Research of Radiated Emissions of a Microcontroller Using Various Power Supplies

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Abstract— **The paper presents the results of research on the influence of the type of power supply for the 1986BE91T microcontroller on its radiated emissions in the TEM cell. The emission measurement results are given when power is supplied to the measuring printed circuit board (PCB) with microcontroller from a pulse power supply unit, mains chargers and power banks, USB-port of PC, as well as a rechargeable battery. It is shown that it is advisable to use a rechargeable battery to minimize radiated emission from the power supply circuits of PCB.**

Keywords—electromagnetic compatibility, electromagnetic radiative interference, digital integrated circuits, microwave propagation

I. Introduction

Improvement of the modern electronic component base used in the development of radioelectronic facilities is aimed at increasing the speed and integrated-circuit density, as well as reducing energy consumption. This is facilitated by an increase in operating frequencies, a decrease in the levels of supply voltages, as well as a transition to submicron production technologies [1], which leads to an increase in the radiated emission from semiconductor components and an increase in their susceptibility to external electromagnetic influences [2].

Different mechanisms of failure of integrated circuits (IC) when exposed to an electromagnetic field are currently being studied. The effects of interference can manifest themselves in the form of malfunction and degradation of the IC. It is known that the most intense amplitudes of currents are induced on conductors in resonant structures with dimensions closed to half the wavelength of the acting field and also when structures are oriented relative to the direction of the polarization vector [3].

Various radioabsorbing materials inside the IC package [4], decoupling capacities on top of each power supply circuit in the chip, as well as current sensors built into the IC package to measure internal noise, are used to reduce radiated emissions from the IC [2]. At the same time, the exact determination of emission sources is a difficult task since the contribution to the emission amplitudes at given frequencies is made not only by the shape of the package and leads but also by the conductors of the PCB with components located near the IC.

The method of measurements in a TEM cell [5] has become widespread for bench tests of ICs on electromagnetic compatibility. According to [6] the IC under test is mounted on the PCB that is secured to the wall of a TEM cell with the IC side facing unto the cell to measure the radiated emission. The TEM cell is connected to the matched load (ML) and the test receiver (TR) (Fig. 1).

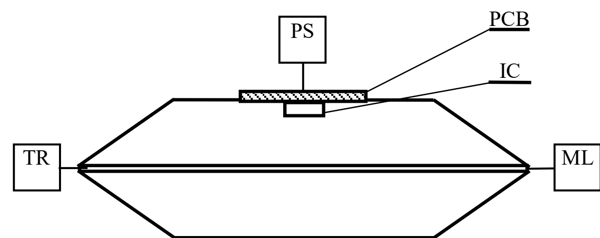

Fig. 1. Schematic of a setup for testing ICs for radiated emission in a TEM cell [6].

First, external power is supplied to the PCB and the correct functioning of the IC is checked. Further, the voltage is measured using the TR, which is formed from the induced currents from the IC to the center conductor of the cell. To obtain a more detailed estimate of the radiated emission, modified measurement methods are used.

From [7] it's known to use a 180° hybrid coupler to separate the contributions of electric and magnetic field coupling in emission measurement of ICs in TEM cell. This also makes it possible to use the measurement results for a mathematical model based on equivalent dipole moments [8] to represent the source of radiated electromagnetic emissions from IC. For spatial localization of radiated emissions, the combination of measurement in the TEM cell and by the surface scanning method is used [9].

However, the standard [6] does not regulate the requirements for the PCB power supply (PS), the type of which must be recorded in the test report. In this regard, it is required to assess the influence of the power supply on the measurement results of the radiated emission of IC with different power supplies.

The aim of this work is to present the results of a research of the radiated emissions of a microcontroller 1986BE91T in a TEM cell using various types of PS.

II. Description Of The Test Set-up

The circuit and the measuring PCB are designed to measure the radiated emission of the investigated IC. From the power circuit diagram (Fig. 2) it can be seen that the microcontroller on the test PCB is powered from an external power source and supplied through the AMS1117-3.3V linear voltage regulator (LVR), which has filtering capacitors with values of 22 μF and 0.1 μF on the input and output

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sides. Blocking capacitors $C_1, \dots, C_N$ are located near each power output of the microcontroller.

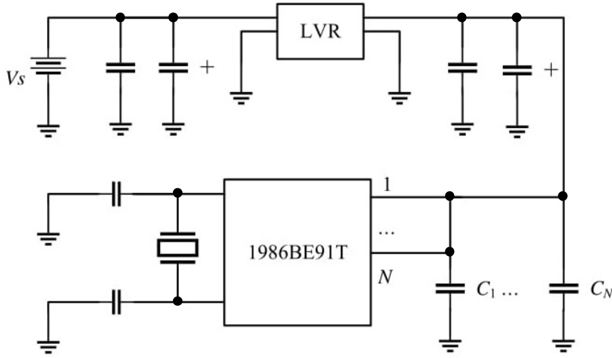

Fig. 2. Power circuit diagram of the test PCB.

The front side of the PCB with the investigated IC is shown in Fig. 3*a*, the reverse side with peripheral interfaces and components necessary to ensure the operation of the IC is shown in Fig. 3*b*.

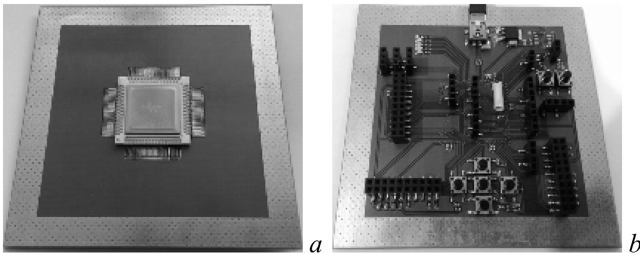

Fig. 3. Front (*a*) and reverse (*b*) sides of the test PCB with IC.

The test set-up for measuring the radiated emission is assembled using a small-sized TEM cell with an upper cutoff frequency of 5.2 GHz and a reflection coefficient $|S_{11}|$ less than minus 17 dB [10, 11] (Fig. 4). It also includes a 3.5 mm ML with 50 Ohm resistance and a value of $|S_{11}|$ less minus 30 dB in the frequency range up to 18 GHz. To measure the emission amplitude, a Rohde & Schwarz ESPR 7 is used.

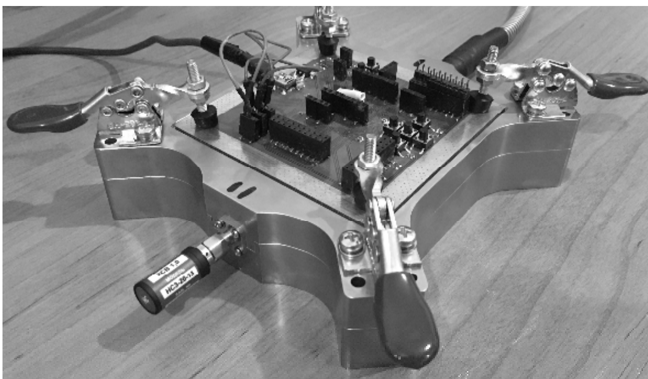

Fig. 4. Test set-up for measuring the radiated emission of the MC.

To reduce the contribution of the microcontroller operation to the measurement results, it is clocked at a minimum frequency of 8 MHz and cyclically calculates the values of the data array according to a given arithmetic expression.

A pulse power supply unit (PPSU), mains chargers (MC), and power banks (PB) of different manufacturers, as well as a USB port of the PC and a rechargeable battery (RB) of 18650 type, are used as power sources for the measuring PCB. All sources, except for the battery, had an output voltage of 5±0.2 V but different maximum output power. Also, the difference between sources is associated with their principle of operation. So the PPSU, MC, and USB-port are built according to a circuit containing a pulse-width modulation generator, and RB has a group of several batteries.

III. Measurement Results and Their Analysis

Measurement of the radiated emission of the microcontroller performed in the frequency range from 50 kHz to 5 MHz with a step of 9 kHz. Below, the frequency dependences of the voltage at the input of the test receiver will be given following the maximum values obtained by measuring the emission when the PCB with the microcontroller is rotated relative to the aperture of the TEM cell every 90 degrees.

A. Using the PPSU and the MC

From the results of emission measurements when the test PCB is powered by the PPSU, an increase in the frequency dependence of U is observed in the frequency range from 50 to 400 kHz with a peak level of A_1=29.51 dB at a frequency of f=282.7 kHz (Fig. 6). This growth is associated with the operation of the pulse-width modulation generator, and their increased amplitude with high output maximum power.

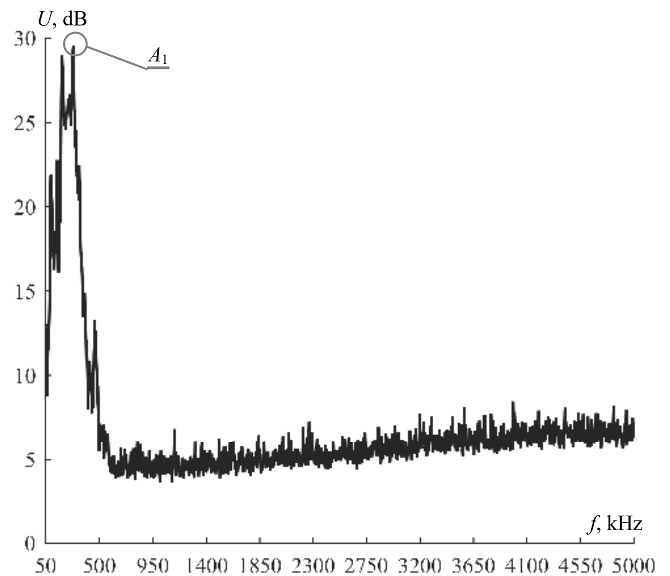

Fig. 5. Frequency dependence of the emission voltage U, measured using a PPSU.

From the frequency dependences of U when using power from sources MC 1 and MC 2 (Fig. 6) it can be seen that the maximum emission value was A_2=9.62 dB at a frequency of f=63.5 kHz when using MC 1. However, the emission peaks with levels A_3=16.47 dB and A_4=14.63 dB are pronounced for the MC 2 source at frequencies f=552.75 kHz and 4010 kHz, respectively.

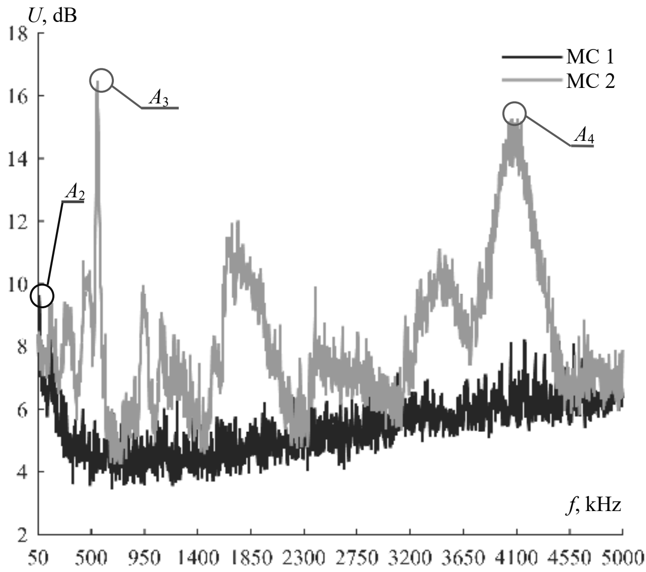

Fig. 6. Frequency dependence of the emission voltage U, measured using the MC 1 and MC 2.

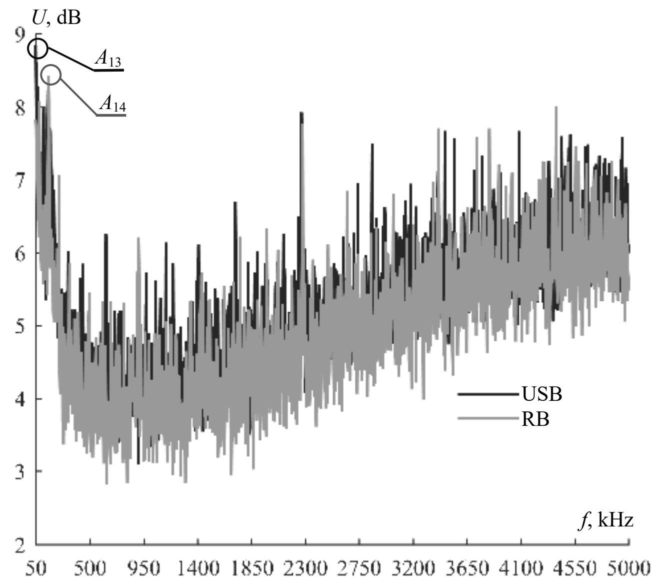

Fig. 8. Frequency dependence of the emission voltage U, measured using the USB port and RB.

B. Using the PB and the RB

Several emission peaks are observed in the investigated frequency range (A_5–A_{11}) with a maximum level of A_9=15.44 dB at a frequency of 2834.3 kHz when using the PB 1. The emission peak at a frequency of 2267.3 kHz with a level of A_{12}=9.2 dB is pronounced when using the PB 2 (Fig. 7).

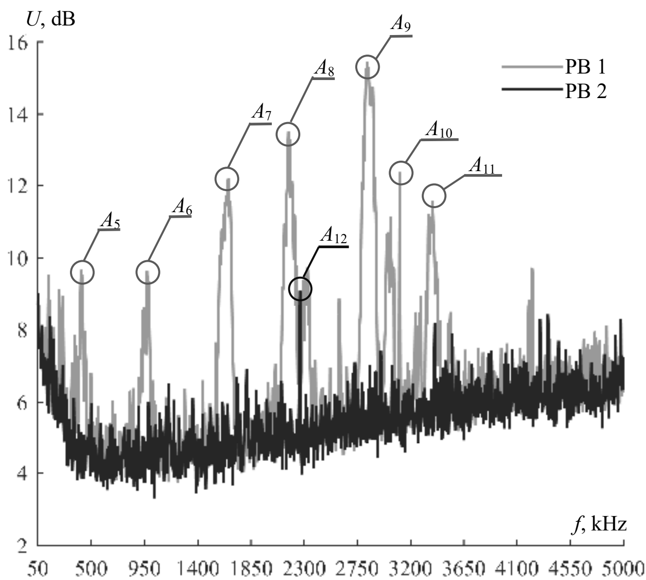

Fig. 7. Frequency dependence of the emission voltage U, measured using the PB 1 and PB 2.

The lowest emission level is observed when using the power supply from the USB port of the PC (A_{13}=8.84 dB at f = 50 kHz) and the RB (A_{14}=8.43 dB at f=159 kHz) (Fig. 8). Peak emission levels indicated in Figures 5-8 are summarized in Table I.

TABLE I. PEAK EMISSION LEVELS

Source	A	Emission Peak	
		Amplitude	***Frequency***
PPSU	1	29.51 dB	282.7 kHz
MC 1	2	9.62 dB	63.5 kHz
MC 2	3	16.47 dB	552.75 kHz
	4	14.63 dB	4010 kHz
PB 1	5	9.67 dB	417.25 kHz
	6	9.64 dB	973.5 kHz
	7	12.9 dB	1659.75 kHz
	8	13.53 dB	2168.25 kHz
	9	15.44 dB	2834.3 kHz
	10	12.37 dB	3108.75 kHz
	11	11.58 dB	3385.5 kHz
PB 2	12	9.2 dB	2267.3 kHz
USB	13	8.84 dB	50 kHz
RB	14	8.43 dB	159 kHz

From the Table, it can be seen that the PPSU has the greatest influence on the measurement results, while the emission amplitude was 29.51 dB. The largest number of emission peaks with levels in the range from 9.67 to 15.44 dB was detected when using the MC 1. It is also shown that when using an RB, the lowest measured emission level is 8.43 dB.

IV. CONCLUSION

The paper presents the results of a research of the radiated emission of 1986BE91T microcontroller in a TEM cell using various PS. It is shown that the highest level of emission is observed when using the power supply from the PPSU and MC. When using a battery, the lowest emission level is observed, and therefore it is advisable to use this type of PS for further study of radiated emissions from the IC.

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