AMPLIFICATION TECHNOLOGIES

DATASHEET

1550nm Digital 5x5 DAPD Array Time-of-Flight LiDAR Receiver

Discrete Amplification Photon Detector 5x5 Array Including Digitization and time-of-flight data acquisition and processing hardware and software

The 1550nm Digital DAPD 5x5 Array Time-of-Flight (ToF) Receiver utilizes the breakthrough discrete amplification method of detecting and amplifying single- as well as multi-photon, using multi micro-cell amplification channels combined with a monolithically integrated negative feedback avalanche mechanism, a method which was developed and patented by Amplification Technologies. The Discrete Amplification Photon Detector (DAPD) technology includes internal amplification and an integrated negative feedback mechanism, offers very high gain (of approximately 100,000), a gain which is combined with a very low excess noise factor (lower than 1.05) and a fast response (rise time shorter than 0.4ns). These characteristics enable the DAPD to detect and discern single photons, as well as multi-photon events, with a linear output response. The output response signal is proportional to the amount of incident photons, a fact that is useful specifically in improving the multi-photon events detection signal to noise ratio (SNR). Since the dark events signal distribution is limited, as not many multi dark-photon events occur, setting the detection thresholds at a level equivalent to a desired multi-photon response optimizes the multi-photon photo-detection SNR. The DAPD 5x5 Array has an $In_{0.53}Ga_{0.47}As$ absorber layer, suitable for photon detection in the wavelength range of 950nm to 1650nm.

The digital time of flight (ToF) receiver is built by integrating the DAPD 5x5 array with a custom readout and digitization Application Specific Integrated Circuit (ASIC), which together with control electronics and software, forms the time-of-flight digital receiver. The readout ASIC is the TOFPET2, which is designed to operate with multi-micro-cell single- and multi-photon detectors in time of-flight applications, and was developed and patented by PETsys Electronics. Each of the 25 channels of the TOFPET2 ASIC consists of: a pre-amplifier, signal amplification, discriminators, charge integration Analog-to-Digital Converter (ADC), and a high-performance Time-to-Digital Converter (TDC), one for each of the 25 independent channels. The pre-amplifier is a low impedance current conveyor. Two transimpedance post-amplifiers are optimized for time resolution and charge integration. The discriminators use three voltage modes with configurable thresholds for timing measurements: to reject low amplitude pulses, to start the charge integration window, and to trigger the event data readout. Each channel has quad-buffered analog interpolation TDCs with time binning of 30ps, as well as charge integration Analog-to-Digital Convertors (ADCs) with linear response to the input charge, which is proportional to the number of the detected photons in the event. The input pulse amplitude is given either by the Integrated-Charge (IC) or the Time-over-Threshold (ToT) methods.

The digital 5x5 DAPD array ToF receiver is delivered in two separated units (modules):

1. Front-End Module 1 (FEM1), which contains the DAPD array + ASIC

2. Control Module (CM2), with a field-programmable gate array (FPGA) based control and processing functions

The two modules are connected using a flexible cable and together form the ToF Light Detection and Ranging (LiDAR) readout receiver. The receiver is designed to be used in ToF LiDAR applications where 25 channels are read with a high event-rate, and it provides an easy to use way for exploring the unique, powerful and versatile features of the integrated DAPD array / TOFPET2 ASIC.

The Front-End Module 1 (FEM1) includes the 5x5 DAPD array, the TOFPET 2C ASIC and the thermo-electric cooler (TEC) control circuit, in an enclosure that provides support circuitry, shielding and cooling. The TOFPET2 ASIC consists of 64 independent channels, of which 25 are activated, each channel containing independent amplifiers, discriminators, time-to-digital converters and charge-to-digital converters. The 5x5 DAPD array is packaged in a custom hermetically sealed Kovar package, which contains a high efficiency two-stage thermoelectric cooler (TEC) and a feedback thermistor for temperature control. The photon detector array has a square optically-sensitive area of 0.5mm by 0.5mm with 25 elements, arranged as a five columns and five rows array. Each element's active area size is 90µm by 90µm, with a pitch of 100µm, and 81% fill-factor. Each element is isolated electrically and optically from its adjacent neighbors. The optical window is made of BK7 glass; it is centered on the top side of the Kovar package.

The Control Module (CM2) comprises of a Field Programmable Gate Array (FPGA), supplied with firmware for configuration of the ASIC; DC/DC converters biasing of the DAPD array and the ASIC; Gigabit Ethernet to allow the readout of the data; and application software for receiving the data in a Personal Computer (PC). The entire receiver is powered by a single 12VDC/4A input power port. The computer should run Linux RHEL / CentOS 6.x or 7.x, 64-bit. All the firmware and software needed for acquiring and analyzing the signals of the TOFPET2 ASIC is provided. A Graphical User Interface (GUI) allows for easy interaction with the hardware. The source code of the data acquisition (DAQ) software is provided, giving the user the freedom to explore the performance of the system, and to adapt it to the user specific application based needs.

Key Features

- $In_{0.53}Ga_{0.47}As$ absorber design for a wide wavelength operation range of 950nm to 1650nm
- Designed to operate at a wide range of ambient temperatures of -55°C to 65°C, where the array temperature is cooled to a steady -25°C, using a low power two-stage Thermo Electric Cooler
- Single 12V/4A DC supply
- Signal amplification and discrimination for each of the 25 independent channels
- Dual branch quad-buffered analog interpolation TDCs for each channel.
- Two GUI-switchable sensitivity modes, with 400 pulse levels in each mode
    - High sensitivity (ToT) 1 to 1000 photons/pulse
    - Low sensitivity (IC): above 1000 photons/pulse with ~1000 photons granularity
- 64 threshold levels
- Dynamic range of 1500pC (1 to ~93,750 photons; 50 dB)
- Gain adjustment per channel: 1, 1/2, 1/4, 1/8
- Maximum channel hit rate: 600 kHz
- Burst detection mode: up to four pulses in a burst with 100ns separation (10MHz)
- Time-to-Digital Converter (TDC) time binning: 30ps
- Internal or external trigger

- Configurable timing, trigger and Time-over-Threshold (ToT) threshold levels
- Fully digital output provided in Gigabit Ethernet link
- Max output data rate: 3.2 Gb/s

Modes of Operation and Applications

The DAPD 5x5 Array LiDAR Receiver is designed to operate with Time of Flight measurement LiDAR systems, particularly where high rate is required. The unique capabilities of the DAPD detector array with combination of the TOFPET2 ASIC offers many advantages of this receiver in comparison to other single-photon APD detection systems.

Specifically, there are several unique abilities:

High Detection Rate

The high supported rate of 600 kHz can help increase the observed field of view / resolution by combining beam scanning techniques with this receiver.

Burst Detection Option

Burst detection is supported, to accommodate optional time-domain modulation as well as amplitude-modulation to include digital coding for identification and forward error correction techniques.
In burst detection mode, the time between bursts is as follows:

Number of Consecutive Pulses In A Burst (#)	Time Between Pulses (ns)	Time Between Bursts (µs)	Pulse frequency (kHz)
1 (no burst mode)	NA	1.67	600
2	100	3.33	300
3	100	5.00	200
4	100	6.67	150

Adjustable Threshold

Adjustable threshold setting option is supported, from a level of one photon up to any desired level, with 64 increments. This option can dramatically improve the signal to noise ratio because the distribution of the dark events mostly is below the signal which is equivalent to detecting 5 photons (80%) or 9 photons (99%). If a detection threshold is set above this level, the dark event rate is reduced to approximately 12 kHz, thus setting the detection threshold at the detected signal of 9 photons yields a very low dark event rate, yet still with superior sensitivity.

Internal or External Trigger

Several triggering options are supported providing operational flexibility, such as fast dark count rejection. The receiver can operate either using the internal clock, or with an external clock.

Specifications

Specifications are at array temperature of -30°C and package ambient temperature of 22°C

All values are typical

5x5 DAPD Array 1550 LiDAR Receiver 100 µm Pitch

Parameter	Value	Unit
DAPD 5x5 Array		
Active area dimensions	500 by 500	μm^2
Active area single channel	90 by 90	μm^2
Number of pixels (channels)	25	-
Pixel (Channel) pitch	100	µm
Single-Photon Detection Efficiency @1550nm (PDE)[1]	15 (Typical)	%
Spectral response range (λ)	950 – 1650	nm
Minimum Dark Event Rate (single channel, with highest threshold setting; Single-photon detection)	12	kHz
Maximum Dark Event Rate (single channel, with lowest threshold setting; Single-photon detection)	10	MHz
Linearity range per pulse	1200	Photons/pulse
ASIC		
Time to Digital Converter (TDC): Binning Resolution	 30 20	 ps ps
Charge to Digital Converter (QDC) Binning QDC Range	 3.6 400	 pC Least Significant Bit
Dynamic Range per pulse	1 to 93,750	Photons/pulse

Event digitization clock frequency	200	MHz
Data transmission Output link rate Max event rate	 3200 40	 Mbit/s Mevents/s
Module		
Power supply Voltage Max current	 12 4	 V A
Ambient Temperature Max Min	 65 -55	 °C °C
Gigabit Ethernet Data link Maximum Speed	 1.0	 Gb/s

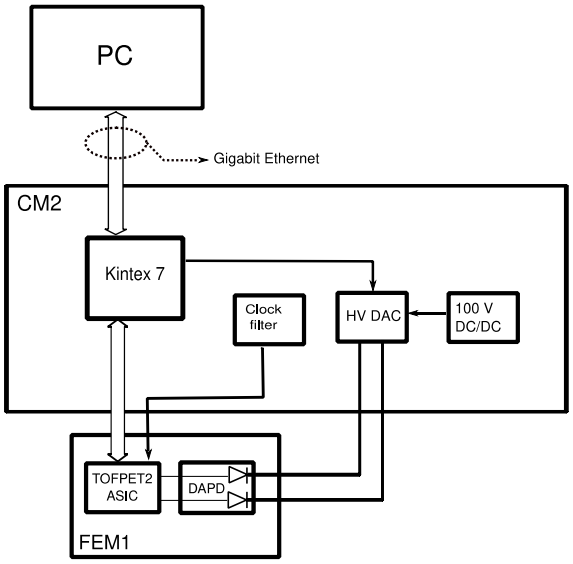
(1) Photon detection efficiency includes afterpulsing

Absolute Maximum Rating(1)

Parameter	Value	Unit
Input light energy damage threshold	0.5	nJ
ESD (Array in PCB)	2	kV
Operating Temperature	-55 to 65	°C

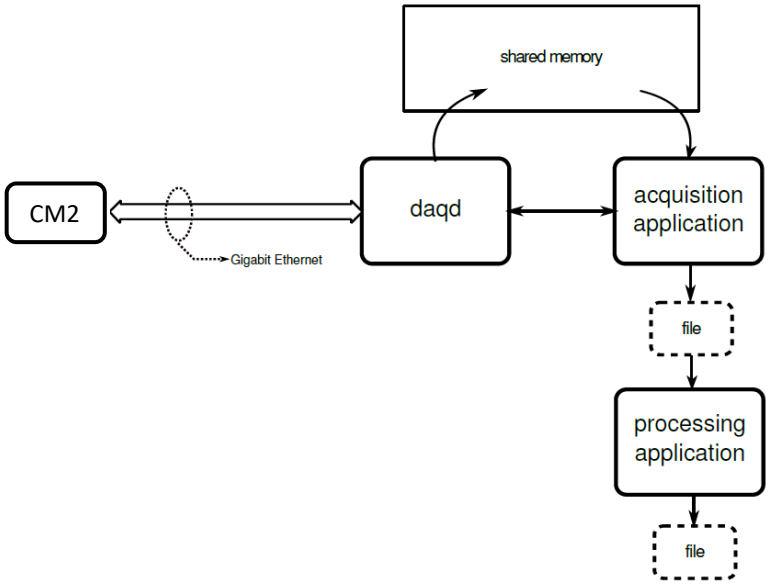
(1) Functional operation of the device in Absolute Maximum Rating conditions or any conditions outside those specified in is not implied

Electronic Connection Block Diagram



Additional details are found in the document “1550nm Digital 5x5 DAPD Array Time-of-Flight Receiver Module Hardware User Guide”

Software Architecture Diagram



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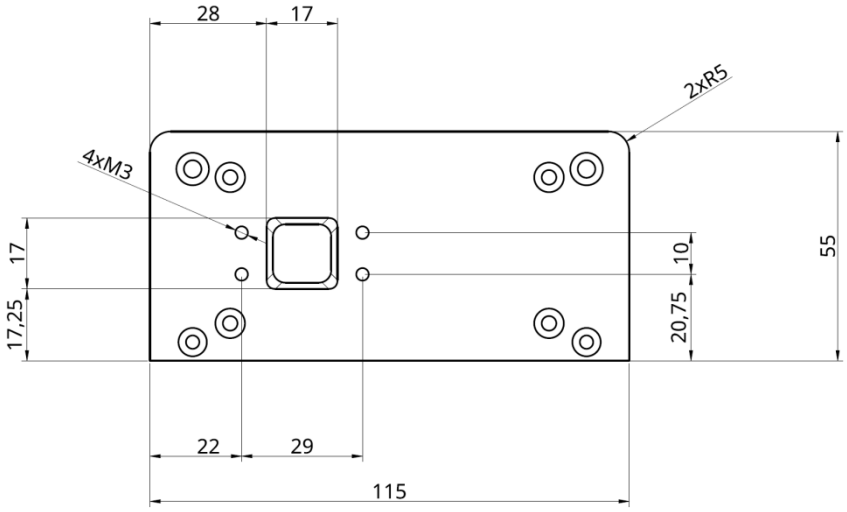
Hardware Description and Dimensions

FEM1 Module

Photo of a FEM1 module Front and Rear (Left: Front; Right: rear)



Dimentions of the FEM1 Module (mm)

Notes:

1. Dimensions are in [mm].
2. Four drilled 4mm holes with centers forming a 29.0mm x 10.0mm rectangle allow for optical lens attachment. The holes are threaded with M3 thread, and supplied with hex socket M3 screws.

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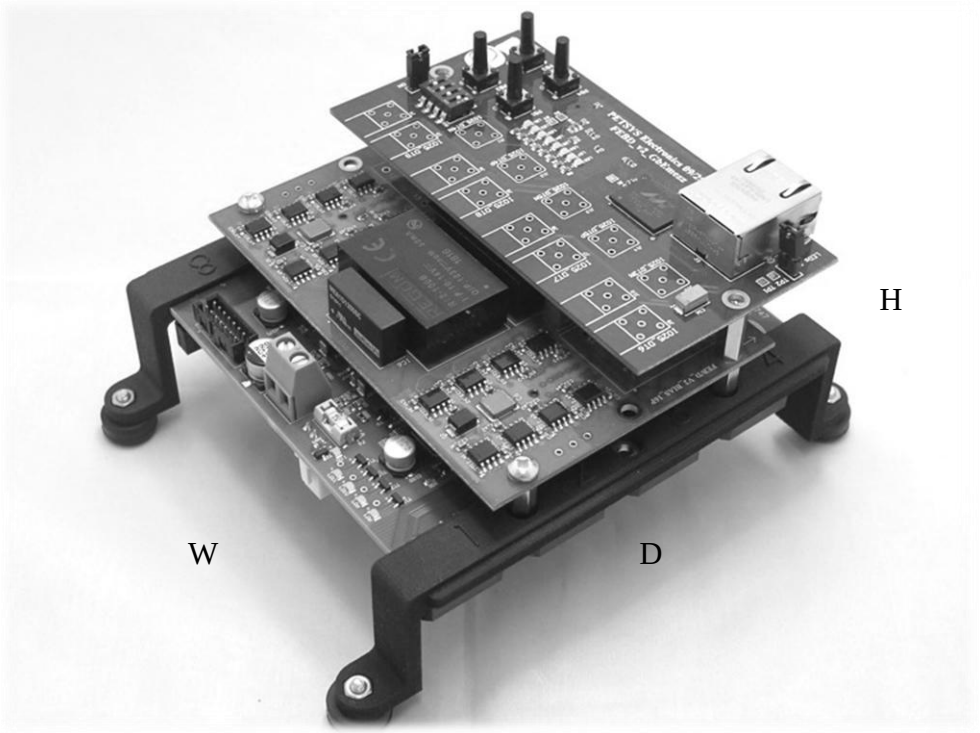
CM2 Module



Dimensions:

Height, including rubber pieces and support legs: 76 mm
Width: 112 mm
Depth: 140 mm

Notes:

1. The dimensions of the footprint without the legs, e.g. the bottom PCB layer, is 104.5 x 104.5 mm and the height is 64 mm
2. The support rubber pieces are shown in the photograph
3. Not visible in the photograph or the drawing is a cooling fan at the bottom of the CM2 Module

FEB1 and CM2 Combination Including Cables

Notes:

Shown are:

1. The FEM1 module is on the Right (front facing; showing the 5x5 DAPD array)
2. The communication flexible cable
3. The CM2 module on the left

Not Shown:

1. The 12V supply power cables (red + black); connects between the CM2 and the FEM1

Channel-ID Matching to Physical Array Location

The physical location of each active receiver channel is indicated in the 5x5 matrix below. The view shown is Front-View.

1,5	2,5	3,5	4,5	5,5
1,4	2,4	3,4	4,4	5,4
1,3	2,3	3,3	4,3	5,3
1,2	2,2	3,2	4,2	5,2
1,1	2,1	3,1	4,1	5,1

The ASIC Channel number associated with the sensor- pixel physical location is indicated in the 5x5 matrix below.

44	27	52	56	60
40	49	58	42	50
31	33	54	28	37
25	2	12	0	15
17	4	7	10	20

The channel number map is shown as Front-View.

Precautions for Use

The device is ESD sensitive. The use of grounding straps, anti-static mats and other standard electrostatic discharge protective equipment and methods are mandatory when handling or testing these devices.

Operating the modules without a proper heat sink can cause overflow of current and irreversible damage to the detector array and the TEC.

Quality Vision

Amplification Technologies is committed to providing products with the highest levels of quality and reliability using best available manufacturing processes. Our top priority is total customer satisfaction. Amplification Technologies maintains a strict quality control program to ensure that all products meet or surpass published specifications. Amplification Technologies guaranty its products and will offer free replacement of parts that have failed, provided the maximum operations rating haven't been exceeded and electro-static discharge procedures have been kept.

Supporting Documents

In addition to this datasheet the following manuals are referenced:

1. 1550nm Digital 5x5 DAPD Array Time-of-Flight Receiver Module – Hardware User Guide
2. 1550nm Digital 5x5 DAPD Array Time-of-Flight Receiver Module – Software User Guide
3. 5x5 DAPD Array (stand-alone) datasheet
4. TOFPET2 Datasheet

Ordering Information

When ordering, please specify the following part number information:
5x5-DAPD-Array-1550-100-RX

Contact Information

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