digital Output	Channel 24 Trigger Output	
92	T<23>	Digital Output	Channel 23 Trigger Output	
93	T<22>	Digital Output	Channel 22 Trigger Output	
94	T<21>	Digital Output	Channel 21 Trigger Output	
95	T<20>	Digital Output	Channel 20 Trigger Output	
96	T<19>	Digital Output	Channel 19 Trigger Output	
97	T<18>	Digital Output	Channel 18 Trigger Output	
98	T<17>	Digital Output	Channel 17 Trigger Output	
99	T<16>	Digital Output	Channel 16 Trigger Output	
100	vlo	Power	Digital Output Buffer Minimum Power Supply	Positive
101	vssd	Power	Digital part Bulk	to GND
102	vhi	Power	Digital Output Buffer Maximum Power Supply	
103	T<15>	Digital Output	Channel 15 Trigger Output	
104	T<14>	Digital Output	Channel 14 Trigger Output	
105	T<13>	Digital Output	Channel 13 Trigger Output	
106	T<12>	Digital Output	Channel 12 Trigger Output	
107	T<11>	Digital Output	Channel 11 Trigger Output	
108	T<10>	Digital Output	Channel 10 Trigger Output	
109	T<9>	Digital Output	Channel 9 Trigger Output	
110	T<8>	Digital Output	Channel 8 Trigger Output	
111	T<7>	Digital Output	Channel 7 Trigger Output	
112	T<6>	Digital Output	Channel 6 Trigger Output	
113	T<5>	Digital Output	Channel 5 Trigger Output	
114	T<4>	Digital Output	Channel 4 Trigger Output	
115	T<3>	Digital Output	Channel 3 Trigger Output	
116	T<2>	Digital Output	Channel 2 Trigger Output	
117	T<1>	Digital Output	Channel 1 Trigger Output	
118	T<0>	Digital Output	Channel 0 Trigger Output	
119	digital_probe	Digital Output		
120	PS_modeb_ext	Digital Input		
121	vssd	Power	Digital part Bulk	to GND
122	gndd	Power		to GND

123	vddd	Power	Digital (LVDS receivers & digital parts) Power Supply	to 3.3V
124	load_sc	Digital Input	Slow Control Register Load Signal	see Figure 25
125	srout_sr	Digital Output	Selected Register Output	see Figure 25
126	srin_sr	Digital Input	Selected Register Input	see Figure 25
127	clk_sr	Digital Input	Selected Register Clock	see Figure 25
128	rstb_sr	Digital Input	Selected Register Reset	see Figure 25
129	vssd	Power	Digital part Bulk	to GND
130	vssm	Power	Mixed part Bulk	to GND
131	hold_lg	Digital Input	Analogue Memory Hold Signal for Low Gain	see Figure 27
132	resetb_read	Digital Input	Read Register Reset	see Figure 25
133	srout_read	Digital Output	Read Register Output	see Figure 25
134	srin_read	Digital Input	Read Register Input	see Figure 25
135	clk_read	Digital Input	Read Register Clock	see Figure 25
136	hold_hg	Digital Input	Analogue Memory Hold Signal for High Gain	see Figure 27
137	vdd_discr	Power	Analogue (Discriminator) Power Supply	to 3.3V
138	gnd_discr	Power	Analogue (Discriminator) Ground	to GND
	vssm	Power	Mixed part Bulk	to GND
139	vssa	Power	Analogue part Bulk	to GND
140	gnd_ssh	Power	Analogue (Slow Shaper) Ground	to GND
141	vdd_ssh	Power	Analogue (Slow Shaper) Power Supply	to 3.3V
142	vdd_sc	Power	Digital (Slow Control Register) Power Supply	to 3.3V
143	gnd_sc	Power	Digital (Slow Control Register) Ground	to GND
144	ib_sca	Analogue Bias	SCA bias current	
145	gnd_capa	Power	Analogue (Slow Shaper Capacitor) Ground	to GND
146	ib_inA_peak	Analogue Bias		
147	ibo_peak	Analogue Bias		
148	ibi_peak	Analogue Bias		
149	in_calib	Analogue Input	Calibration input	
150	gnd_pa	Power	Analogue (PreAmplifier) Ground	to GND
151	vssa	Power		
152	vdd_pa	Power	Analogue (PreAmplifier) Power Supply	to 3.3V
153	vdda_pa	Power	Analogue (PreAmplifier) Power Supply	to 3.3V
154	vssi	Power	Analogue part Bulk	to GND
155	NC_top			
156	gnd_dac_5V	Power	Analogue (8-bit Digital to Analogue Convertor) Ground	to GND
157	vref_dac_5V	Analogue Bias	8-bit DAC reference bias voltage	
158	vdd_dac_5V	Power	Analogue (8-bit Digital to Analogue Convertor) Power Supply	to 5V
159	ib_dac_5V	Analogue Bias	8-bit DAC bias voltage	
160	ibi_discr_t	Analogue Bias		

Table 11 – LQFP 160 pinout



### 11.3 TFBGA 353 package

#### 11.3.1 Package layout & mechanics

	1	2	3	4	5	6	7	8	9	10	11	12
<b>A</b>	ib_1nA_dac	ibo_ota_dac	ibi_ota_dac	ibi_pa_hg	ibo_pa_hg	ibmin_p_a	ibo_pa_lg	ib_suiv_r_c_lg	ibi_ssh_lg	ibo_ssh_lg	ib_suiv_r_c_hg	ibo_ssh_hg
<b>B</b>	in0	ibo_discr_i_t	ib_dac_5V	vref_dac_5V	NC_top	ibm_pa_hg	ibm_pa_lg	ibi_pa_lg	ib_1nA_peak	ib_sca	ibi_ssh_hg	ibfol_discr_i_t
<b>C</b>	in1	vref_iGen_dac_5V										
<b>D</b>	in2	ib_dac_4b										
<b>E</b>	in4	in3			VDDI	VDDI	VDDI	VDDI	in_calib	ibi_peak	ibo_peak	ibi_fs
<b>F</b>	in6	in5			VDDI	VDDI	VDDI	VDDI	VDDA	VDDA	VDDA	VDDA
<b>G</b>	in8	in7			VDDI	VDDI						
<b>H</b>	in10	in9			VDDI	VDDI		VSS	VSS	VSS	VSS	VSS
<b>J</b>	in12	in11			VDDI	VDDI		VSS	VSS	VSS	VSS	VSS
<b>K</b>	in13	VDDI			VDDI	VDDI		VSS	VSS	VSS	VSS	VSS
<b>L</b>	in14	VDDI			VDDI	VDD_5V		VSS	VSS	VSS	VSS	VSS
<b>M</b>	in16	in15			VDDI	VDD_5V		VSS	VSS	VSS	VSS	VSS

Figure 28 – North-west Citiroc 1A ball out

12	13	14	15	16	17	18	19	20	21	22	23	
ibo_ssh_hg	ibo_fs	clk_read	srout_read	ibo_discr_i	hold_lg	clk_sr	srin_sr	PS_mod eb_ext	digital_p robe	T1	T3	A
ibfol_discr_t	ib_suiv_f s	ibm_discr_t	ibm_discr_i	lbmin_discr_i	ibi_discr_t	rstb_sr	srout_sr	load_sc	T0	T2	T4	B
										NC	T5	C
										NC	T6	D
ibi_fs	hold_hg	srin_read	rstb_read	ibi_discr_i	VDDD	VDDD	VDDD			NC	T7	E
VDDA	VDDA	VDDD	VDDD	VDDD	VDDD	VDDD	VDDD			NC	T8	F
						VDDD	NC			NC	T9	G
VSS	VSS	VSS	VSS	VSS		VDDD	NC			NC	T10	H
VSS	VSS	VSS	VSS	VSS		VDDD	NC			NC	T11	J
VSS	VSS	VSS	VSS	VSS		VDDD	NC			NC	T12	K
VSS	VSS	VSS	VSS	VSS		vhi	vhi			T13	T14	L
VSS	VSS	VSS	VSS	VSS		VDDD	VDDD			T15	T16	M

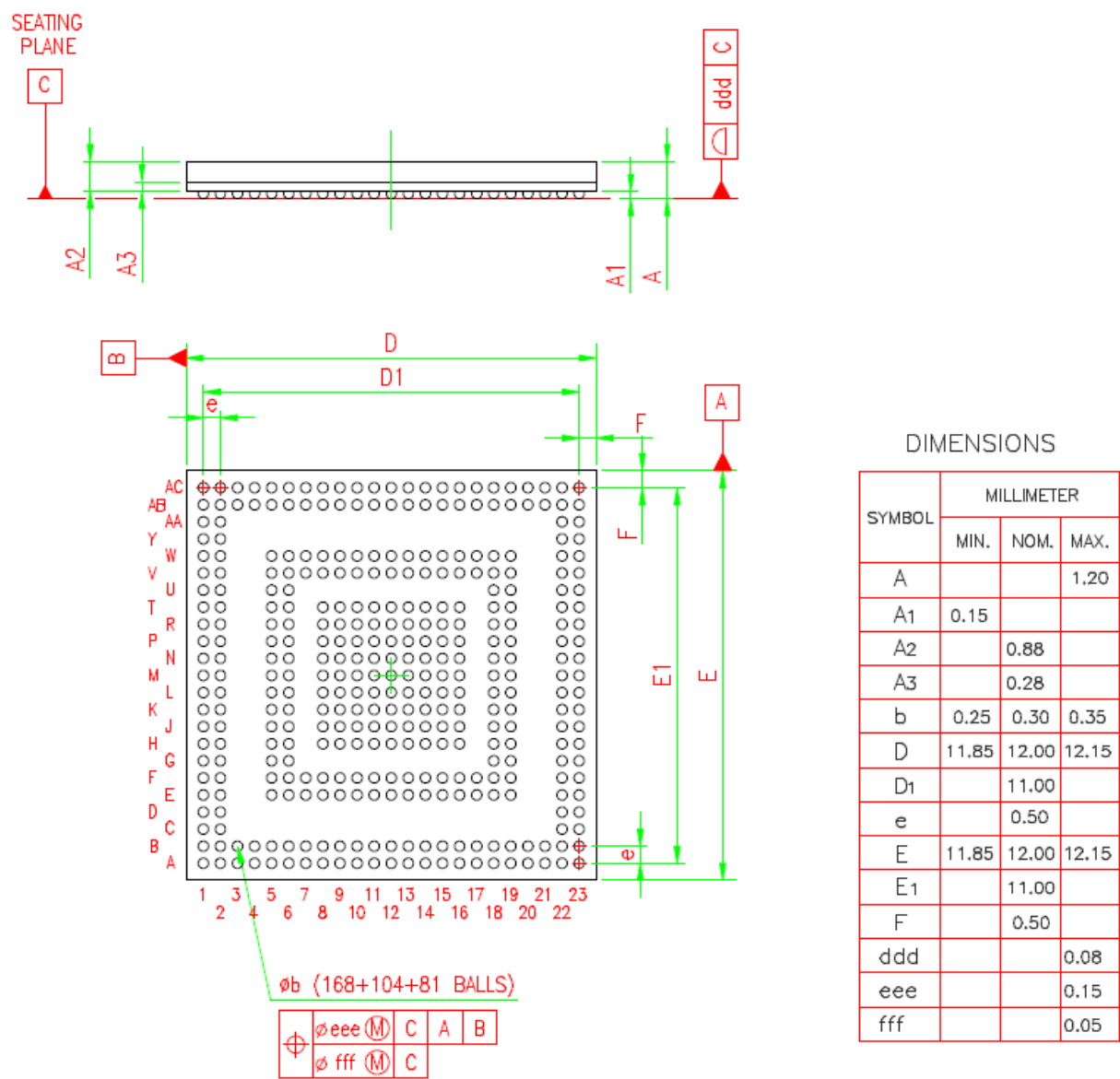
Figure 29 – North-east Citiroc 1A ball-out

<b>M</b>	in16	in15			VDDI	VDD_5V		VSS	VSS	VSS	VSS	VSS
<b>N</b>	in17	VDDI			VDDI	VDD_5V		VSS	VSS	VSS	VSS	VSS
<b>P</b>	in18	VDDI			VDDI	VDDI		VSS	VSS	VSS	VSS	VSS
<b>R</b>	in19	in20			VDDI	VDDI		VSS	VSS	VSS	VSS	VSS
<b>T</b>	in21	in22			VDDI	VDDI		VSS	VSS	VSS	VSS	VSS
<b>U</b>	in23	in24			VDDI	VDDI						
<b>V</b>	in25	in26			VDDI	VDDI	VDDA	VDDA	VDDA	VDDA	VDDA	VDDA
<b>W</b>	in27	in28			VDDI	VDDI	VDDA	VDDA	NC	NC	VDDA	NC
<b>Y</b>	in29	ib_temp										
<b>AA</b>	in30	out_tem p										
<b>AB</b>	in31	out_pro be_dac_ 5V	vg_pa_h g	vref_dac	ibi_dac	iref_dac	vref_ssh _lg	vref_ssh _hg	NC	NC	NC	NC
<b>AC</b>	ib_ota_b g	vg_pa_lg	v_bg	va_pa	vth	ibo_dac	vth_t	vref_fs	NC	NC	out_hg	out_lg
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>	<b>12</b>

Figure 30 – South-west Citiroc 1A ball-out

VSS	VSS	VSS	VSS	VSS		VDDD	VDDD			T15	T16	M
VSS	VSS	VSS	VSS	VSS		vlo	vlo			T17	T18	N
VSS	VSS	VSS	VSS	VSS		VDDD	NC			NC	T19	P
VSS	VSS	VSS	VSS	VSS		VDDD	NC			NC	T20	R
VSS	VSS	VSS	VSS	VSS		VDDD	NC			NC	T21	T
						VDDD	NC			NC	T22	U
VDDA	VDDA	VDDA	VDDA	VDDD	VDDD	VDDD	VDDD			NC	T23	V
NC	Resetb_pa	Pwr_on	NC	NC	NC	VDDD	VDDD			NC	T24	W
										NC	T25	Y
										NC	T26	AA
NC	ib_otaq	NC	ib_rec	rstb_PS_C	OR32	digitalOutput	select	NOR32_oc	T31	T29	T27	AB
out_lg	NC	out_probe	NC	Raz_Ch_n_p	Raz_Ch_n_n	Val_Evt_p	Val_Evt_n	PS_global_trig	NOR32T_oc	T30	T28	AC
12	13	14	15	16	17	18	19	20	21	22	23	

Figure 31 – South-east Citiroc1A ball-out



12 Bug list & log

Date	Description

### 13 Document version

That section log the document version within major release.

Version	Date	# pages	Change log
2.0	27/07/2017	30	Initial version of release 2
2.1	24/08/2017	43	New format, new figures, text respin
2.2	05/12/2017	44	Ctest Schematic added, bit order correction for charge shaper and preamplifier slow control bits.
2.3	31/01/2018	44	Slow control modification en/pp for high gain and low gain pa (bit inversion)
2.4	15/02/2018	46	Section 10.5 added – TFBGA353 pinout modified
2.4a	24/08/2018	46	Figure 4 and figure 14 updated
2.4b	07/09/2018	46	Typo correction section 3.2
2.5	29/05/2019	46	Figure 19 & 20 & 21 & 25 updated. Load_sc explained for Slow Control
2.53	17/12/219	46	Added ramp up value in 10.1