College of women, Arts,
Science and Education
Physics Department.

Design, Analysis, Simulation, and Applications of 741 Op-Amps as a Signal Converter Circuits on Different Environmental Conditions

Thesis
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By

Wafaa Abed El-Basit Abed El-Rhman Abed El-Latif

Under Supervision of

Prof. Dr. Hoda A. Ashry
Professor of Radiation Physics
National Center for Radiation Research & Technology

Prof. Dr. Fouad A.S. Soliman
Professor of Electronics and Computer Eng.
Nuclear Materials Authority

Prof. Dr. Aisha M. Swidan
Professor of Electronics

Dr. Safaa M.R. El-Ghanam
Lecturer of Electronics

Physics Department
University College of Women for Arts, Science and Education
Ain Shams University

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دراسة تصميم و تحليل ومحاكاة و تطبيقات مكبرات العمليات فى الدوائر الرقمية فى ظروف بيئة تشغيل مختلفة

مقدمة من

وفاء عبد الباسط عبد الرحمن عبد اللطيف

المدرس المساعد بقسم الفيزياء
كلية البنات ـ جامعة عين شمس

للحصول على درجة الدكتوراه فى فلسفة العلوم
(الفيزياء)

تحت إشراف

أ.د/ هدى عبد المنعم عشرى
أستاذ الفيزياء الإشعاعية بالمركز القومى لبحوث و تكنولوجيا الإشعاع

أ.د/ فؤاد عبد المنعم سعد سليمان
أستاذ هندسة الإلكترونيات و الحاسبات
هيئة المواد النووية

أ. د/ عائشة مصطفى سويدان
أستاذ الإلكترونيات بقسم الفيزياء
كلية البنات جامعة عين شمس

د/ صفاء محمد رشدى الغنام
مدرس الإلكترونيات بقسم الفيزياء
كلية البنات جامعة عين شمس

كليــة البنات للعـلوم والآداب والتــربيــة
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بسم الله الرحمن الرحيم

(سبحانك لا علم لنا إلا ما علمتنا إنك أنت العليم الحكيم)

(صدق الله العظيم)

الآية (35) سورة البقرة.

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Abstract

The present thesis is devoted on studying the effect of the different environmental conditions (heat and radiation) on the electrical parameters of the four sets of 741 operational amplifiers (op-amps). The samples are chosen with different manufacturing techniques, they are: μA741 CN (Fairchild), LM741 CN (National Semiconductor), and HA17741 OK & HA17741 1D1 (Hitachi). The main investigated electrical parameters are input offset voltage, input bias current, input offset current, closed loop gain, common-mode rejection ratio, input impedance, output impedance and slew rate. Besides, the study is extended to include some applications for such commonly used amplifiers on the field of digital- and signal conversion- circuits; digital-to-analog, analog-to-digital converters, integrator, differentiator and Schmitt trigger. In this concern, the design and analysis of the different investigated circuits were carried out experimentally, where the obtained results were compared with those obtained either by applying a special Electronic Workbench Software Package or from mathematical models solved by computer programming using C++ language.

The effect of the circuit elements on the operation of the proposed signal conversion circuits (Integrator, Differentiator and Schmitt trigger) is considered experimentally, where the obtained results are shown to be in close agreement with the simulation- and theoretical- results.

The study is extended to include the effect of temperature (up to around 75 ^{o}C) on the electrical parameters of the different operational amplifiers and the operation of the proposed signal conversion circuits.

The obtained results were compared with those of the simulation, where an excellent agreement was achieved.

As the op-amps are widely used in many electronic instrumentation which can be exposed to different types of radiation, so, the present study can be considered as a trial to shed further light on the effect of gamma radiation on the physical and electrical properties of the proposed operational amplifiers. As well as on the operation of the investigated signal conversion circuits. It is clearly shown that a pronounced change occurs on the electrical characteristics of the op-amps., and consequently the devices may lose their main features. The input offset voltage, input offset current, and input bias current are shown to increase with increasing gamma dose. Also, the closed loop gain of the op-amps. are shown to decrease with increasing gamma dose, where its decreasing rate is considered as a function of the operating frequency value. As a result, the slew rate, common-mode rejection ratio and input impedance were shown to decrease with increasing gamma dose levels. On the other hand, and as the output impedance is inversely proportional to the gain; so, its value increases with increasing gamma exposure. Finally, it is clearly shown that the radiation dependence of the op-amp electrical parameters is a function of the fabrication technique of the op-amps, where, the op-amps of the types HA17741 1D1 and HA17741 OK are shown to be less sensitive to gamma rays exposure than the op-amps of the types LM741 CN and μA741 CN.

Also, the behavior of signal conversion circuits was studied under the effect of gamma rays dose levels (from 0 up to 20 kGy). The transfer functions of binary weighted resistor DAC and R-2R ladder DAC lose

their linearity, due to gamma exposure. On the other hand, there is a decrease in the output voltage of the ladder R-2R DAC circuit under the influence of gamma ray. While the radiation slightly affected the transfer function of flash analog-to-digital converter.

In the integrator and differentiator circuits, the dc voltage increases with increasing the input offset voltage of operational amplifiers. This input offset voltage increases with increasing radiation doses, so, the output waveforms of both circuits the maximum-and-minimum-edges are shifted upward. On the other hand, the gain of these circuits was independent on gamma doses from the low frequency up to around 40 kHz, but in higher frequencies the gain decreases. Also, the results show that, the maximum and minimum edges at different gamma doses of integrator and differentiator were dependent on frequency values in all op-amps.

Finally, in the Schmitt trigger circuit, the lower threshold voltage level (LTL) increases with increasing the offset voltage, which increases with increasing γ-dose levels.

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List of Symbols and Abbreviations

Op-Amp	Operational amplifier
DAC	Digital-to-analog converter
ADC	Analog-to-digital converter
V_{io}	Input offset voltage
I_B	Input bias current
I_{io}	Input offset current
Z_{in}	Input impedance
Z_{out}	Output impedance
A_o	Open-loop voltage gain
SR	Slew rate
CMRR	Common-Mode Rejection Ratio
GBW	Gain bandwidth product
f_T	Unity gain bandwidth
A_C	Closed loop gain
	Feedback ratio
A_o	Loop gain
A_d	Differential gain
A_{cm}	Common-mode gain
dB	Decibel
LSB	Least-significant bit
MSB	Most-significant bit
DNL	Differential non linearity
INL	Integral non linearity
Maximum	The maximum amplitude, typically the most positive peak voltage

Minimum	The minimum amplitude, typically the most negative peak voltage.
LTL	Lower trigger level
UTL	Upper trigger level