A DEVICE FOR MEASURING VARICAP CAPACITY

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The measurement and testing of varicaps during production output/input control or during repair of electronic equipment requires the use of a special device, providing to perform measurement under the same working conditions as the element's actual working-mode conditions. For the purpose, the device should measure near-working frequency, provide the required varicap control electric voltage range, and feature the required measurement accuracy.

The paper describes a designed device for measuring varicaps and the used measurement method depending on its designation and price. The block diagrams of two designed versions of the device are shown: with analogue and digital indications of the measured capacity. Two options are provided: for simultaneous or switched-over indication of the capacity and voltage. The detailed principal diagrams of the two options are shown, analysis of the possible mistakes is made, and methods for these mistakes' reduction during the device's calibration are given.

The proposed device can be used not only for measuring the capacity of opposite polarized p-n junction, but also for measuring the capacity of typical capacitors.

The designed device can be also used for training purposes.

Keywords: varicap, electrical capacity, measurement equipment.

1. TECHNICAL NEED

The measurement and testing of varicaps during production output/input control or during repair of electronic equipment requires the use of a special device, providing to perform measurement under the same working conditions as the element's actual working-mode conditions. For the purpose, the device should measure near-working frequency, provide the required varicap control electric voltage range, and feature the required measurement accuracy.

2. MEASURING METHOD

The chosen measurement method is based on measuring the capacity current through a bipolar - in our case a varicap, powered by a high-frequency standard voltage source. This current is a linear function of the capacity value which varies depending on the applied reverse voltage. The function showing varicap capacity's change with voltage is an exponent-like curve, where the maximal capacity values are observed at minimal value of the polarization voltage and vice versa - at maximal voltage, the capacity is minimal.

Besides polarization voltage, an alternating high-frequency voltage (varicap working voltage) is also necessary and a device to measure the high-frequency current passed through it. Since the impedance of the reverse polarized p-n transition is a function of the leakage current (minimal value) and the current through the transition's capacity, by measuring the passed current we may know varicap capacity. And by changing the reverse polarization's direct voltage, we may determine the entire capacity variation range.

3. Block Diagram

Fig. 1 and Fig. 2 present the block diagrams of a device using the above-described method to measure varicap capacity. Both diagrams contain a low-output-impedance basic generator providing high-frequency sine voltage which is used as standard alternating voltage to measure varicap capacity (p. A). The control block synthesizes the control voltage to measure the varicap's volt-capacity characteristic (p. B). To measure the current that has passed through the varicap p. B must have pseudo-zero potential. This can be achieved by an amplifier involved in a very deep parallel negative feedback (PNF), i.e. the amplifier can be regarded as current-to-voltage converter (CVC). Three negative feedback circuits are used to achieve the required dynamic measurement range of the current passing through the varicap. At the converter's output (p. C), alternating voltage is produced, proportional to the current that has passed through the varicap, its factor depending on the feedback elements' values. Measuring this voltage is sufficient to know the capacity of the varicap at each given polarization voltage.

The version with digital indication (Fig. 1) uses a linear rectifier and a digital indication block, comprising an analogue-to-digital converter (ADC) and indication control.

The version with analogue indication requires an indication amplifier, a detector which is actually an amplifier with a detector in its feedback for the purpose of linearizing the diodes' volt-ampere characteristic. Notwithstanding the type of indication, it is necessary to indicate the permanent polarizing voltage of the varicap, which means using either two indication blocks or one indication block which can be switched over.

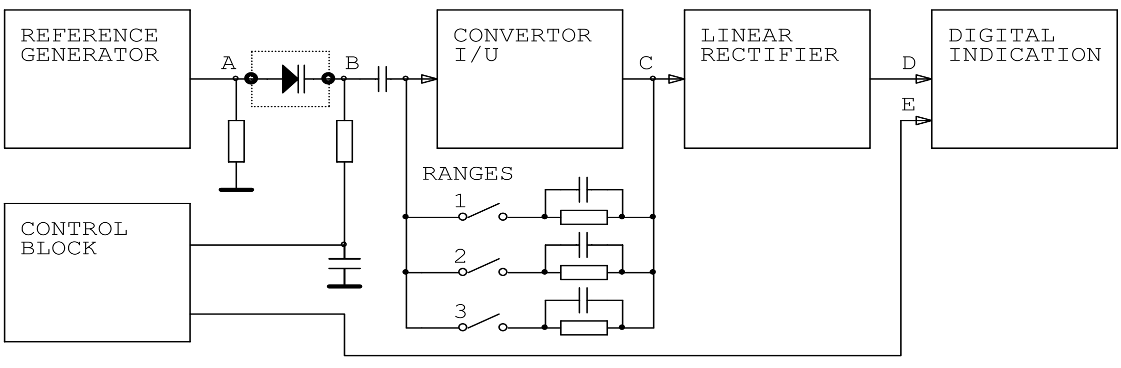

Fig. 1. Structural diagram with digital indication

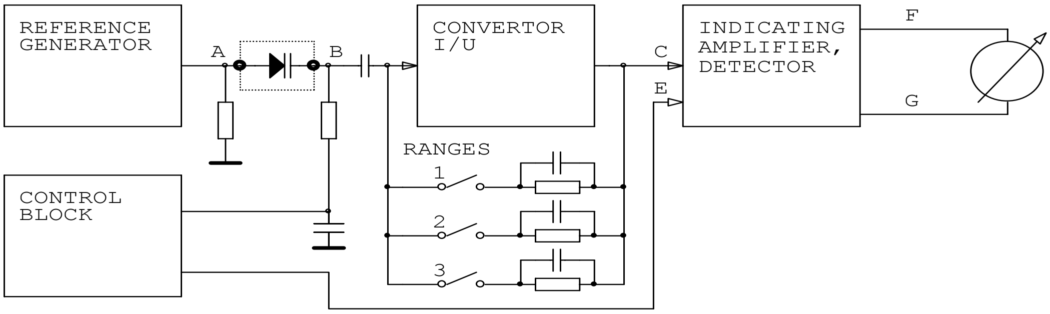

Fig. 2. Structural diagram with analogue indication

4. IMPLEMENTATION

Basic Generator. The generator's functions are to generate high-frequency sine voltage with constant frequency and amplitude, irrespective of the load at its output. It is accomplished as a sine generator of 1 MHz with quartz in the feedback (Fig. 3). Through the symmetrical ZD1–KC162 zener diode connected in parallel to the oscillating circle, constant voltage amplitude is achieved. An emitter repeater based on Q2 transistor plays the role of the generator's load. To reduce the distortions of the generated sine voltage, its higher harmonics are subject to additional filtration by an LC filter (L2, C6, C7). The low output impedance of the basic generator is provided using the emitter repeaters Q3 and Q4 which work in parallel while the output amplitude is regulated by RP1. In this particular design, the outgoing impedance is $R_{out} < 5\ \Omega$. Instead of repeaters based on Q2 and Q3/Q4, followers for wide-band operating amplifiers (OA) may be used.

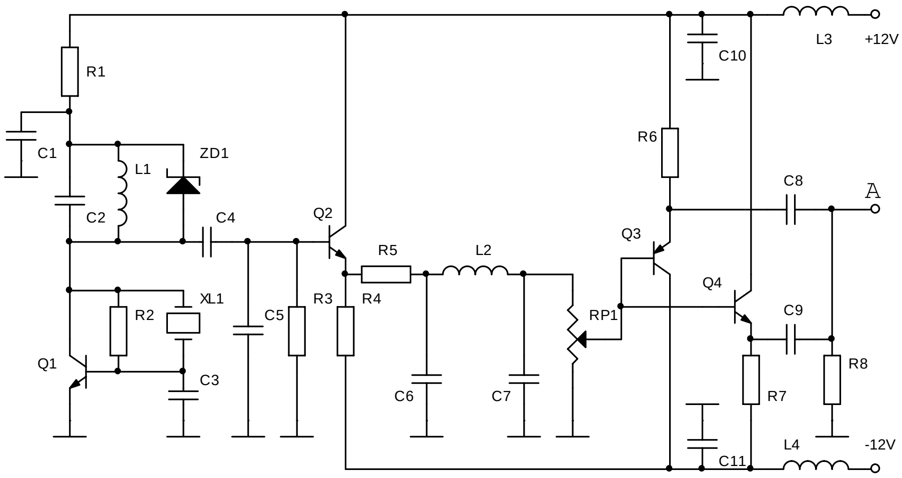

Fig. 3. Basic generator

Power supply and control block. To power-up the device, steady electrical voltage of +/- 12 V must be provided, and to control the varicap's control – constant control voltage within the range from +1 V to + 30 V is required. The design of both blocks is presented in Fig. 4. A network transformer and one-way rectification of the power-supply voltages with subsequent stabilization by the integral stabilizers UA7812 [1] and UA7912 [1] are used. The control voltage is achieved by tripling the voltage and applying parallel stabilization through R1 and D5, D6, D8 and ZD7 – integral stabilizer for the voltage of 33 V of the KA33V [1], TAA550 [2] and so on types. The output control voltage is regulated by potentiometer RP1, buffered by a Q2-based follower, and through circuits R4, C10, R5 – supplied to control the varicap, and through R3 and RP2 – supplied to the indicator block. A current generator based on Q1 transistor plays the role of a load for the Q2 follower.

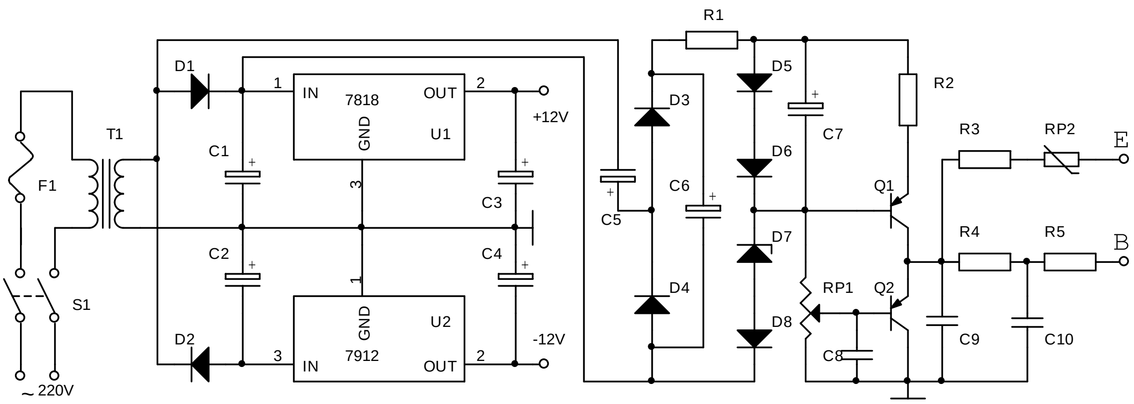

Fig. 4. Power-supply and control blocks

Transistor design of a device with analogue indication. Fig.5 presents the circuit of a device version with analogue indication (design from Fig. 2) based on bipolar transistors. The typical thing here is that the transistor-based wide-band amplifiers feature a circuitry similar to the circuitry of charge-sensitive amplifiers. To eliminate Q1's transition capacity, it is loaded with Q2, operating in a common base circuit. On its part, Q2 has a dynamic load (current-generator Q3), which provides much greater amplification (≥ 80 dB), small input capacity, and wide pass-through band (≥ 30 MHz). This step, involved in DNF (R6IIC4; R7IIC5; R8IIC6) ensures near-zero input impedance and correct input-current-to-output-voltage conversion with 3 different conversion factors: x 1, x 10, x 100. Thus, three ranges of varicap capacity measurement are provided – with maximal indication of 10 pF, 100 pF, and 1000 pF, accordingly.

The amplifier based on Q5, Q6, and Q7 is similar to the one described above, except for the fact that, for the purpose of detection linearization, the rectifier is included in the feedback. Q4 helps to harmonize amplifiers one and two.

Integrated-circuits-based designs. Fig. 6 shows a design based on an OA, where the functions are identical with those of the circuit described so far. Here, wide-band OAs may be used, with standard power supply of ± 12 V, individual amplification frequency above 100 MHz, amplification above 60 dB without feedback for the working frequency of 1 MHz, and high output operability above 350 V/μs. Some suitable types are, for instance AD817, AD829, and AD5539 of Analog Devices [3].

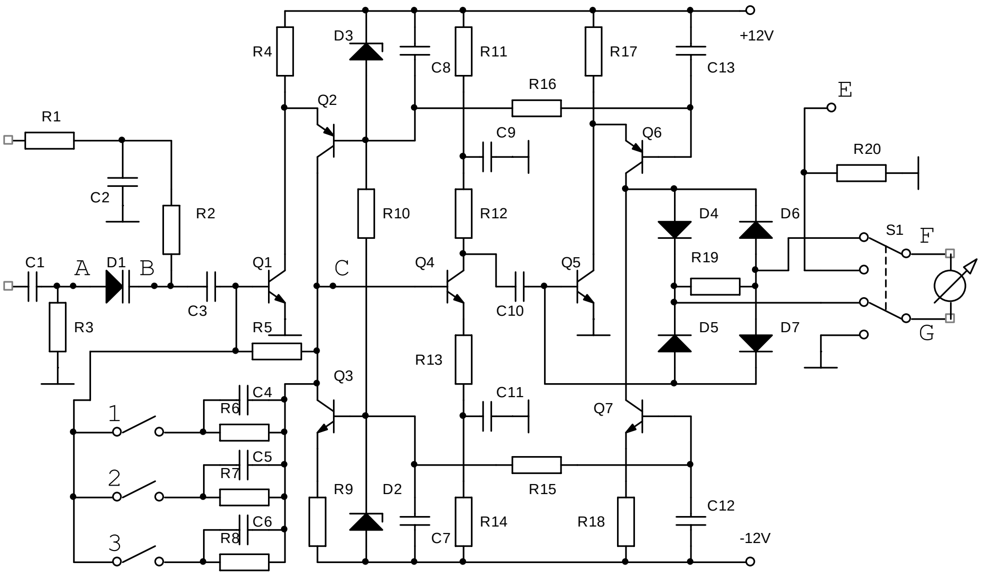

Fig. 5. Circuit with analogue indication based on transistors

Types featuring very high parameters are known, however working with lower power supply: ± 6 V, ± 5 V and ± 2,5 V. They may be used if the power supply block is reworked first. A particularly adequate choice for the OA is the NJM2136, 7, 8 type, i.e. a single, double or quadruple OA of New Japan Radio Co., Ltd. [4]. Except for its very good high-frequency parameters, this type features very low consumption, the typical value being 0,63 mA for each OA, as a result of which the device may operate on batteries.

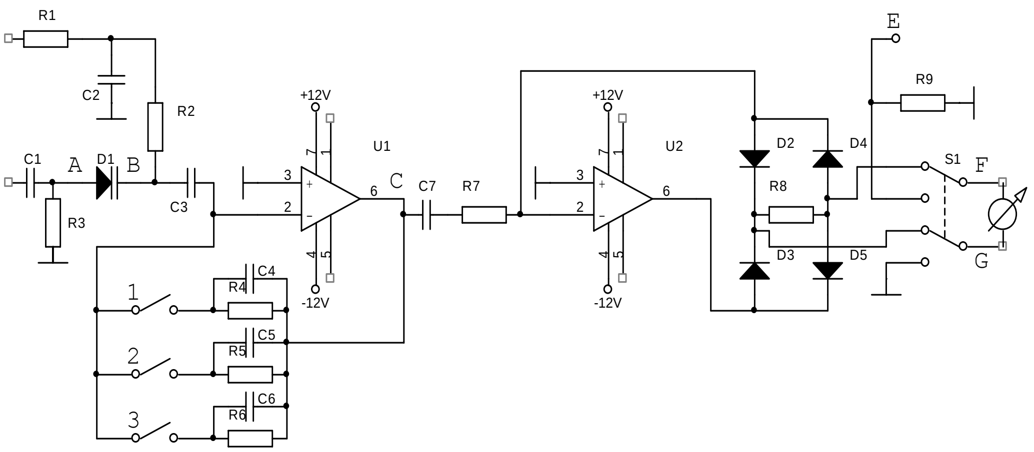

Fig. 6. Circuit with analogue indication based on integrated circuits

Our design uses an ADC based on ADD3501CCN of National Semiconductor [6], but on account of the universality and the possibility to use other indications, we shall not describe this block in detail here. In portable versions, circuits based on liquid-crystal indicators should be used.

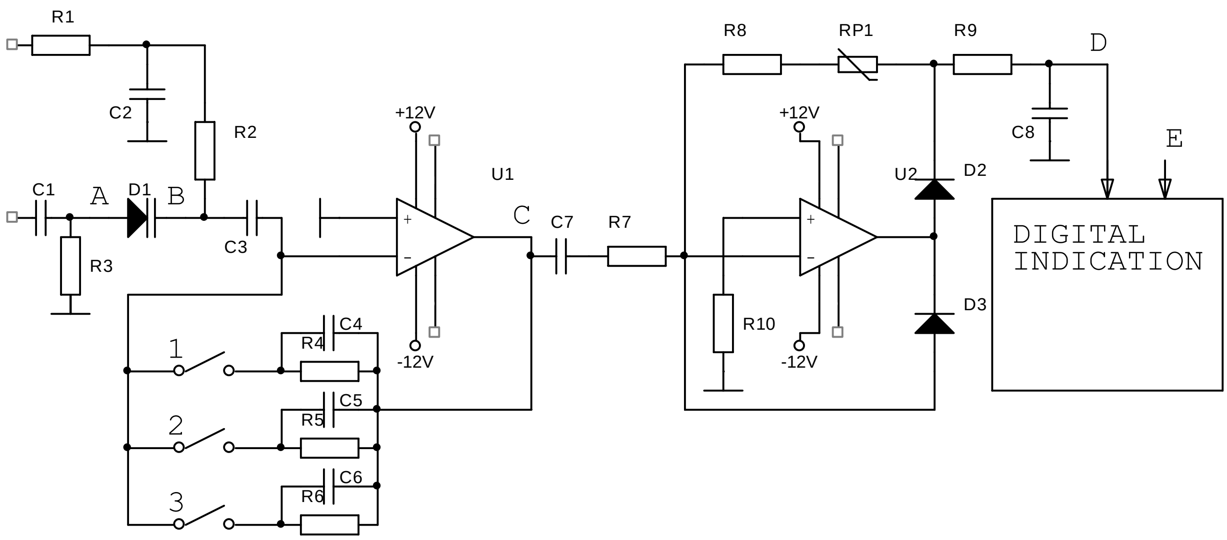

Fig. 7. Circuit with digital indication based on integrated circuits

5. CONCLUSION

The described device for measuring varicap capacity has been tested in laboratory conditions, where it displayed good enough accuracy for its designation – an error of less than 1 % throughout the entire varicap capacity measurement range. Error increase (up to 3 %) is observed when measuring values below 3 pF in the most sensitive range (up to 10 pF). The reason for this lies with the assembly capacities and the real parameters of the first amplifier (CVC), since in this regime a higher conversion factor must be achieved. Some error increase is also observed when measuring capacities greater than 500 pF, because of the actual value of the basic generator's output impedance. This error may be reduced by reducing the generator's output impedance.

Except for measuring the capacity of reversely polarized *p-n* transitions, the proposed device may be also used to measure the capacities of ordinary capacitors with capacity of up to 1000 pF.

The designed device for measuring varicap capacity is also suitable for education purposes.

6. REFERENCES:

[1] Data Sheets UA7812, UA7912, KA33V, www.farchildsemi.com
[2] Data Sheets TAA550 www.philips.com
[3] Data Sheets AD817, AD829, AD5539, www.analog.com
[4] Data Sheets NJM2136,NJM2137, NJM2138 www.njr.com
[5] Data Sheets ICL7106, ICL7107, www.harris.com
[6] Data Sheets ADD3501, www.national.com