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(54) **Electronic coin validators.**

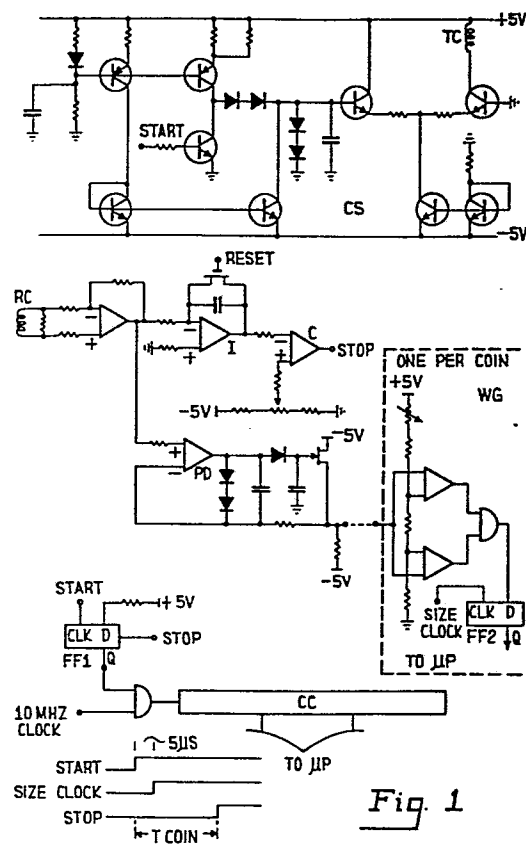
(57) The validator has a transmit coil TC for creating a magnetic field and a receive RC coil for detecting changes in the field due to the presence of a coin adjacent to the coils. The validator performs a test on each coin to provide a first parameter which is a measure of coin face area, and a second parameter which is a measure of coin resistance.

The parameters are utilised to establish the validity of the coin.

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TITLE: ELECTRONIC COIN VALIDATORS

The present invention relates to electronic coin validators. When a step change of magnetic flux is applied axially to a coin an eddy current is induced
5 which flows in the periphery of the coin, the coin acts like a coil comprising a single shorted turn. The coin has an inductance L_c and an equivalent series resistance R_c , related to the resistivity of the coin and its resistance. The eddy current induced in the coin is
10 also related to the current step I in the transmit coil that produces the step change of magnetic flux and the mutual coupling M_c between the coil and coin.

The current can be used to give an electronic signature that defines the coin type.

15 According to the present invention there is provided an electronic coin validator including a transmit coil for creating a magnetic field, a receive coil for detecting changes in the magnetic field due to the presence of a coin adjacent to the coils, and means whereby the validator
20 operates to perform a test on the coin, to give a first parameter which is a measure of the coin face area, and a second parameter which is a measure of the coin resistance, said first and second parameters being used to establish the validity of the coin.

25 According to a further aspect of the invention there is provided an electronic coin validator including a transmit coil for creating a magnetic field and a receive coil for detecting the transmitted magnetic field, said

receive coil being used to detect a compensation signal when the transmit coil is activated, which signal is unaffected by the coin to be validated.

5 The invention will now be described with reference to the accompanying drawings wherein;

Figure 1 shows the circuit diagram of an electronic coin validator according to the present invention,

Figure 2 shows a set of waveforms which are produced at various points in the circuitry of Figure 1,

10 Figure 3 shows the output waveforms of the circuitry of Figure 1 for each coin denomination,

Figure 4 shows a coin validator of another embodiment of the present invention,

15 Figure 5 shows a graph of the normalised coil voltage against frequency with a coin present in the embodiment shown in Figure 4.

Referring to Figures 1,2 and 3, an embodiment of the invention, an impulse test type validator, will now be described.

20 For impulse testing the magnetic field is larger than the largest coin to be tested and two parameters are measured, coin face area and coin resistance. The receive coil current waveform is shown in Figure 2. If the open circuit voltage in the coin, is detected, the
25 peak voltage is a measure of a coin face area and the integrated voltage waveform has a time constant related to the coin resistance.

The circuit of Figure 1, produces the waveforms of

Figure 2. It consists of a current switch CS which has a defined turn on time, and drives the transmit coil TC. The receive coil RC drives an amplifier which is connected to an integrator I and a peak detector PD. A comparator set at 90% of the integrator maximum output voltage gives a signal that allows t_{coin} to be measured, where t_{coin} is the time taken for the integrator output voltage to rise to the 90% level. A start pulse gates a 10 MHz clock into a counter chain CC via flip flop FF1 when the transmit current step is applied, and, the integrator output stops the count. The number in the counter is now a measure of t_{coin} which relates to coin resistance, and may be applied to a microprocessor μP for evaluation. The peak detector holds the peak impulse shown in Figure 2 and can produce the set of output voltages shown in Figure 3 for the different coins. The peak detector drives four window gates WG, one of which is shown, whose thresholds are adjusted to each coin face area distribution. The window comparator outputs are gated into a 'D' type flip-flop FF2 that are clocked $5 \mu S$ after the start of the coin test, this effectively produces a peak detector output sample at $5 \mu S$, as shown in Figure 3. The output of each flip-flop FF2 may be applied to the microprocessor μP for evaluation. Alternatively, the peak detector voltage may be entered into an analog-to-digital converter and the output applied to a microprocessor for evaluation.

The theory of operation of the impulse test type coin validator is as follows:-

Direct flux linkage transmit to receive coil $eoc = -M \frac{dI}{dt}$

5 which for a current step of I $eoc(t) = -M.I.RT. \frac{e^{-\frac{RT}{L}}}{L}$

where RT is the damping resistor across the receive coil and $RT \gg R_x$.

If the step is of rise time T , this is modified to:

10
$$eoc(t) = -M.I \frac{1}{T} \left[1 - f(t-T) - e^{-\frac{RT}{L}} + f(t-T) e^{-\frac{RT}{L}} (t-T) \right]$$

It can be shown that L is large and T small then the rise time variation does not have a great effect on eoc .

The voltage in the receive coil due to the presence of the
15 coin is modified to:

20
$$V_T = \frac{-MR.Mc}{L L_c} .I. \left[\frac{\frac{RT}{L} e^{-\frac{RT}{L}} t - \frac{R_c}{L} e^{-\frac{R_c}{L_c}} t}{\frac{R_x}{L} - \frac{R_c}{L_c}} \right]$$

and this has to be added to the voltage due to the direct flux in order to give the complete receive waveform.

It can be seen from the equations that if a test impulse is
25 applied when no coin is present then this can be used to provide a reference level providing compensation for the effects of drift etc. The coin validator verifies two parameters of a coin before it is passed as genuine.

Any disc of the correct size will meet the size parameter, but then has to have a time t coin inside the correct time distribution to meet the second parameter and be recognised as genuine.

5 The validator uses identical transmit and receive coils wound on the outside of a ferrite vinkor. The area of the coil is quite critical and has to be such as to allow sufficient flux to pass around each coin and also produce an easily measurable t -coin period in excess of 10 μ S.

10 Referring to Figures 4 and 5 an alternative embodiment of the invention will now be described.

 The multi-frequency validator carries out a test to verify two parameters of the coin. The first parameter is of face area of the coin, and the second parameter is of the
15 coin resistance.

 A magnetic field larger than the largest coin face area is produced across the coin runway between the transmit and receive coils. The field can be either produced by an alternating current or a step change of current in the
20 transmit coil.

 The multi-frequency validator has a transmit coil TC which is driven by a coil drive circuit CD. The coil drive circuit CD is fed with a multi-frequency signal generated from oscillator OSC and divider circuit DV via a signal
25 amplitude control circuit AC, filter circuits F1-F4 and summing and amplitude weighting circuit SW.

 The receive coil RC drives a differential amplifier DA and filters F5-F8. The output of the filters is fed via

respective rectifier circuits R1-R3 to detector circuits D1-D3 the outputs of which are selectively switched by switch S to analog-to-digital converter ADC to a microprocessor μP for evaluation.

5 Rectifier R4 feeds an automatic gain control circuit AGC which also receives a voltage reference signal from circuit VR. The output of the automatic gain control circuit AGC is used to modify the operation of signal amplitude control circuit AC to compensate for temperature changes in inductance, drift etc. The graph shown in Figure 5 shows the normalized receive coil voltage NCV against transmit current frequency f . At frequencies below 1KHz the received signal amplitude is unaffected by the presence of the coin set of interest and so can be used for a continuous reference tone that compensates for variations in mutual inductance, temperature effects and component drift. At high frequencies the coin is opaque to the applied magnetic field and so the majority of the received signal is due to the field that gets round the edge of the coin, therefore the ratio of the amplitude of the received signal with and without the coin present gives a measure of the coin face area. If amplitude measurements are taken in the receive coil at two frequencies between 1KHz and 100KHz we can get a measure of the coin resistance. The open circuit receive coil voltage is:-

$$V_{oc} = A w \cos wt - \frac{B w^2 R_c}{R_c^2 + w^2 L_c^2} \sin wt + \frac{B w^3 L_c}{R_c^2 + w^2 L_c^2} \cos wt + \frac{B w}{R_c^2 + w^2 L_c^2} e^{-t/\tau} / L_c / R_c$$

$$A = M L_0$$

$$B = M c M_R I_0$$

The term $A w \cos wt$ gives a measure of coin face area at high frequency and the other terms at lower frequencies give a measure of coin resistance.

Mutual coupling between two coils $M = \frac{\mu_0 \mu_e N_T N_R (\text{Area of receive coil})}{\text{distance between coils}}$

5

distance between coils

where N_T is Number of turns on the transmit coil

N_R is Number of turns on the receive coil

μ_e is the effective permeability

10

The equation shows that V_{oc} varies in amplitude with w and M .

An accurately controlled frequency using a crystal master clock will prevent variations in w effecting V_{oc} . However, coin face area is the ratio of the magnetic field passing round the coin to that when no coin is present and is directly proportional to the mechanical dimensions of the receive coil, which vary from coil to coil. As a result one absolute adjustment is needed to set up the validator in production and can be carried out with a disc of accurate proportions. The ratios from coin to coin will always be the same once the initial adjustment is made.

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What we claim is

1. An electronic coin validator including a transmit coil for creating a magnetic field, a receive coil for detecting changes in the magnetic field due to the presence of a coin adjacent to the coils, and means whereby the validator operates to perform a test on the coin, to give a first parameter which is a measure of the coin face area, and a second parameter which is a measure of the coin resistance, said first and second parameters being used to establish the validity of the coin.
2. An electronic coin validator including a transmit coil for creating a magnetic field and a receive coil for detecting the created magnetic field, said receive coil being used to detect a compensation signal when the transmit coil is activated, which signal is unaffected by the coin to be validated.
3. An electronic coin validator as claimed in claim 1 or 2 wherein the transmit coil is driven by a current switch having a defined turn on time, and the receive coil drives an amplifier which is connected to an integrator and peak detector.
4. An electronic coin validator as claimed in claim 3 wherein the integrator is connected to a comparator set at a percentage of the integrator maximum output voltage to provide a control signal.
5. An electronic coin validator as claimed in claim 4 wherein the control signal controls a counter which is started when the transmit coil is activated, the control signal

being used as a stop signal for the counter in which the count is indicative of a measured value relating to the coin resistance.

6. An electronic coin validator as claimed in claim 3 wherein the peak detector is connected to and drives a plurality of window gates having a respective threshold adjusted for a respective coin face area, and which provide respective output signals.

7. An electronic coin validator as claimed in claims 5 and 6 wherein the count value and the output signals are applied to a microprocessor for evaluation.

8. An electronic coin validator as claimed in claims 1 or 2 wherein the transmit coil is activated by a multi-frequency signal which is applied to the coil via a signal amplitude control circuit, filter circuits and a summing and an amplitude weighting circuit.

9. An electronic coin validator as claimed in claim 8 wherein the receive coil is connected to and drives filter circuits, rectifier circuits, and detector circuits which provide output signals indicative of the detected coin which are selectively switched via an analog-to-digital converter to a microprocessor for evaluation.

10. An electronic coin validator as claimed in claim 9 wherein the ratio of the amplitude of the signal received by the receive coil with and without a coin present gives a measure of coin face area.

11. An electronic coin validator as claimed in claim 10 wherein amplitude measurements are taken in the receive

coil at two frequencies to obtain a measure of coin resistance.

12. An electronic coin validator as claimed in claim 11 wherein the measurements are taken at two frequencies between 1KHz and 100KHz.

13. An electronic coin validator as claimed in claim 12 wherein one of the rectifier circuits drive an automatic gain control circuit which also receives a reference voltage, the output signal from which is used to modify the operation of the signal amplitude control circuit for compensation purposes.

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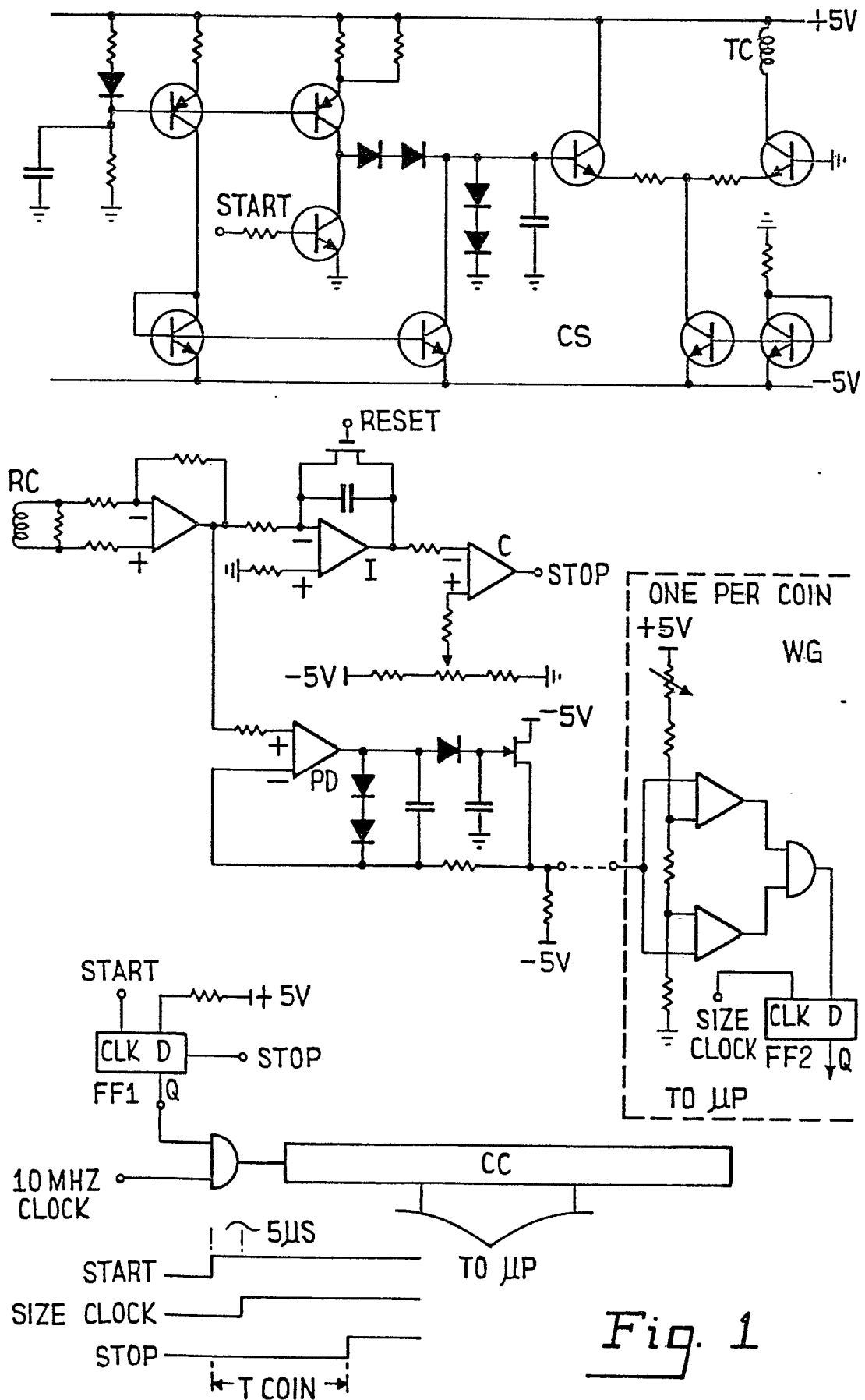
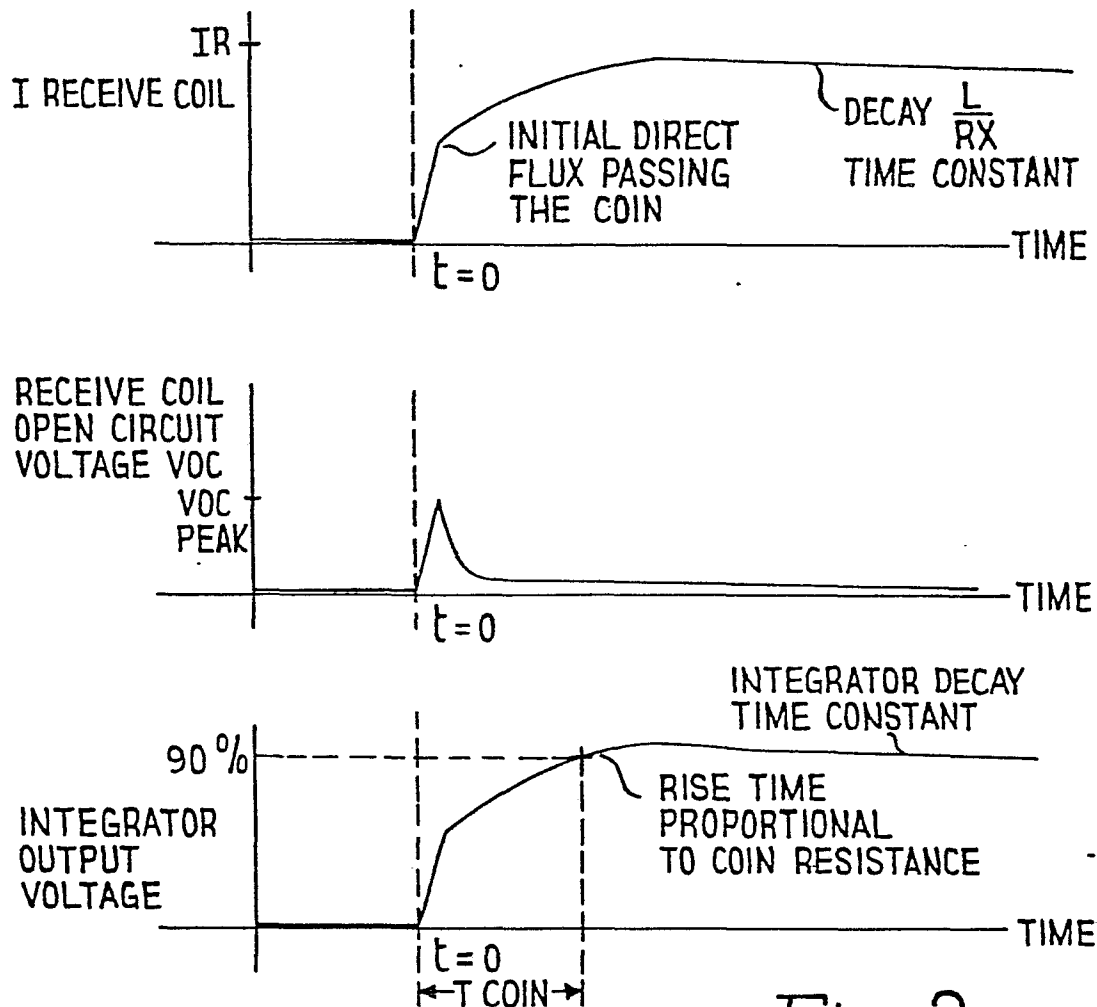
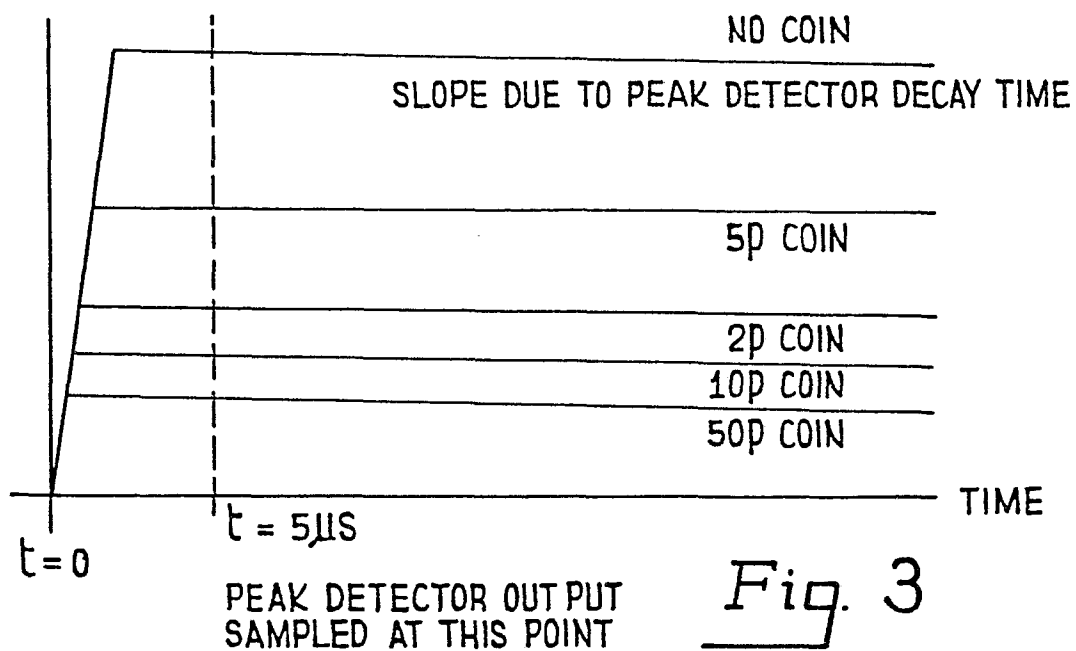
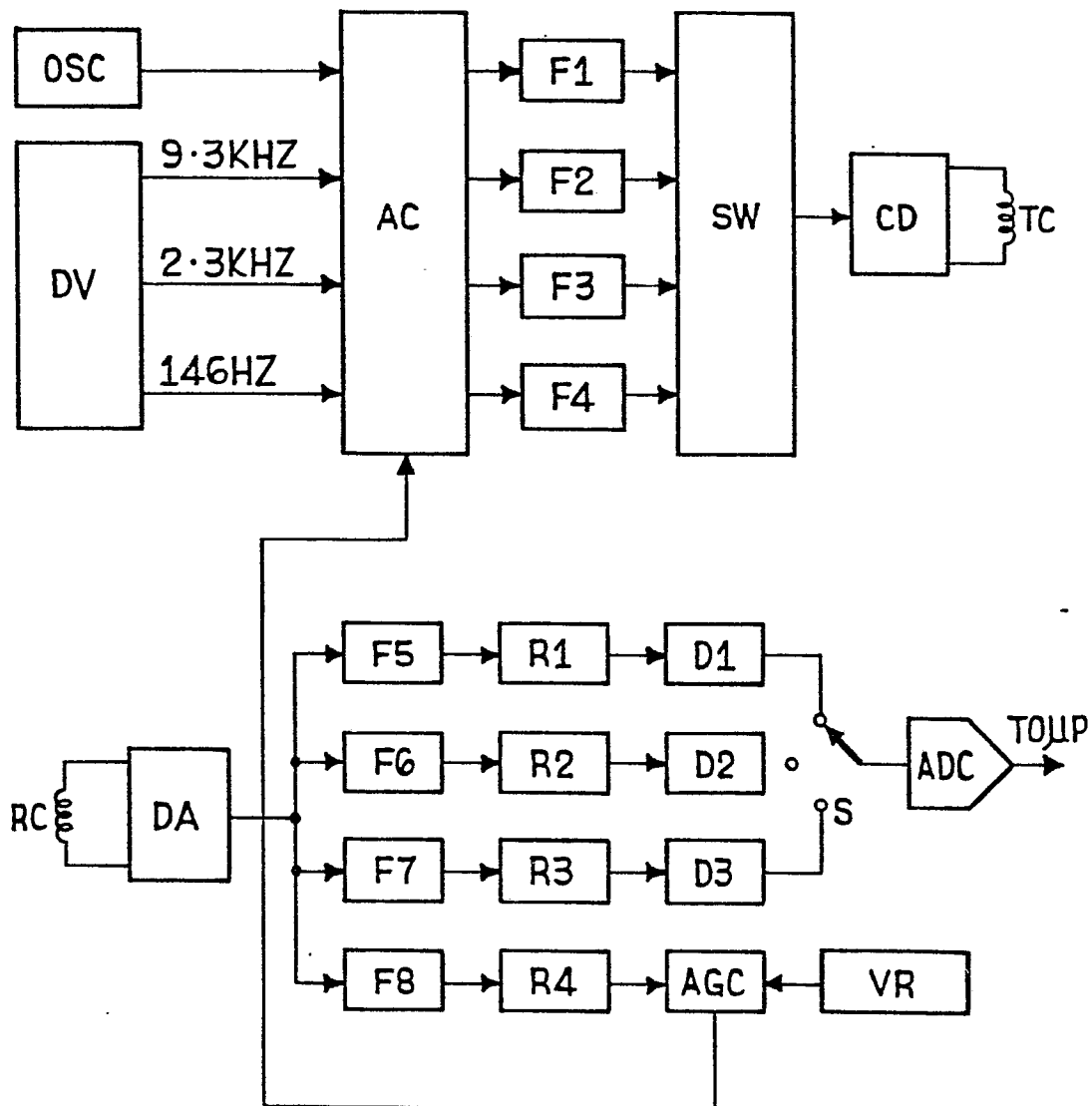


Fig. 1

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Fig. 2Fig. 3

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Fig. 4

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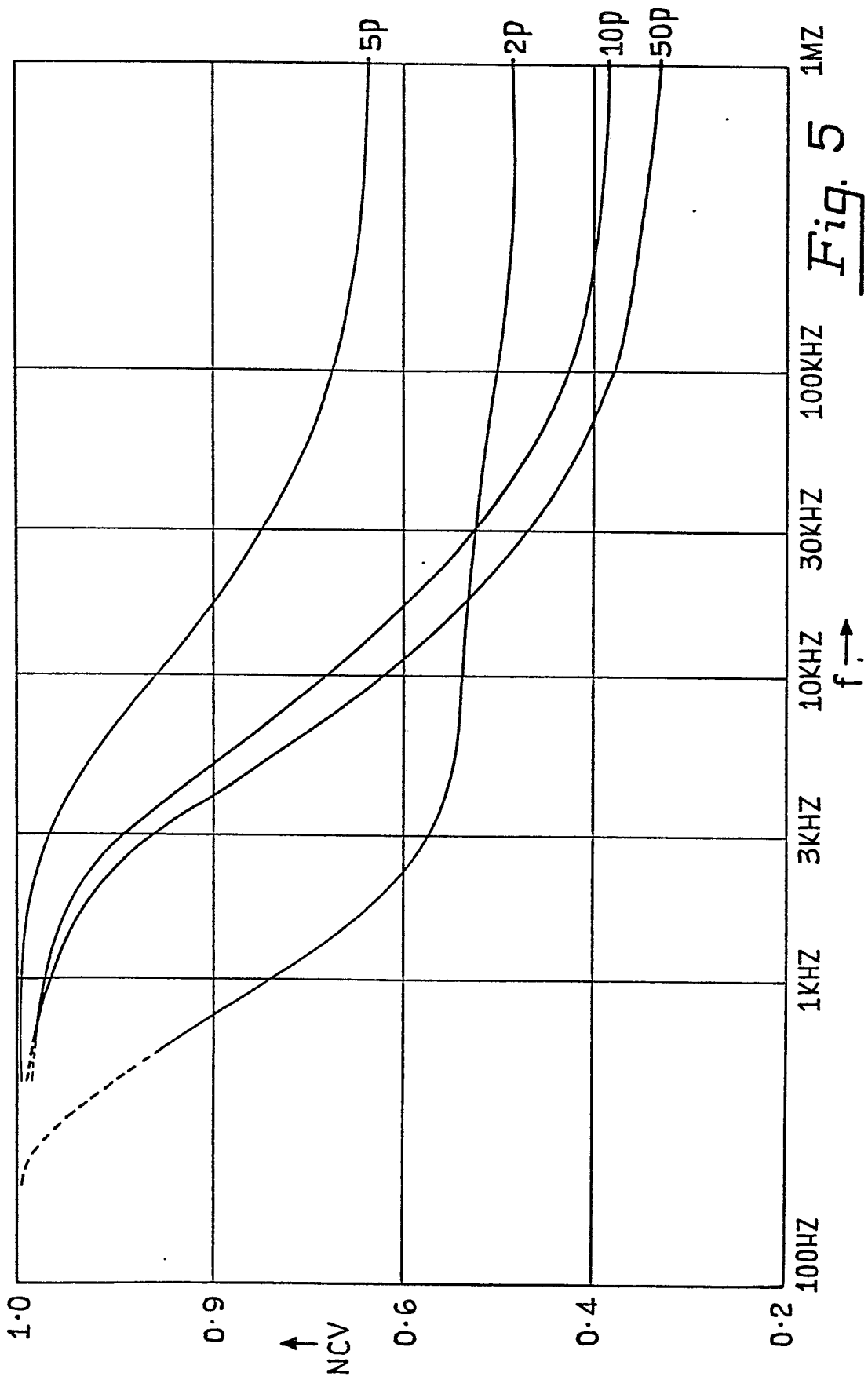


Fig. 5



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EUROPEAN SEARCH REPORT

0048557

Application number

EP 81 30 4000

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
	<p><u>DE - A - 1 925 042</u> (J. STEGMÜLLER)</p> <p>* the whole document *</p> <p>---</p>	1-4,6	<p>G 07 F 3/02</p> <p>G 07 D 5/00</p>
	<p><u>DE - A - 1 930 345</u> (NATIONAL REJECTORS)</p> <p>* pages 2-5, 7 and 8; claims; figures 1-5 *</p> <p>---</p>	1-4,6	
	<p><u>US - A - 3 962 627</u> (J.F. PTACEK)</p> <p>* figures 1,7-10; column 18, line 42 to column 21, line 39 *</p> <p>---</p>	1,5,7	<p>TECHNICAL FIELDS SEARCHED (Int. Cl.)</p>
	<p><u>US - A - 4 124 111</u> (Y. HAYASHI)</p> <p>* abstract; figure 14; column 10, line 15 to column 12, line 2 *</p> <p>---</p>	1-3,6, 8-11	<p>G 07 F 3/00</p> <p>3/02</p> <p>G 07 D 5/00</p> <p>5/08</p> <p>5/02</p>
	<p><u>US - A - 4 086 527</u> (A.G. CADOT)</p> <p>* abstract; figures; column 3, line 10 to column 6, line 8 *</p> <p>---</p>	1,3, 6-9, 11,12	
A	<p><u>US - A - 4 091 908</u> (Y. HAYASHI)</p> <p>* abstract; figures; column 6, line 51 to column 7, line 5 *</p> <p>---</p>	1-3,6, 8-11	<p>CATEGORY OF CITED DOCUMENTS</p>
A	<p><u>US - A - 4 108 296</u> (Y. HAYASHI)</p> <p>* abstract; figures; column 1, line 30 to column 4, line 2 *</p> <p>---</p>	1-3,6, 8-11	<p>X: particularly relevant</p> <p>A: technological background</p> <p>O: non-written disclosure</p> <p>P: intermediate document</p> <p>T: theory or principle underlying the invention</p> <p>E: conflicting application</p> <p>D: document cited in the application</p> <p>L: citation for other reasons</p>
A	<p><u>FR - A - 2 212 589</u> (SATMAM)</p> <p>* claims and figures *</p> <p>---</p> <p>./..</p>	1,3, 4,6, 8-11	<p>&: member of the same patent family, corresponding document</p>
<p>X The present search report has been drawn up for all claims</p>			
Place of search		Date of completion of the search	Examiner
The Hague		05.01.1982	DAVID



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EUROPEAN SEARCH REPORT

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Application number

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DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
A	<u>DE - A - 2 551 321</u> (BERLINER MASCHINENBAU) * claims and figure; page 9 *	1,3, 4,6, 7,9, 10	
			TECHNICAL FIELDS SEARCHED (Int. Cl.)