Trends in the design of microcircuits for front-end electronics (overview)

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The aim of the paper is to reveal the existing trends in the implementation of microelectronic units, collecting and processing the signals of multichannel radiation detectors in large-scale physical experiments.

The comparison of present-day microelectronic products of the above mentioned destination is carried out by their most important parameters, particularly:

number of channels N_{ch},

power consumption per channel P_{con},

input noise charge Q_n and

charge-to-voltage conversion factor K_{con}.

The technology of manufacture is also paid attention.

Table. Characteristics of Front-end Electronics ICs

Source	Name of ASIC. Purpose and/or name of Project.	N_{ch}	Technology	Q_n	$К_{con}$	P_{con}
[1]	SAS. STAR	16	CMOS, 1.2 mcm	600e +13e/pF, tp=180 ns	16 mV/fC	60 mW
[2]	ASIC for PMT Hamamatsu H8500. In a facility for ion therapy	16	BiCMOS, 0.35mcm	4fC	-	11 mW
[3]	FSDR16. CBM STS.	16	UMC	214e + 13.3e/pF, tp=99 ns	91 mV/fC	10 mW
[4]	ASIC for the LAr TOF chamber. MicroBooNE	16	CMOS, 180nm	1200e at 293K, 550e at 77K,	4.7…25 mV/fC	6 mW
[5]	ADAM. LHC	32	CMOS	800e +80e/pF, tp= 8 ns	10 mV/fC	-
[6]	APV3. CMS	32	CMOS, 1.2mcm HARRIS,	480e +43e/pF	–	2 mW
[7]	SCT32A(B); silicon strip detector	32	BiCMOS, radiation-hard DMILL	620e+33e/pF	100 mV/fC	–
[8]	ICECAL. calorimeter LHCb, up-dating	32	SiGe BiCMOS, 0.35mcm, AMS	1nV/√Hz	-	-

Source	Name of ASIC. Purpose and/or name of Project.	N_{ch}	Technology	Q_n	K_{con}	P_{con}
[9]	SPADIC 1.0 for TRD. RICH	32	CMOS, 180 nm UMC,	387e + 11e/pF	-	3.8 mW
[10]	SAMPA. Time-of-flight chamber	32	CMOS, 130 nm TSMC Esup. 1.25V	536e, tp=80 ns	20 mV/fC	8 mW
[10]	ASIC SAMPA**.** Muon tracking chamber	32	CMOS, 130 nm TSMC E=1.25V	950e, Cd=40pF 1600e, Cd=80pF	4 mV/fC	8 mW
[11]	FABRIC. NA50 silicon detector	64	Bipolar Tektronix	476e +63e/pF, tp= 15 ns	100 mV/fC	1.3 mW
[12]	MICROROC. Digital hadron calorimeter	64	SiGe BiCMOS, 0.35mcm, AMS	0.24fC, Cd = 80pF	2,38 mV/fC	3.7 mW
[13]	SPACIROC. EUSO-Balloon experiment,	64	SiGe BiCMOS, 0.35mcm	100% registration of charges >50 fC	Кgain $=10^6$.	1 mW
[14]	VMM1. ATLAS small “wheel”	64	CMOS, 130 nm, radiation hard IBM,	5000 e, Cd=200pF	9 mV/fC	-
[15]	APVD. CMS silicon tracker	128	CMOS, DMILL	450e+49e/pF, tp=50 ns	108 mV/MIP	1 mW
[16]	ALICE128C. ALICE silicon detector	128	CMOS, 1.2 mcm, AMS	400e, tp = (1.4…1.8) us	50 mV/MIP	0.34 mW

[17]	SCT128B. HERA-B silicon detector	128	BiCMOS, radiation hard DMILL	559e+35e/pF	107 mV/fC	–
[18]	APV25. CMS tracking system	128	CMOS, 0.25 mcm, Harris Semic. DMILL	430e+61e/pF, tp= 25ns	–	2 mW
[19]	HELIX128. HERA-B silicon tracker	128	CMOS, 1.2 mcm	405e+76e/pF, tp=50нс	63 mV/MIP	2 mW
[20]	HELIX128S-2.1. HERA-B	128	CMOS, 0.8 mcm, AMS	33.6 e/pF, tp=(45…100) ns	45 mV/MIP	–
[21]	CAFÉ. LHC silicon tracker	128	Complementary bipolar AT&T	550e +33e/pF, tp=25ns	–	1.8 mW
[22]	ASIC for the CBM tracking system	128	CMOS, 180 nm, UMC (Taiwan)	2000e, Cd<30pF	50 mV/fC	2 mW
[23]	Binary architecture CMS. SLHC	128	CMOS, 0.13 mcm	500e+64 e/pF, tp = 20 ns		50 mW E=1,2V
[24]	CBC2. CMS microstrip tracker	128	CMOS, 130 nm, IBM	800e	40 mV/fC	0,3 mW
[25]	Pasta – Front-end electronics ASIC. PANDA	128	CMOS, 130 nm	600e	-	1 mW

Conclusion

1. The main way of improving the electrical and mass-dimensional characteristics of front-end electronics (FEE) units is their implementation in the form of multichannel ASICs.

2. Typical values of the basic parameters of present-day FEE ICs are as follows: P_{con} – units of mW per channel, Q_n – hundreds of electrons, K_{con} – tens of mV/fC.

3. The FEE ICs are most often found with the following numbers of channels: 16, 32, 64 and 128. Present-day technologies allow the manufacturer to create ICs with a greater number of channels, but, from the practical viewpoint (considering particularly the placement of ICs on a PCB, whereon the IC inputs should be connected to detector outputs), those greater numbers may not appear expedient.

4. Among the possible technologies the FEE ASIC designers prefer the one of CMOS, that allows them to minimize power consumption, cost and chip area in a much simpler way.

5. If quite recently the FEE equipment contained only analog electronics, nowadays a distinct trend is well observed to include in it some digital processing units.

6. Radiation hardness, that a long time was demanded predominantly for space-intended equipment, nowadays is more and more often requested for stationary equipment, especially when the latter is placed near the “beam zone” of accelerator.

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