Technical Report on
Multi-TAC NIM module

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Developed by:

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TECHNICAL REPORT

TITLE : **Technical Report on Multi-TAC NIM module**

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CATEGORY : Instrumentation (Nuclear Electronics)

REFerence : ***IUAC/TR/SV/2018-19/__***

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Technical Report on
Multi-TAC NIM module

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Abstract: A 3 channel, single width Time to Amplitude Converter (TAC) NIM module has been successfully developed and limited mass produced for general purpose applications. The module also supports with additional channel of logic Gate & Delay (GDG) generator for delaying the START/STOP signal of TAC unit. The module can be used to convert time difference of 100 ns to 5000 nS to a corresponding 0-10V linear (wagon type) analog output of varying durations.

Asset creation with no: ***IUAC/10A/76/1, 2***

Title: **Multi-TAC NIM module**

Budget head: IA.9.25, HYRA

Specifications

Multi - Time to Amplitude Converter (TAC) NIM module

Number of Channels	:	3
Form factor	:	Single width NIM cabinet
Input DC supply	:	+/-6(0.2A/1.5A), +/-12V(+/-0.2A), -24V(0.1A)
Connectors	:	Lemo-00 type (F)
Terminations (forward & reverse)	:	51 ohms
Time to Amplitude Converter		
Input Logic signals	:	Fast NIM logic (-16mA / 50 ohms)
		START, STOP inputs with < 50nS duration
Output signal	:	Positive Linear (wagon type) output 0-10V, reverse terminated
TAC Type	:	Hybrid micro chip BMC1522 of M/s.BEL make
Range	:	100 nS, 200 nS & 300 nS
		Jumper selected internal / 3 way switch, Panel selected
Multiplier	:	x5, x10 & x15 times of above range
		Jumper selected internal / 3 way switch- Panel selected
Delay / Dead time selection	:	2.5uS or 8uS
		2 way switch - Panel selected
Indicator	:	LED (5mS) blink indicates presence of STOP signal
Gate & Delay Generator		
Input & Output	:	Fast NIM logic (-16mA / 50 ohms) signals
		with <50nS duration
Delay control	:	50nS to 2000ns in two ranges (jumper selected)
Width control	:	75ns to 500nS (PCB adjustable)
Performances[#]:		
Resolution	:	<700pS or <0.7% in 100nS range
Stability	:	<40ps or <0.04% in 100nS range
Linearity	:	<0.1% from 25% to 90% of full scale in 100nS range
Start-Stop conversion time	:	<5nS to 5000nS

 # : Refer to the attched observations sheets

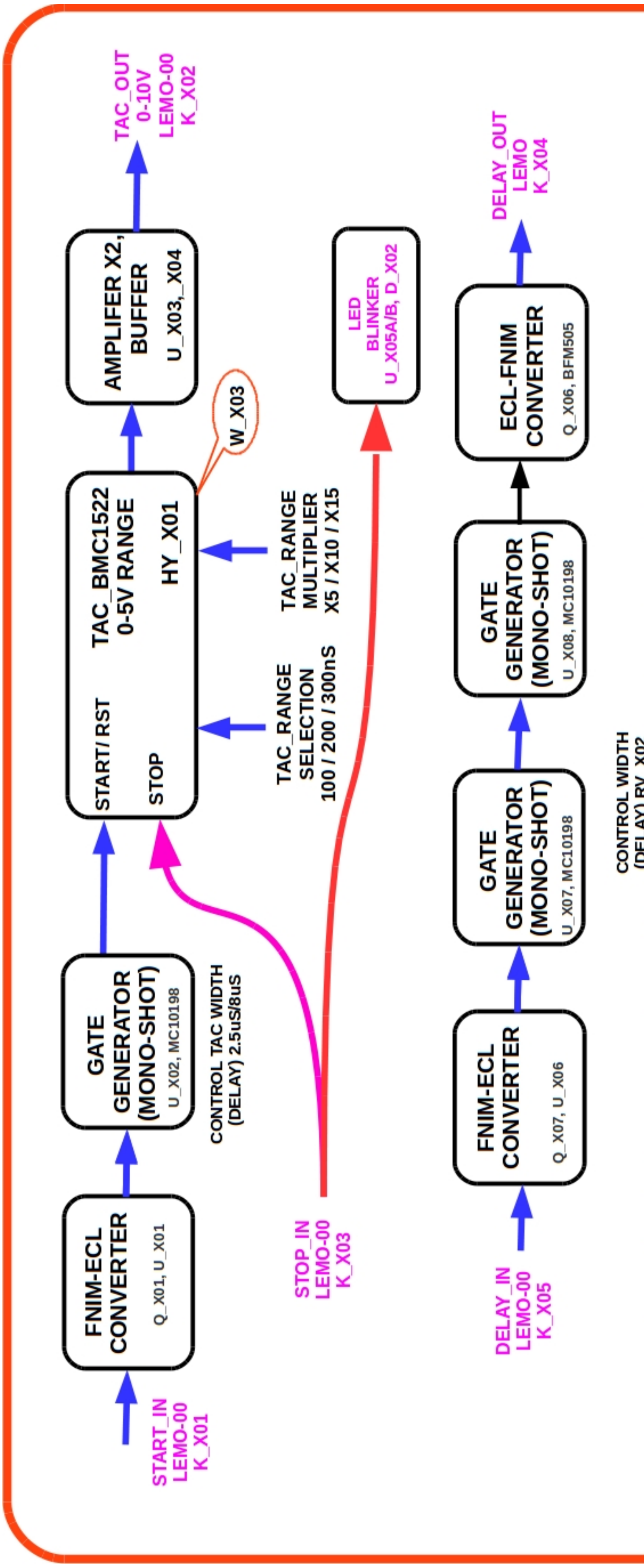

Fig: Block diagram of Multi-Channel TAC (NIM) module TAC_2017 PT:2

Descriptions

The single width NIM module contains three independent channels of TAC circuitry as shown in the block diagram. All input and output signals, controls, monitoring test points are provided on the neatly labeled front panel. All the channels are supplied with required DC power from rear panel NIM connector through PI type LC filter. The built-in power supply regulator circuits generate -2V supply, -1.1V (VBB) for ECL termination and biasing applications respectively. Simple potential divider from stable supply lines are used along with operational amplifiers MC1458 (U4, U5) and emitter followers (Q501, 502) to generate these supply lines. Heavily filtered three pin negative regulators (LM337) are used to generate -5V and -12V for control applications, where -5V line is used to set the pulse duration in MC10198 (UX02, XX07, UX08) and -12V line is used to preset the charging current in TAC.

The entire circuit is fabricated on a 4 layer, FR4, 1.6mm thick PCB. State of the art, ultrafast 100EL series emitter coupled logic (ECL) chips are used for level converting F/NIM signal into ECL signals. Standard ECL termination techniques and differential line are routed to preserve the bandwidth. Ultra wide band transistor (BFM505,115) pair is used in ECL-F/NIM (Fast NIM) conversion circuit to retain the bandwidth of the signal. Monostable multivibrator 74LS123 is used for generating LED blinking signal in order to indicate the presence of TAC-STOP signal.

Monostable multivibrator MC10198N is used to generate ECL logic signals of suitable width to START/RESET the TAC hybrid chip BMC1522. The TAC is started on the falling edge of the START/RESET signal. When there is no corresponding STOP signal within selected time range to stop the TAC, the START/RESET signal itself resets in its rising edge, with maximum signal (~9V) at the output. The duration of START/RESET signal is selectable between 2.5uS (SHORT) and 8uS (LONG). The duration is set wide in order to align all other signals and generate corresponding ADC gate signal in a complex experimental setup. The TAC chip is fed with user selected programming current (MULTIPLIER), while fixed value silver mica capacitors are used for TAC range selection 100nS/200nS/300nS. These are selected by front panel ON-OFF-ON toggle switches. The TAC conversion range is 100nS to 5000nS corresponding to 0-5V at the output of hybrid chip BMC1522. The TAC output is boosted to 0-10V with a composite amplifier consisting operational amplifier LM6171 and buffer amplifier BUF634. Typical TAC output signals at different TAC durations are shown in the following figures.

The standard assembly procedure of SMD is adopted for assembling the components. The module is checked for DC power lines and expected variations from various potentiometers on the PCB and panel etc,. Any variations, oscillations were suppressed with suitable filtering in fully loaded conditions. The TAC is initially warmed up for 3 hours and test bench measurements were carried with fast pulser, CFD modules, GDG, and CRO to generate suitable START and STOP signals. The traces and corresponding values are recorded and tabulated. The same is reproduced in various figures, tables.

For any feedback, alterations in the timing and TAC range, the corresponding author shall be contacted.

References:

1. Data sheet Hybrid microcircuit BMC1522, Time to Amplitude converter, M/s.BEL, Bangalore.

2. Development of Time to Amplitude Converter (TAC) Hybrid, V.B.Chandratre et al, Electronics division, BARC, Mumbai. Proceedings of NSNI-2004, Page: 277.

3. Technical report on Time to Amplitude Converter for Neutron Array at IUAC, S.Venkataramanan et al, IUAC/TR/SV/2006-2007/____.

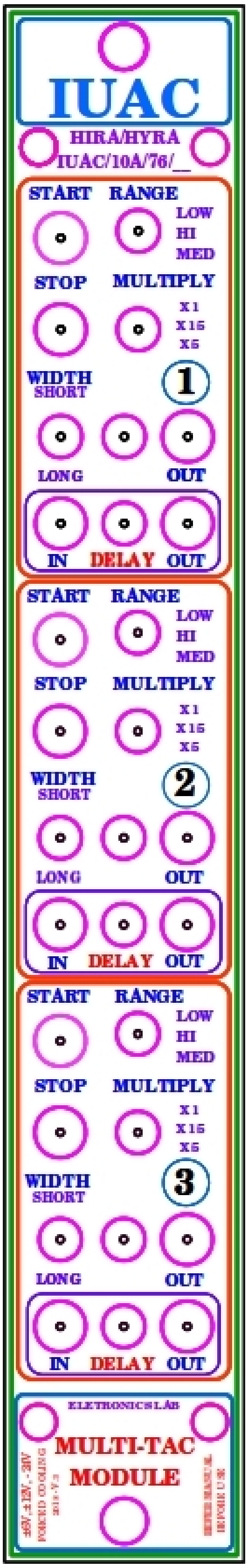

Fig:2 Front panel Label details

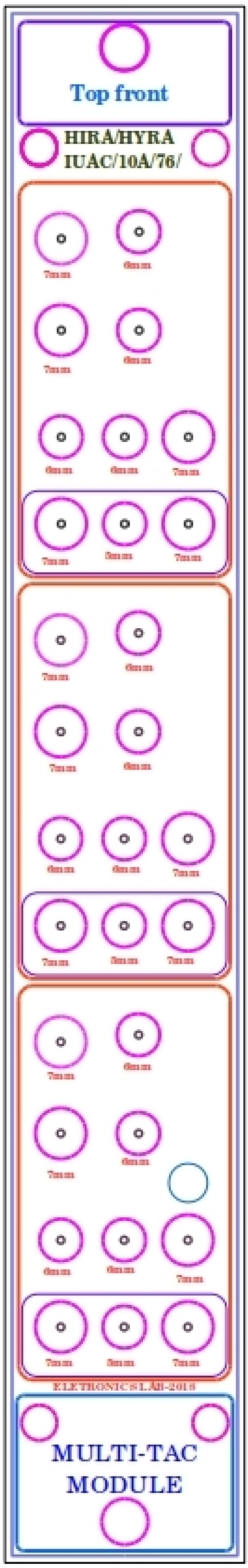

Fig:3 Front panel drill details

Table:1 Bill of material for 3 channel TAC module

Id	Designator	Package	Qty	Designation
1	U307,U202,U207,U208,U302,U306,U402,U407,U408	DIP-16_W7.62mm	9	MC10198N
2	SW401,SW201,SW203,SW301,SW303,SW403	Pin_Header_Straight_1x03	6	SWITCH_ON-OFF-ON
3	R215,R315,R415	SM_R_0805	3	10K
4	C201,C209,C216,C218,C220,C222,C224,C226,C227,C228,C229,C230,C232,C234,C236,C301,C309,C316,C318,C320,C322,C324,C326,C327,C328,C329,C330,C332,C334,C336,C401,C409,C416,C418,C420,C422,C424,C426,C427,C428,C429,C430,C432,C434,C436,C504,C506,C507,C509,C512,C514,C516,C518,C519,C521,C523,C524,C526,C528,C529,C531,C532,C534	MYSM_C_0805	63	0.1u
5	C202,C302,C402	MYSM_C_0805	3	10pF
6	C203,C207,C210,C211,C212,C214,C215,C239,C240,C241,C244,C246,C303,C307,C310,C311,C312,C314,C315,C339,C340,C341,C344,C346,C403,C407,C410,C411,C412,C414,C415,C439,C440,C441,C444,C446	MYSM_C_0805	36	10nF
7	C204,C238,C304,C338,C404,C438	MYSM_C_0805	6	1nF
8	C205,C305,C405	Dipmica_CD10E	3	75pF/SM
9	C206,C306,C406	Dipmica_CD10E	3	100pF/SM
10	C208,C308,C408	Dipmica_CD10E	3	200pF/SM
11	C213,C219,C221,C223,C225,C231,C233,C235,C237,C313,C319,C321,C323,C325,C331,C333,C335,C337,C413,C419,C421,C423,C425,C431,C433,C435,C437	MY_TAN_B	27	3u3/B
12	C217,C317,C417	MY_TAN_B	3	3U3/B
13	C242,C243,C245,C342,C343,C345,C442,C443,C445	MYSM_C_0805	9	47pF
14	C501,C502	MYSM_C_0805	2	1uF
15	C503,C505,C511,C513,C515,C517,C520,C522	TantalC_SizeD_EIA-7343_Reflow	8	10uF/C
16	C508,C510,C530,C533	MY_TAN_B	4	3.3uF/B
17	C525,C527	C_Radial_D7.5_L11.2_P2.5	2	10uF/TH
18	D201,D205,D206,D301,D305,D306,D401,D405,D406,D204,D304,D404	SOT-23	12	BAV99
19	D202,D302,D402,D501	1n4007_melf	4	1N4007
20	D203,D303,D403	Pin_Header_Straight_1x02	3	LED
21	FI201,FI202,FI301,FI302,FI401,FI402	EMI_FilteR_NFM61R	6	EMI_FILTER
22	HY201,HY301,HY401	BMC1522	3	BMC1522
23	JP201,JP301,JP401	Pin_Header_Straight_1x02	3	Jumper_NO_Small
24	K201,K202,K203,K204,K205,K301,K302,K303,K304,K305,K401,K402,K403,K404,K405	BNC_COAX_S	15	LEMO2
25	L501,L502,L503,L504,L505	chokeBig_2944777741	5	INDUCTOR_SMALL
26	mh501,mh502,mh503,mh504	MountingHole_3-7mm	4	MH_3.3
27	P501	Pin_Header_Angled_2x05	1	CONN_01X10
28	R201,R211,R301,R311,R401,R411	SM_R_0805	6	1
29	R202,R213,R217,R302,R313,R317,R402,R413,R417,R506,R507,R509,R512,R514	SM_R_0805	14	1K
30	R203,R222,R250,R303,R322,R350,R403,R422,R450	SM_R_0805	9	3K3
31	R204,R214,R304,R314,R404,R414	SM_R_0805	6	15K

32	R205,R206,R209,R210,R219,R227,R229,R234,R235,R238,R239,R242,R243,R247,R305,R306,R309,R310,R319,R327,R329,R334,R335,R338,R339,R342,R343,R347,R405,R406,R409,R410,R419,R427,R429,R434,R435,R438,R439,R442,R443,R447	SM_R_0805	42	110
33	R207,R208,R236,R237,R240,R241,R307,R308,R336,R337,R340,R341,R407,R408,R436,R437,R440,R441	SM_R_0805	18	2K
34	R212,R224,R312,R324,R412,R424,R510	SM_R_0805	7	5K6
35	R216,R218,R230,R244,R245,R246,R316,R318,R330,R344,R345,R346,R416,R418,R430,R444,R445,R446	SM_R_0805	18	51
36	R220,R320,R420	SM_R_0805	3	475
37	R221,R321,R421	SM_R_0805	3	??
38	R223,R323,R423,R503,R511	SM_R_0805	5	1K6
39	R226,R326,R426	SM_R_0805	3	220K
40	R228,R328,R428	SM_R_0805	3	4K7
41	R248,R348,R448,R502	SM_R_0805	4	220
42	R249,R349,R449	SM_R_0805	3	100
43	R501	SM_R_0805	1	180
44	R504	SM_R_0805	1	680
45	R505	SM_R_0805	1	1K5
46	R508,R513	SM_R_0805	2	5K1
47	RV201,RV301,RV401	Potentiometer_Bourns_3296W_3-8Zoll_Inline_ScrewUp	3	5K
48	RV202,RV302,RV402	Potentiometer_Bourns_3296W_3-8Zoll_Inline_ScrewUp	3	2K
49	SW202,SW302,SW402	Pin_Header_Straight_1x03	3	SWITCH_INV
50	U201,U206,U301,U305,U401,U406	TSSOP-8_3x3mm_Pitch0.65mm	6	MC100EL16
51	U203,U303,U403	SOIC-8_3.9x4.9mm_Pitch1.27mm	3	LM6171
52	U204,U304,U404	SOIC-8_3.9x4.9mm_Pitch1.27mm	3	BUF634
53	U205,U405	SOIC-16_3.9x9.9mm_Pitch1.27mm	2	74LS123N
54	U501,U502	SOT-223	2	LM337EXT
55	U503	SOIC-8_3.9x4.9mm_Pitch1.27mm	1	MC1458
56	W201,W202,W301,W302,W401,W402	tp_j	6	TP
57	W501	tp_1.4TH	1	GND1
58	W502	tp_1.4TH	1	GND2
59	W503	tp_j	1	M12V_PI
60	W504	tp_j	1	PWC
61	W505	tp_1.4TH	1	P12V
62	W506	tp_1.4TH	1	M12V
63	W507	tp_1.4TH	1	P6V
64	W508	tp_1.4TH	1	M6V
65	W509	tp_1.4TH	1	M24V

66	Q201,Q202,Q204,Q301,Q302,Q304,Q401,Q402,Q404	SOT-23	9	BFR92
67	Q501	TO-220_Neutral123_Vertical_LargePads	1	BD140
68	R225,R231,R232,R233,R325,R331,R332,R333,R425,R431,R432,R433	SM_R_0805	12	0
69	Q502	TO-92_Inline_Wide	1	2n3906
70	Q403,Q303,Q203	SOT-363	3	BFM505
71	NIM 1 WIDE		1	
72	CONNECTOR NIM POWER		1	
73	PCB	ML-4 VERSION:3/3	1	
74	COAXIAL CABLE	RG-196		
	TRIM AS PER REQUIREMENT	160MM	3	
		170MM	3	
		80MM	3	
		100MM	3	
		220MM	3	
75	3 CORE PTFE flat white	2M	1	

Measured observations

Module linearity performance was compared with Ortec 566 TAC using Ortec Time calibrator 462 for identical ranges. We have used “xmgrace” to generate linearity plots (Fig.1 - 4) and observed the reduced chi square values in the range from 2.12 to 5.69.

The module was subjected to live test with NAND type detector (STOP) and BaF_2 type detector (START) with Co-60 radiation source to study the performance of this module for long duration (54 hours). The performance was compared with commercial TAC module [EG&G model 566]. For detailed data please refer Table 2.

Calibrations: MCA of 4k type, TAC range: 100nS (0-10V full scale), 1channel=24.414pS or 1ns=40.96channels

Typical observations made are

IUAC/10A/76/2	Resolution	Centroid shift		Remarks
	FWHM (pS)	Channel variance	Time variance (pS)	Measured TAC range
Channel-1	666.91	± 1.205	±37.33	126.9
Channel-2	636.48	± 0.96	± 31.28	133.44
Channel-3	638.13	±0.18	± 5.58	130.67
TAC-566	682.48	± 0.41	± 10.01	100.02

Later we adjusted charging current resistors to match IUAC TAC range with the Ortec 566 TAC as close as possible. Measured ranges for two modules (IUAC/10A/76/1-2) are as shown in Table 3. Now range variation among all the channels in a module is <+/-3.5%.

FIG 1: Linearity comparison of IUAC TAC with ORTEC 566 TAC for 500nS

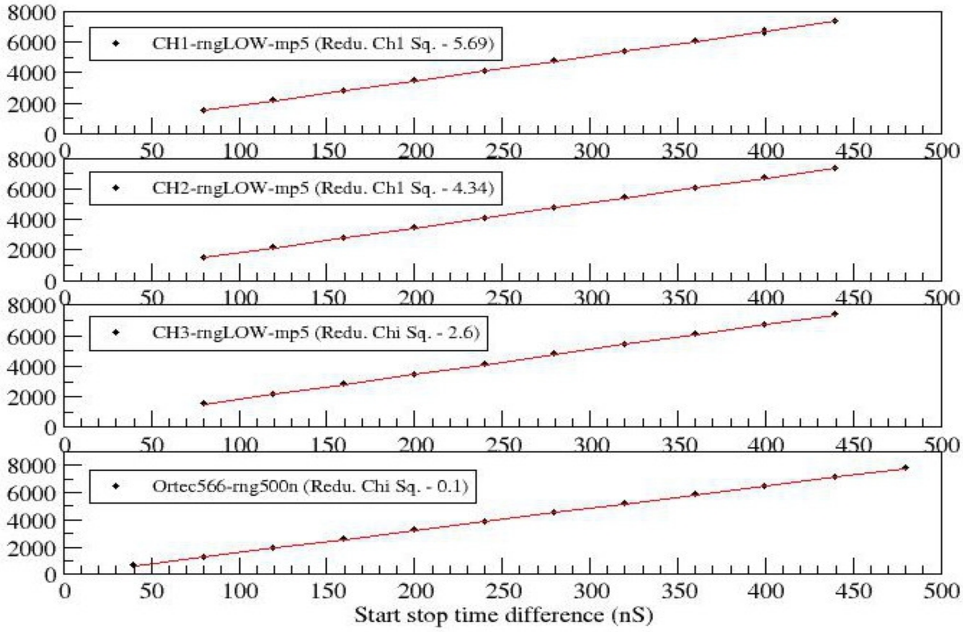

FIG 2: Linearity comparison of IUAC TAC with ORTEC 566 TAC for 1000nS

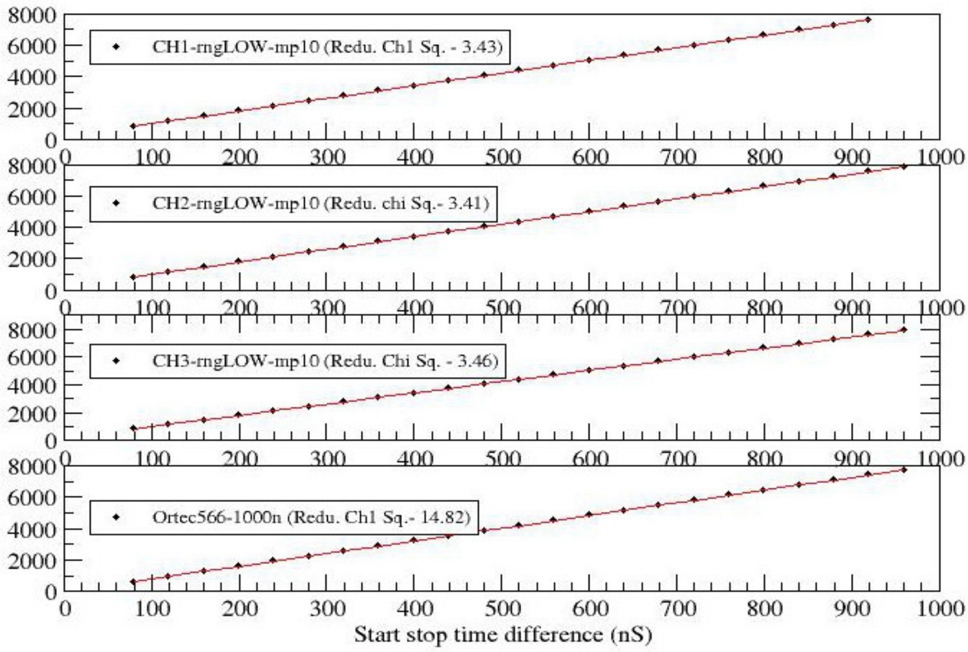

Fig 3: Linearity comparison of IUAC TAC with ORTEC 566 TAC for 2000nS

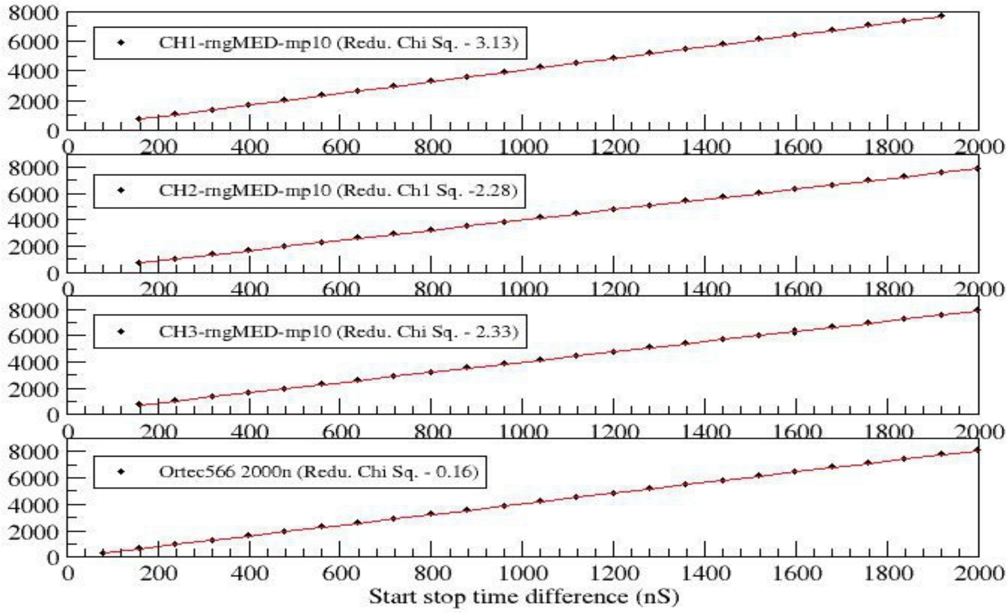

Fig 4: Linearity comparison of IUAC TAC (5000nS) with ORTEC 566 TAC for 5000nS

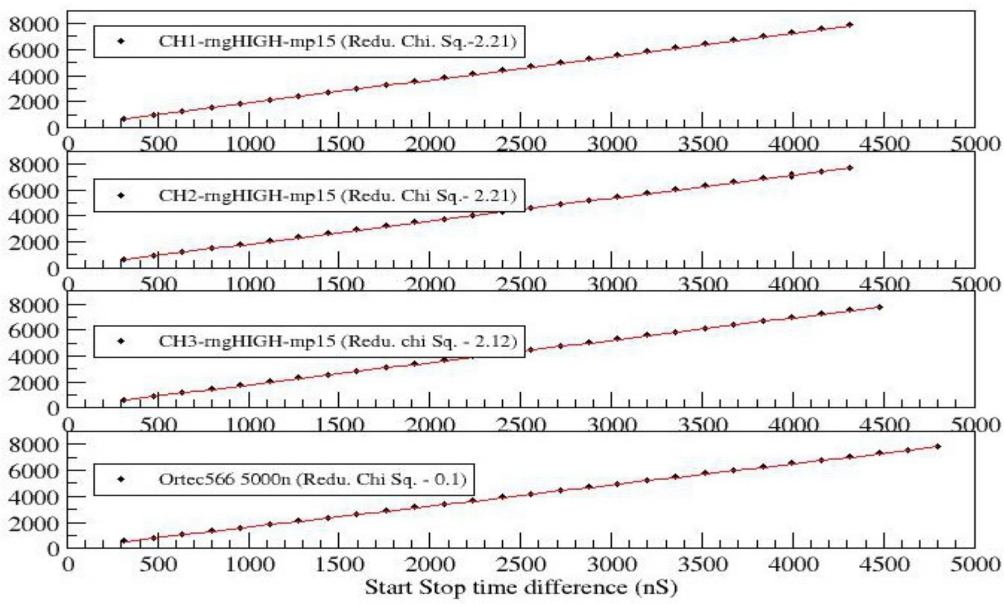

Table:2 Resolution and stability observations and comparison

Ortec 566 and IUAC TAC (10A/76/2) list mode test data (Start: BaF2: Stop: BC501 scintillation detector; ^{60}Co)

Centroid and FWHM noted from list mode data started on 2nd Nov'2018 18:40hrs and continued for nearly 54 hours. Each file was saved after nearly 5 hrs.

TAC	Centroid (ch) from List mode files											Av. Cent. variation (ch)	Meas. TAC Range (nS)	1 channel equi. in time (pS)	Centroid variation (ch)	Centroid variation (pS)	Centroid variation (± pS)
	3	4	5	6	7	8	9	10	11	12	13						
IUAC/Ch1	**1433.500**	1432.720	1432.310	1432.230	1431.950	1432.090	1431.890	1431.980	1431.370	1431.210	1431.97	1312.77	138.428	33.8	2.410	81.448	40.72
IUAC/Ch2	1362.990	**1363.090**	1362.060	1362.820	1361.510	1361.520	1361.350	1361.410	1361.420	1361.270	1361.4	1248.4	145.565	35.54	1.920	68.233	34.12
IUAC/Ch3	1390.800	**1390.910**	1390.760	1390.750	1390.560	1390.720	1390.630	1390.710	1390.750	1390.570	1390.72	1274.82	142.548	34.8	0.350	12.181	6.09
566 TAC	1816.420	1816.510	1816.560	1816.640	1816.770	1816.890	1817.020	1817.030	1816.930	1816.980	1817.02	1665.4	109.117	26.64	0.820	21.845	10.922

TAC	FWHM (ch) from List mode files											1 ch equi. in time (pS)	Resolution (pS)
	3	4	5	6	7	8	9	10	11	12	13		
IUAC/Ch1	**21.526**	21.187	21.306	21.445	21.329	21.337	21.282	21.295	21.422	21.441	21.069	30.980	666.875
IUAC/Ch2	19.355	19.313	19.401	**19.537**	19.387	19.351	19.343	19.428	19.482	19.494	19.169	32.580	636.515
IUAC/Ch3	19.739	19.746	19.834	19.886	19.811	19.857	19.728	**20.003**	19.848	19.941	19.884	31.900	638.096
566 TAC	**27.209**	27.409	27.318	27.337	27.182	27.230	27.085	27.235	27.953	**27.948**	27.877	24.420	682.490

Table 3: IUAC TAC Ranges (nS) measured using Ortec Time calibrator module 462

Module#1 (IUAC/10A/76/1)

RANGE: LOW			
	X5	X10	X15
CH1	505.68	1024	1517.04
CH2	505.68	1020.81	1517.04
CH3	501.04	1002.08	1482.71
RANGE: MED			
	X5	X10	X15
CH1	1033.69	2100.51	3120.76
CH2	1024	2073.92	3091.32
CH3	1030.44	2073.92	3034.07
RANGE: HIGH			
	X5	X10	X15
CH1	1583	3212.55	4818.82
CH2	1524.09	3091.32	4551.11
CH3	1524.09	3062.43	4488.77

Module#2 (IUAC/10A/76/2)

RANGE: LOW			
	X5	X10	X15
CH1	507.64	1017.07	1481.7
CH2	505.21	1024.14	1505.15
CH3	503.5	1019.57	1493.65
RANGE: MED			
	X5	X10	X15
CH1	1031.15	2080.51	3030.36
CH2	1042.84	2108.4	3100.35
CH3	1042.12	2109.53	3089.61
RANGE: HIGH			
	X5	X10	X15
CH1	1537.73	3103.81	4558.07
CH2	1544.29	3122.95	4637.42
CH3	1591.89	3227.05	4768.92

Table 4: IUAC TAC Range current programming resistor values (for trimming during production)

S. No.	Module No.	Ch. No.	**Resistor values to set TAC range**					
			Multiplier x5		**Multiplier x10**		**Multiplier x15**	
1	IUAC/10A/76/1	1	R409 = 1.5k//15k	R410 = 3.32k	R407 = 1.5k//15k	R408 = 22k//100k	R412 = 1.21k//150k	R413 = 10k
		2	R509 = 1.3k	R510 = 3.32k	R507 = 1k//22k	R508 = 22k//100k	R512 = 1k//47.5k	R513 = 10k
		3	R609 = 1.21k//10k	R610 = 3.32k	R607 = 68//1k	R608 = 22k//82.5k	R612 = 1k	R613 = 8.25k
2	IUAC/10A/76/2	1	R409 = 1.3k//220k	R410 = 3.32k	R407 = 4.75k	R408 = 15k	R412 = 750//150k	R413 = 10k
		2	R509 = 1.3k//220k	R510 = 3.32k	R507 = 1.62k//15k	R508 = 22k//100k	R512 = 1.21k//4.75k	R513 = 10k
		3	R609 = 1.3k//6.8k	R610 = 3.32k	R607 = 1.21k//1.21k	R608 = 22k//100k	R612 = 680//680	R613 = 10k

Fig:4 TAC output traces of SHORT, LONG widths