2128N

Constant Fraction Discriminator

User Manual

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Model 2128N
Constant Fraction Discriminator

FEATURES

- **100 Mhz Count Rate**
- **1000 : 1 Dynamic range**
- **Three Operating Modes: CFT, CFRR constant fraction discriminator with slow risetime reject, and LET leading edge trigger**
- **Walk < 30 ps typically for 100 : 1 Range**
- **Simultaneous Dual Positive and Negative Outputs**
- **Multicolor Count Rate Indicator**
- **DC coupling**

DESCRIPTION

The Model 2128N replaces the Model 2128. It is a fully dc-coupled constant fraction discriminator with a dynamic range of up to 1000:1. Selectable fraction and three operating modes provide optimum time resolution for many detector types and applications. For example:
CFT – Constant fraction mode for fast detectors
CFRR – Slow rise time reject mode for Ge detectors
LET – Leading edge mode for single photon counting

The unit accepts negative polarity pulses to the 50Ω terminated dc-coupled inputs. On customer request the module can be modified to accept positive input signals. The constant fraction composite signal is formed by the sum of a direct, attenuated (fraction f=0.4 standard) signal path and a delayed, unattenuated path. The delay time is selectable according to the propagation delay of a (external) 50Ω BNC cable. Careful selection of fraction and delay cable provides full compensation of timing distortions due to both amplitude and risetime variations in the input signal. Output signals are generated whenever the input signal exceeds the selected threshold set by a front panel potentiometer.

Four simultaneous, independent output signals are provided. The two positive outputs are adjustable in width, the width then determines the internal deadtime required to suppress spurious outputs due to input signal anomalies. The two negative outputs are fixed-width pulses keyed to the start of the dead time period.
The front panel ADJUST control and INSPECT output permit the user to trim the walk characteristics of the experimental setup for optimum timing resolution. A frontpanel LED indicates count rate by color change.

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SPECIFICATIONS

Inputs
Input: - accepts -5 mV to about -3.0 V linear pulses: width ≥ 1ns, Z_{in} = 50 Ohms, dc coupled; front panel BNC connector.
Delay: two front panel BNC connectors accept 50 Ohm delay cable in order to form the internal constant fraction signal.

Outputs
Inspect displays signal of zero crossing discriminator for use in trimming time walk.
Neg output two independent negative current outputs, each providing -32 mA into 50Ω, risetime < 3 ns, pulsewidth 5 ns nominal, dc coupled.
Pos output two independent positive voltage outputs, providing 2 V (minimum) into 50Ω, risetime < 10 ns, width adjustable by front panel width trimming potentiometer, which also determines the internal dead time.

Controls
Threshold Front panel 10-turn locking dial potentiometer to set acceptance threshold for input pulses (range ≈ -5 mV to -1 V).
Adjust front panel trimming potentiometer (screwdriver) to compensate walk of the internal zero crossing discriminator
Leading edge width of the leading edge signal is internally set by the trimming potentiometer on the printed board to 20 ns.
CFRR-CFT-LET Frontpanel three-position switch to select constant fraction with slow rise time reject (CFRR), basic constant fraction (CFT), or leading edge timing (LET) modes of operation.
OUTPUT WIDTH Front panel 22-turn screwdriver adjustable potentiometer to set width of slow positive output pulse, which is equal to the internal dead time of the discriminator – max setting: 1.5 micro sec.

PERFORMANCE

Dynamic range 1000 : 1

CF mode Walk ≤ ±50ps (typically ±30ps) for -30mV to -3V range with <2ns rise time.

Count rate up to 100 MHz, limited by dead time (OUTPUT WIDTH setting)

Pulse pair resolution <10 ns, or as limited by dead time.

Threshold stability better than ±0.02% / ^{0}C (± 200 ppm / ^{0}C)

Threshold linearity ± 0.25 % integral

Temperature range 0 ^{0}C to + 50 ^{0}C

Delay cable typical lengths (RG-58)
for Plastic, NaI and Si (S.B.) detectors 0.5m to 1m,
for Planar Germanium detectors 1m to 2m
for Coaxial Ge 2.0 to 4m

Typical Power requirements
Standard version
+6.0V 150mA
-6.0V 450 mA

Physical
Size single width 1/12 NIM module (3.43 x 22.13 cm; 1.35 x 8.71 inches) as per TID – 20893 (rev.)
Net weight 0.7 kg (2.0 lbs)

Options
- can be modified to accept positive pulses
- 12V Version available on request
- on request 220 V (ac) / 110V (ac) independent from a NIM bin
- Output width for negative output can be modified
- threshold setting supplied externally via rear panel connector
- signal shaping using small fractions and RC shaping by modifying f and capacitors.

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The information in this manual describes the hardware and the software as accurately as possible, but is subject to change without notice.

Table of Contents

1 Introduction 6
1.1 General description 6
1.2 Setup information 6
1.2.1 Selection of modes 6
1.2.2 Fraction 6
2 Specifications 7
2.1 Inputs 7
2.2 Outputs 7
2.3 Controls 7
2.4 Indicators 7
2.5 Performance 8
2.6 Delay cable 8
2.7 Power requirements 8
2.8 Physical 8
3 Controls, connectors and indicators 9
3.1 Front panel 9
4 Operation 10
4.1 General 10
4.2 Laboratory bench tests 10
4.2.1 Input 10
4.2.2 Operating mode 10
4.2.3 Delay cable 11
4.2.4 Walk trim 11
4.2.5 Outputs 11
5 Circuit description 12
5.1 General 12
5.2 LET mode 12
5.3 CFT and CFRR mode 12
6 Special features and options 13
6.1 Power supply 13
6.2 Input polarity 13
6.3 Output width 13
6.4 Threshold 13
6.5 Signal shaping 13
7 Diagrams 14
7.1 Circuit diagram 14
7.2 Board 15

Table of Figures

Fig. 3.1: The Front Panel..... 9
Fig. 7.1: The Circuit diagram..... 14
Fig. 7.2: The Board..... 15

1 Introduction

1.1 General description

The model 2128N is a fully dc-coupled constant fraction discriminator with a dynamic range of up to 1000:1. Selectable fraction and three operating modes provide optimum time resolution for many detector types and applications, for example

CFT constant fraction mode for fast detectors

CFRR slow rise time reject mode (e.g. germanium detectors)

LET leading edge mode for single photon counting

(more features are given in section 6)

The model **2128N** accepts negative polarity pulses to its 50Ω terminated dc-coupled input. For positive polarity input pulses see section 6.

The constant fraction composite signal is formed by the sum of a direct, attenuated (fraction f) signal path and a delayed, unattenuated path. The delay time is selectable according to the propagation delay of a (external) 50Ω BNC cable. Careful selection of fraction and delay cable provides full compensation of timing distortions due to both amplitude and rise time variations in the input signal. Output signals are generated whenever the the input signal exceeds the selected threshold set by a front panel 10 – turn dial potentiometer.

Four simultaneous, independent output signals are provided. The two positive NIM voltage outputs are adjustable in width; the width duration sets the internal dead time as required to suppress spurious outputs due to input signal anomalies. The two independent negative NIM current outputs are derived as fixed width pulses (see also section 3 and 4).

The wide dynamic range of the model 2128N permits its use in many timing applications without the need of fast pulse amplifiers.

1.2 Setup information

1.2.1 Selection of modes

Front panel mode switch

CFT	constant fraction discriminator
CFRR	constant fraction discriminator with slow rise time reject
LET	leading edge trigger

1.2.2 Fraction

The factory set fraction is f = 0.4. If a different fraction is required, the resistors R_1 and R_2 (printed board) have to be modified as follows:

$$Z_0 = 50$$
$$R_1 = Z_0 \cdot f$$
$$R_2 = Z_0 / f$$

2 Specifications

2.1 Inputs

Input

proceeds -5mV to about -3.0V linear pulses (ref. to the common mode range of ultra fast comparators),
rise time ≥ 700ps typically,
Z_{in} = 50Ω; dc-coupled front panel BNC connector;
minimum input width ≥ 1 ns,
in the LET mode the CFD 2128N accepts shorter input pulses

Delay

two BNC connectors for an external delay cable in order to form the internal constant fraction signal. For specific length see section 4.2.3.

2.2 Outputs

Inspect

displays output signal of zero crossing discriminator for use in trimming the time walk.

Neg. outputs

two independent negative current outputs, each providing -32mA into 50Ω, rise time ≈ 2 ns, pulse width ≤ 5 ns nominal (for longer pulse width capacitor C_4 has to be changed).

Pos. outputs

two independent positive voltage outputs, providing 2V into 50Ω, rise time ≈ 4 ns, width adjustable by front panel trimming potentiometer, the width then determines the internal dead time. The maximum width should not exceed 300 ns.

2.3 Controls

Threshold

front panel 10-turn locking dial potentiometer to set acceptance level for input pulses (range ≈ -5 mV to -1V)

Walk adjust

front panel trimming potentiometer (screwdriver) to compensate walk of the internal zero crossing discriminator

CFT-CFRR-LET

front panel three position switch to select basic constant fraction timing (CFT), constant fraction with slow rise time reject (CFRR) or leading edge timing (LET)

Width

front panel trimming potentiometer (screwdriver) to set the width of the positive output pulse. The width determines the internal dead time.

2.4 Indicators

Rate

LED indicates activity of the discriminator, colour of LED changes by count rate; yellow-green up to ≈ 5 kHz, orange 5 to about 10 kHz, red above 10 kHz

2.5 Performance

Dynamic range	1000:1 (regarding the linearity of the input pulses)
Walk (CFT mode)	in CFT mode for a 1 ns rise time input pulse over a 100:1 dynamic range (reference – 2.5 V) ≈ 60 ps: typically ± 30 ps
Count rate	up to 100 MHz, limited by dead time (width setting)
Pulse pair Resolution	less than 10 ns, or as limited by dead time
Threshold Stability	better than ± 0.02% / ^{0}C (± 200 ppm / ^{0}C)
Threshold Linearity	± 25 % integral
Temperature Range	0 ^{0}C to + 50 ^{0}C

2.6 Delay cable

Typical lengths

- for fast pulses ≈ 0,25 m to 1 m
- for pulses from slow detectors (e.g. germanium detectors) 1.5 m to 4 m

For a better determination of the cable length see also section 4.2.3 for very fast rise times the internal cable lengths have to be taken into account, see also section 4.2.3.

2.7 Power requirements

+6 V / 150 mA
-6 V / 450 mA (standard version), this power exceeds the normal BIN power allotment of 167 mA for a single 1/12 width NIM module.

2.8 Physical

Size	single width NIM module (3.43 x 22.13 cm; 1.35 x 8.71 inches) per TID – 20893 (rev.)
Net weight	0.7 kg (1.6 lbs)

3 Controls, connectors and indicators

3.1 Front panel

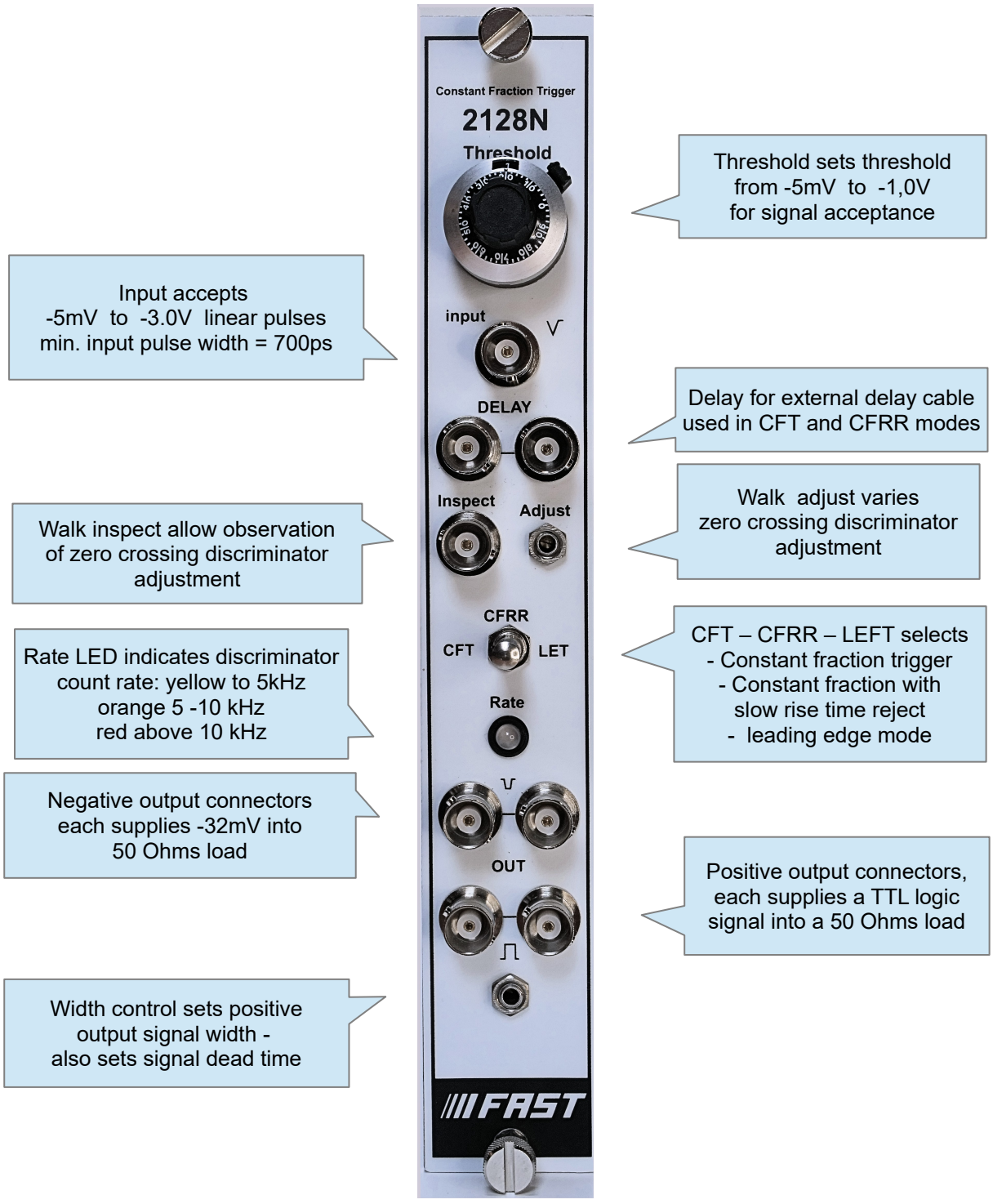

Fig. 3.1: The Front Panel

4 Operation

4.1 General

The purpose of this section is to familiarize the user with the operation of the model 2128N and to prove that the unit is working properly. The module can be operated in many different system configurations, therefore it is difficult to give explicit operating instructions. However, if the guide line of the listed procedures is followed, the experimentalist will gain sufficient experience with this unit in order to use it properly.

4.2 Laboratory bench tests

Basic performance tests of the model 2128N may be exercised either in a rack mounted NIM-BIN (**N**uclear **I**nstrumentation **M**odule) power supply or on a laboratory bench with the unit powered by an extender cable from a NIM-BIN (TID-20893). It is recommended that electrical connections be made with BIN power off.

4.2.1 Input

Suitable driving pulses may be obtained from laboratory pulsers or pulse generators, or readily available detector pulse signals. The input network is protected for pulses exceeding 5V in amplitude. But the user should keep in mind that the linearity is limited by the common mode range of the ultra fast comparators in the input stages.

4.2.2 Operating mode

The selection of the operating mode depends on the requirements of the experiment.
In the **CFT** mode (normal constant fraction) the timing is derived from a comparison between an attenuated pulse (fraction f = 0.4; factory set; f can be easily changed by the user) and a delayed pulse (delay time t_d; external delay cable). The derived time mark is (theoretically) independent of the pulse height of the input signal. For a detailed description of the principle see e.g.:

D.A. Gedcke and W.J. McDonald, Nucl. Instr.& Meth. 56(1968)253
M.R. Maier and P. Sperr, Nucl. Instr. & Meth. 87(1970)13
The choice of the fraction f and the time t_d (see also section 4.2.3) depends on the detector and the experimental setup.

In the **CFRR** mode (constant fraction with slow rise time reject) an option is provided to handle longer rise times (e.g. solid state Ge-detectors). Normally the timing mark for the CF is derived with the presumption that the threshold level has been set quite low and this level is exceeded prior to to the derivation of the time mark. In the case of long varying wavefronts of the input pulses (and if relatively short delay cables are used) the timing conditions as given above may not be valid. In that case the level discriminator may switch late. The resulting timing mark will represent some mixture of the intended CFT timing with leading edge timing. This effect causes tails or even a satellite peak in a time spectrum. In the CFRR mode an option is given which rejects pulses which have not exceeded the threshold level prior to the derived CF timing mark. Some loss in the count rate is obvious.

In the **LET** mode the model 2128N can be used as a simple leading edge trigger up to very high count rates. The leading edge mode should only be used with signals having a very short rise time and a very limited range of amplitudes as change in amplitude will cause walk (see also section 5.1).

4.2.3 Delay cable

Normally the delay cable used should provide a delay less than the risetime t_r of the input pulses. Theoretically the total delay required can be estimated from the following relation:

$t_d \approx (1 - f) \cdot t_r$ (f = fraction; t_r = risetime of the input signal; t_d = total delay)

which was found to be the optimum for most applications. The internal delay (cable length front panel BNC connectors to printed board) is about 0.5 ns. For very fast pulses it is recommended to measure the delay direct at the input of the high speed comparator (pin 2 and pin 3) and if necessary to directly install a delay cable omitting the front panel BNC connectors. Delay for RG-58 cables is ≈ 1.46 ns per foot or ≈ 4.8 ns per meter.

4.2.4 Walk trim

The adjustment of the amplitude sensitive variation of the timing mark (time walk) has to be carried out very carefully (in the CFT and the CFRR mode). Proper adjustment is only possible when the dc-offset present at the input is very small. Thus detector leakage or dark current errors must be minimized before attempting adjustment.

Laboratory trimming of the unit using a fast pulse generator for the first test measurements is recommended. Different settings of the walk adjust potentiometer should be tried in order to find the optimum time resolution. When the model 2128N is used with the intended detector, time resolution has to be trimmed experimentally by successive measurements with the setup at hand, because the resolution depends on many parameters such as fraction, threshold, delay t_d and walk trim. A quantitative control is available by monitoring the front panel inspect output with an oscilloscope, externally triggered with the fast output of the unit.

For fast detectors it turned out that in most cases the inspect signal (not to be terminated with 50Ω) should be a sharp signal from – 0.4 V to – 0.2 V. (walk trim is already factory set as described). For slower detectors, a noise band between the levels may be seen, with transitions to high and low of about equal intensity. Symmetrical center setting should be avoided as the ultra fast comparators deviate from their optimum performance in this setting.

4.2.5 Outputs

The output pulses from the model 2128N are intended to drive 50Ω loads through any reasonable length of suitable 50Ω coaxial cable (such as RG-58). As the setting of the width of the positive output signal is consistent with the internal dead time, the user should set this control due to the requirements of the pulse rate for the given experiment. The width of the positive output signal should be less than 300 ns.

5 Circuit description

5.1 General

The model 2128N provides the advantage that various modes of operation (CFT, CFRR, LET) can be chosen by selecting the front panel switch. The fraction (factory set to f = 0.4) can be changed with the resistors R_1 and R_2 on the printed board. This model utilizes a direct coupled negative input to perform integral discrimination or/and to derive a constant fraction timing mark. The bulk of the logic signal processing is executed in emitter-coupled fast integrated circuit logic (ECL using SMD parts). Reference diodes are used to pin all threshold voltages.

5.2 LET mode

Since the model can be operated in various modes, its operation is best appreciated by understanding the simple LET mode. The input signal is split in a network to serve the two identical ultra fast comparators (IC1 and IC2, see figure). In the LET mode, both pulse amplitude discrimination and timing are derived in the comparator IC1. The pulse acceptance level is established by the front panel threshold potentiometer from -5 mV to – 1.0 V dc. Since the timing mark for the comparator is derived from the point where the pulse intercepts the threshold setting, it is quite obvious that the timing mark changes with amplitude and rise time of the input pulse. The output signal of the comparator (IC1) is accepted through gate IC3 (1/4 of a 10H102) appearing at the outputs as positive going signal (- 1.7 V to – 0.8 V) and as negative going signal (- 0.8V to - 1.7V). The width of these signals depends on the setting of the leading edge width potentiometer on the printed board (factory set to about 20ns).

The width can be monitored with a signal probe on the scope. It is recommended, to set the width as wide as the input signal. The negative output signal of IC3 is accepted through the gate IC6. Note that with the LET mode (front panel switch) the outputs of the gates IC4 and IC5 are always set to logic LOW (- 1.7V). The output of gate IC6 is fed to the clock input of a master-slave type D flip-flop IC7 (1/2 of 10H131). The Q – output is fed to a bus driver (10192) and converting the ECL levels to fast NIM levels (- 32 mA in 50Ω). The width of the output pulse is either determined by a RC combination. The output of IC7 goes to the clock enable input of a second master-slave flip-flop IC8 (second half of the 10H131). The output of IC8 is converted by the following ECL - to – TTL translator (10H125) to positive TTL output pulses. The width of the positive output signal is set by the front panel potentiometer (WIDTH control). This width (< 300 ns) also determines the internal dead time of the module.

5.3 CFT and CFRR mode

In the normal constant fraction mode the applied input signal is sensed for the amplitude by IC1 as described above, but also routed to the front panel DELAY cable BNC connectors. The delayed pulse is applied to the inverting input of the comparator IC2. The non delayed but attenuated signal is applied to the non-inverting input of IC2. The attenuation is determined by the fraction module. The difference signal between this inputs is a bipolar signal whose zero crossing is the time mark. Theoretically the time mark for the bipolar signal is zero. Finite errors, such as small dc-offsets on the input signal, the offset bias of the comparator, as well as the finite gain bandwidth of the device can cause some time shift or walk in the normal case. With the front panel WALK ADJUST, by monitoring the inspect signal one has the possibility to minimise the time walk. The optimum setting has to be found experimentally. One logic output of IC2 is applied to gate IC5. Switch S-A is not grounded in CFT operation. The outputs of IC3 and IC5 are applied to gate IC6. In normal operation the first negative going pulse is provided from IC3. The following pulse logic is identical as described above. In the CFT operation switch S-B is grounded, the level at the D-input of the flip-flop (IC7) is always logic LOW (-1.7V).
In cases where slower rise time pulses may cause poor timing performance, the CFRR mode locks out and rejects those pulses which do not satisfy the THRESHOLD setting prior to the derived constant fraction timing mark.
In the CFRR mode switch S-B is left open. The output signal of IC3 is processed through IC4 and applied to the data input of the flip-flop IC7. Therefore output signals are only generated when the threshold signal is prior to the derived timing mark of IC2. Inadvertent timing marks derived from the leading edge discriminator switching late are blocked.

6 Special features and options

In this section some special features of the model 2128N which are available on request are listed.

6.1 Power supply

Normally ± 6 V from a standard NIM BIN, or on customer request, ± 12 V from a NIM BIN. Or on customer request, 220 V (ac)/110 V (ac) independent from a NIM BIN. In this case the unit is mounted in a special housing, for details the supplier should be contacted.

6.2 Input polarity

The standard version of the model 2128N requires negative input polarity. In some cases the output pulses of detectors have positive polarity. If signal transformers (e.g. Ortec IT 100) are not suitable, the module can be modified on customer request to accept positive input signals.

6.3 Output width

As already stated above the model 2128N is available with a fixed output width for the negative output. On customer request the width of the negative output can be enlarged within meaningful values regarding internal settings.

6.4 Threshold

In the standard version the threshold setting is performed via a front panel potentiometer. On customer request the threshold voltage can also be supplied externally (e.g. computer controlled) via a rear panel connector.

6.5 Signal shaping

For some detector systems considerable improvements in time resolution can be achieved using small fractions (f ≈ 0.1) and “RC-shaping” of the input signal or the attenuated signal (examples are given in the literature). The capacitors (to ground) for the signal shaping (input or attenuated signal) can be easily implemented. If the capacitor is set at the attenuated signal the delay time t_d has to be adjusted as follows

$$t_d \approx Z_0 \cdot C + (1\text{-}f) \cdot t_r$$

The best values for the fraction f, the capacitor C and the delay t_d have to be determined experimentally.

7 Diagrams

7.1 Circuit diagram

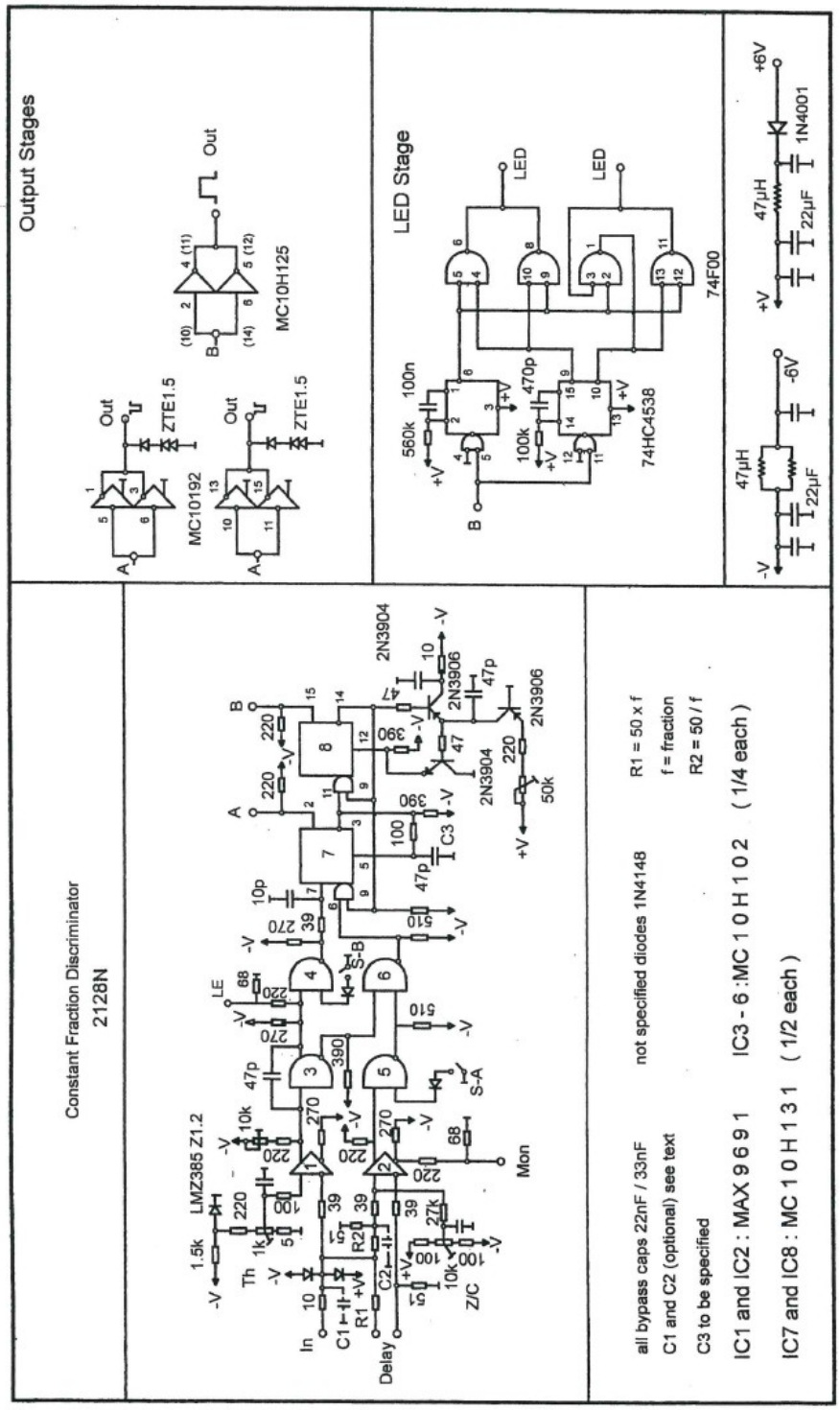

Fig. 7.1: The Circuit diagram

7.2 Board

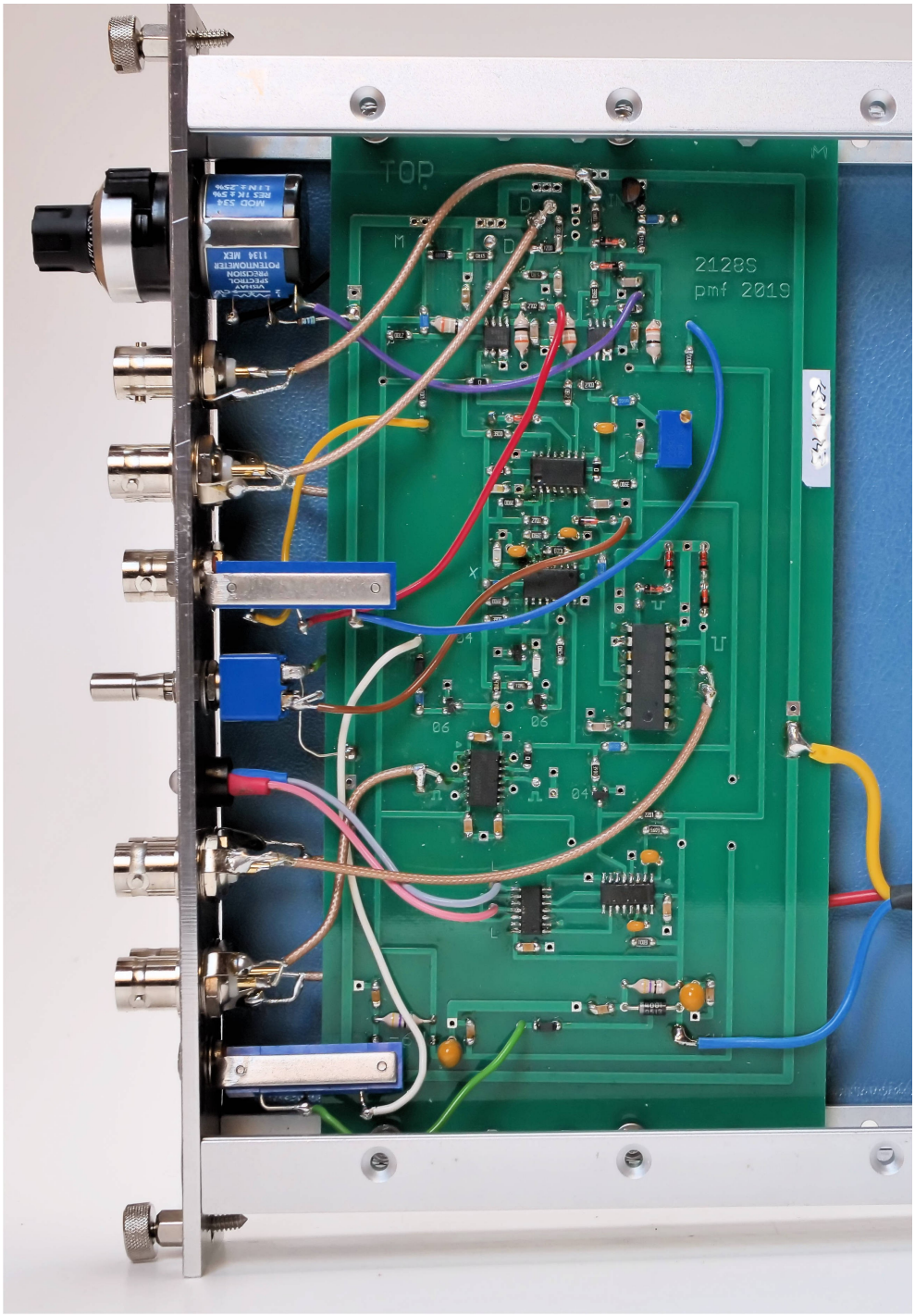

Fig. 7.2: The Board