RELIABILITY STUDY OF SELECTED ELECTRONIC COMPONENTS- A CASE STUDY OF RESISTORS

[1,2]Oluyo, K.S., [3]Nwosu, E.U.,[1] Sode, A.T. and [2,4]Fasesin, S.B.
Department of Physics, Lagos State University, Ojo – Nigeria.
Department of Physical Science, Yaba College of Technology, Lagos – Nigeria.
Department of Industrial Maintenace Engineering, YabaTech., Lagos – Nigeria.
West African Examination Council (WAEC), International Office, Lagos – Nigeria.

Abstract
Instrumentation and control electronics have been established as vital aspects of lots of processes, ranging from manufacturing to regulation for standard as with the Standard Organisation of Nigeria (SON), and the National Agency for Food and Drug Administration and Control (NAFDAC) as well as in oil exploration, transport (road, rail, marine, air) management, technical projects for research and development just to mention a few. Beyond these civil uses of instruments, the military even rely more on control instruments for precision of reliable military operations. Like any electronic gadget, a control electronic instrumentation system, comprising units (e.g. oscillator, amplifier, power supply etc.), is composed of components) like resistors, inductors, capacitors, integrated circuits, thyristors, crystals, inductors, sensors etc. This study investigates the gap between rated and measured values of selected range of components, namely: resistors. A specified variation is expected between the nominal and rated values. This specified deviation is called "tolerance". Every resistor has a specified tolerance range over which the resistance value is allowed to vary; anywhere from approximately 0.1% to 20% of the nominal value. The resistors used for this study, were sourced only from a central location in Lagos (Mushin) South-West Nigeria. Measured values notably vary from the rated values but most variations fall within coded range indicated on the components. The resistors were also tested for reliability in selected circuits. The disparity in values did not significantly affect the circuit performance in the cases examined. Resistors with values above 100 ohms show high difference while those below 100 ohms show minimal error. Components in the category investigated from Mushin may be rated good for instrument maintenance and precision electronic project for students and researchers.

1.0 KEYWORDS: Control instrumentation, reliability, circuit performance, maintenance.

2.0 Introduction

Resistors come in many sizes, shapes, power ratings and tolerances (Holowitz and Hill, 1997). Some have values stamped on the case, while others have a group of colour bands that allows experts to make out the values. Theses discrete components are devices manufactured specifically to provide a fixed or variable resistance to fit a particular electrical circuit application.The field of electronics is run by devices called components. These components may be active or passive. Resistors, capacitors, inductors, thyristors, transistors, integrated circuits (IC), sensors are examples, just to mention a few. Instruments are electronics systems made of these components. Precisely, any technical system is an assembly of components that are connected together to form a functioning unit (Oluyo et al, 2012). This unit is usually variously called a machine, equipment or instrument. Collection, use, operation or study of instrument is called instrumentation. Instrumentation is central to control systems either in the military or in civilian applications. The focus of this research is resistor- a component which offers opposition to the flow of current (with constant resistance). The resistor is one of the simpler electronic components.

Electronic technology is now dominated by semiconductor devices, which era started in 1947 with Bardeen, Brattain and Shockley (Holowitz and Hill, 1997) of Bells Laboratory as a successor of the vacuum technology. The performance or otherwise of a machine is a function of the state of the composing devices, namely components. If a component does not perform as expected it is said to have failed. Component failure may be gradual, sudden or catastrophic.

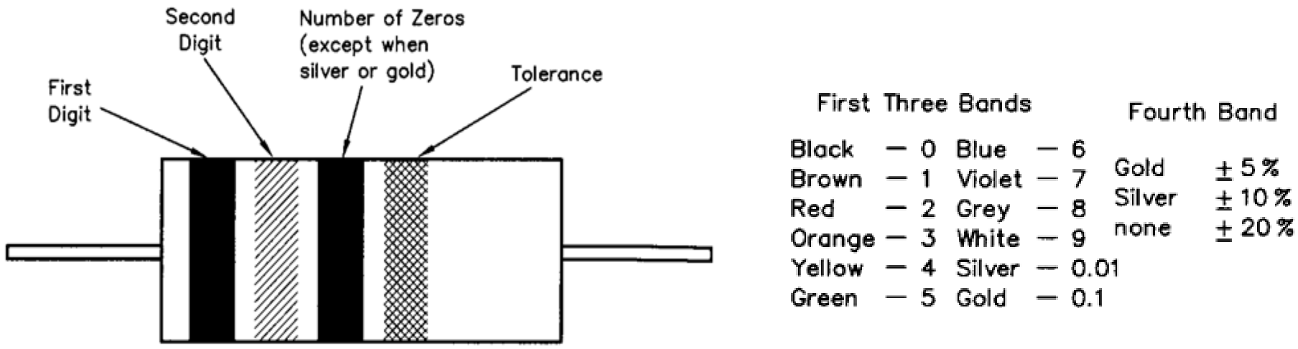

Figure 1: Carbon Film Resistor with Colour Code

The failure of a component (Loveday, 1988) in any equipment thus leads to system failure. Failure is said to be the inability of a system to perform its required function (Aggarwal, 2007). The need for continuous performance of an instrument requires that it is given regular maintenance. The resistor is one of the simpler electronic components. The resistor is hardly suspected during maintenance routines and resistor characteristics may not even be given any attention until there's a resistor-related problem with a circuit design. As a service expert, say engineer or technician, it is pertinent to consider some questions about the resistor prior to fixing a resistor related fault condition(Loveday, 1988). Ask first, what makes a resistor fail? Then, by how much can the resistance vary? Furthermore, ask what magnitude of surge can it withstand? What level of heating is expected in the resistor? A good percentage of resistor related issues may be resolved after answering these five key questions. Empirically, temperature, voltage, resistance, surge are the factors which play very important roles in failure of a resistor.

In order to specify resistors, certain rated parameters have to be indicated. These technical features include resistance value in ohms, power in watts, have rated values

a) **Value:** Resistance (ohm: Ω, k Ω, or m Ω; 1 k Ω = 10^3 Ω, 1 M = 1000 K Ω = 1,000,000Ω): indicated by colour code or written.
b) **Power:** Indicated by the size of the resistor.
c) Tolerance of the resistance: indicated by the colour code.
d) **Features:** Measured resistance corresponds with the indicated value (within the limits of the tolerance).
e) **Faulty:** Open circuit reading
f) Replace with: Resistor with same resistance (identical or better tolerance) same or higher power dissipation.

2.1 RESISTOR FAILURE

Resistor failure (Loveday, 1988)is considered to be electrical opens (open circuit), shorts (short) circuit) or a radical variation from the resistor specifications, (Watkins and Russell, 1984). Recall that components generally may fail gradually, suddenly or catastrophically (Oluyo, et al, 2012). Each of gradual failure, sudden failure or catastrophic failure may be the open circuit, short circuit or radical variation kinds of failure.

2.2 APPLICATIONS

Resistors, especially the general purpose ones, are variously used for impedance matching, loading, biasing, to limit current flow (Holowitz and Hill, 1997) and reduce voltage for many other applications while in the adjustable resistor form is used as volume control as isthe stereo, TV set, transistor or car radio. Two parameters, STOL and voltage stress are considered in this study to explain the behaviour of a given resistor, wire wound, film or composition type, behaviour prior to failure. The composition type are not used in critical applications e.g. on the medical instrumentation in which case a high reliability is a requirement.

2.3 SHORT-TIME-OVERLOAD (STOL)

This is a technical concept that is used to understand a resistor's expected voltage input and this is empirically deduced from the power rating (Watkins and Russell, 1984), which is indicated by the size of the component. STOL is a non-repetitive surge or overload condition. A maximum allowable STOL voltage exists for a given resistor. This is typically two times the maximum continuous rated voltage (V_{RATED}). In practice, ifa resistor is fed two to ten times the rated power for more than 5 or 10 sec, the component may be permanently damaged and can melt the solder joints that hold the part in place. The applied power correlates with operating temperature, which relates to oxidation.

2.4 VOLTAGE STRESS

Voltage stress is a concept that plays a vital role in resistor failure. Normally, this stress comes into play only on resistors with resistance of more than 100 kΩ and voltage of more than 500V. Voltage stress has become a problem if a modest voltage-stress overload results in a negative change in resistance that exceeds the value for the maximum-STOL-percent change!

2.5 INSTRUMENTS PERFORMANCE

Machines at work must be sustained at optimum performance (Aggarwal, 2007). This is impossible if maintenance and repairs become a hard task to achieve. Resistor-related problems come up in circuit designs from time to time. Hence component failure is a commonplace on the field of electronics. A component is said to have failed when it open circuits, short circuits or exhibits radical variation. A component misbehaves in any of the states and it is no longer reliable. However the reliability (Aggarwal, 2007) of an electronic system stems from that of its components. This study sets to investigate how reliable components sourced from a location in Lagos can be when called upon for electronic repairs or component replacement. Maintenance culture is key to any economy as this has a direct bearing on technology dependent systems and organisations. Ohm (1828) propounded a law (Ohm's Law) which relates the current (I), potential difference (V) and the resistance (R) and this is the scientific method by which the behaviour of a resistor is estimated.

3.0 Material and method

Resistors were selected from Mushin market located at Ido Oro, Lagos. South-West, Nigeria. Once mounted, the assumptions are that, the resistors in question have no defects, they perfectly terminate, and attach to the pc board (say) with an ideal solder joint. The first stage used one thousand (1000) selected components (resistors) in four (4) categories with nominal values of

(a) 33Ω, 39 Ω, 56 Ω and 68 Ω.
(b) 160 Ω, 480 Ω and 220 Ω.
(c) 1KΩ (1K0 for short),1K8, 2K2 ,3K3, 3K9 and 4K7.
(d) 10K9, 15K0, 27K0, 30K0, 33K0, 100K0, 560K and 1M Ω.

The nominal (rated) values were determined using resistor colour codes. Using high sensitive test equipment, namely, a professional digital multimeter (previously calibrated for accuracy), each resistor was measured using appropriate meter ranges. Tolerance then estimated! Circuits (shown in Figures2 and 3) were built and selected components were tried as replacements for initial components and circuit performance then studied. A consideration study for precision application outside normal civil use is also included in the analysis to cover the possibility of military engineering application. Recall that such applications (military engineering applications) require high precision for reliable delivery of strategic military services (Oluyo et al, 2012), especially if it concerns warfare and remote sensing or control. Such benchmarks as what is called "Established Reliability" becomes the yard stick to which the components have to conform to.

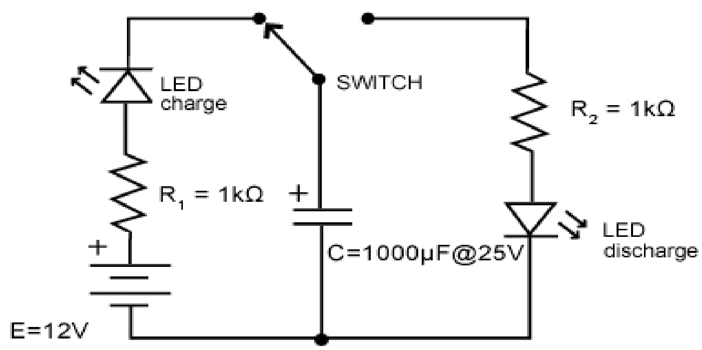

Figure 2: Test Circuit 1-Capacitor charging and discharge circuit.

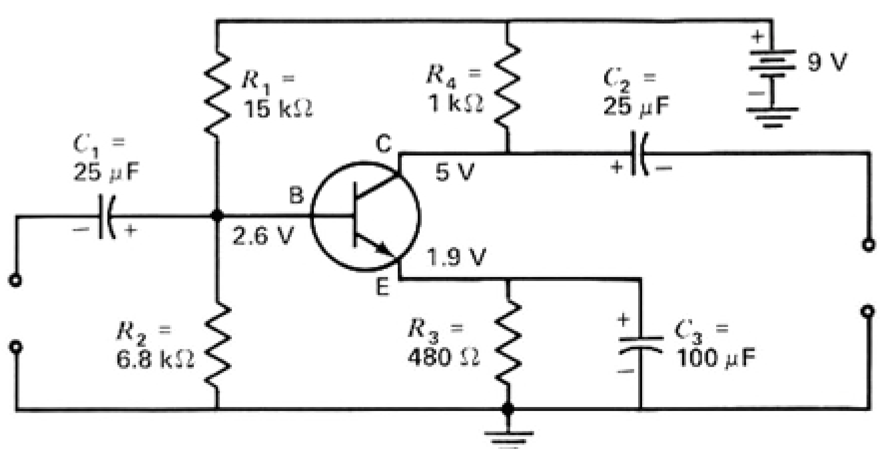

Figure 3: Test Circuit 2- Single stage amplifier

4.0 RESULT

We present the results of this study as tables 1 and two. Results of the follow up experiments presented as test circuits (Figures 2 and 3) were monitored using portable digital dual channel oscilloscope with capability to display both input and output simultaneously. We present a replica each of the input and output of test circuit 2 in Figures 4 and 5.

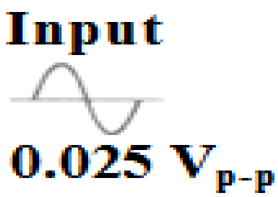

Figure 4: A replica of the input to Test Circuit 2

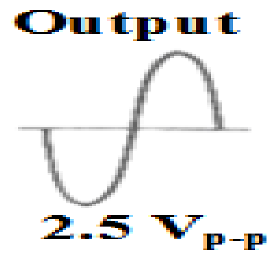

Figure 5: A replica of the output of Test Circuit 2

The summary of the resistance value measurements (measured or nominal value/**Ω**) and colour coded values (rated value/ **Ω**) is presented as tables 1 and 2.

Table 1: Results of rated and nominal values of selected resistors

SN	Rated Value/Ω	Measured Value/Ω	Difference/Ω	% Error
1	33	32.5	0.5	1.54
2	39	38.8	0.2	0.52
3	56	54.5	1.5	2.75
4	68	66.5	1.5	2.26
5	160	97.6	**62.4**	**x**
6	220	213.0	7.0	3.29
7	1000	700.0	**300.0**	**x**
8	1800	980.0	**820.0**	**x**
9	2200	2090.0	110.0	5.26
10	3300	3230.0	**70.0**	2.17
11	3900	3800.0	100.0	2.63
12	4700	4300.0	400.0	9.30
13	10000	9910.0	90.0	0.91
14	15000	14820.0	180.0	1.21
15	27000	26200.0	800.0	3.05
16	30000	29400.0	600.0	2.04
17	33000	32400.0	600.0	1.85
18	100000	97700.0	2300.0	2.35
19	560000	545000.0	15000.0	2.75
20	1000000	980000.0	20000.0	2.04

Table 2: Results of rated and nominal values of test resistors ("spurious" values omitted)

SN	Rated Value/Ω	Measured Value/Ω	Difference/ Ω	% Error
1	33	32.5	0.5	1.54
2	39	38.8	0.2	0.52
3	56	54.5	1.5	2.75
4	68	66.5	1.5	2.26
5	160	97.6	**62.4**	**63.93**
6	220	213.0	7.0	3.29
7	1000	700.0	300.0	**64.86**
8	1800	980.0	820.0	**83.67**
9	2200	2090.0	110.0	5.26
10	3300	3230.0	70.0	2.17
11	3900	3800.0	100.0	2.63
12	4700	4300.0	400.0	9.30
13	10000	9910.0	90.0	0.91
14	15000	14820.0	180.0	1.21
15	27000	26200.0	800.0	3.05
16	30000	29400.0	600.0	2.04
17	33000	32400.0	600.0	1.85
18	100000	97700.0	2300.0	2.35
19	560000	545000.0	**15000.0**	2.75
20	1000000	980000.0	**20000.0**	2.04

5.0 Discussion

The result of measurements of resistor values is given in table 1. It is observed that resistor values less than 100 Ω (see serial 1 to 4 on Table 1) show minimal deviation from rated values. The least error is recorded for 39 Ω resistors with a maximum error recorded for 56 Ω.

However a rather erratic deviation is observed for each resistor above 100 Ω except for 220 Ω with a 3.29% error among error values of over 60% in each of 160 Ω, 1 KΩ and 1K8Ω. This rather strange tendency prompted some statistical investigations in which the average error as well as standard deviation was computed for all test resistor categories. The result (12.9Ω ±25.3Ω) shows that the deviation is large with the inclusion of 160 Ω, 1 KΩ and1K8Ω. Table 2 shows the result of Table 1 with the resistor values above 100ohms (shown in red) removed as indicated with x in red (see Table 2 serial 5, 7 and 8) and the result returns a relatively normal error of 2.7Ω ±2.0Ω. The implication of this investigation is that minimal error is expected in a real life application where the resistors (sourced from Mushin, Lagos South West Nigeria) are in use with higher reliability provided resistors of values above 100 Ω (in red) are not included. To this end the Test Circuit 1 involves two (2) 1 KΩ resistors incorporated in a capacitor charge and discharge circuit shown in Figure 2. The result of the empirical investigation was satisfactory as the outcome does not deviate significantly from the expected circuit behavior. But this is not a sensitive or precision circuit, it rather a simple illustration. The foregoing leads to a relatively complex circuit of Test Circuit 2 comprising a 1 KΩ resistor shown in the single stage amplifier circuit of Figure 2 alongside three (3) other resistors (480Ω, 6.8 KΩ and 15 KΩ) carefully selected from the lots. The output was monitored using portable dual channel oscilloscope to enable simultaneous display of both input and output. The gain was monitored and was satisfactory with 98.85% agreement with the expected outcome circuit performance. This translates to acceptable reliability. Note that the entries in serial 19 1nd 20, namely 560 KΩ and 100 KΩ nominal values, recorded rather high numerical differences (hence indicated in red) but statistically bearable errors as these error values (2.75% and 2.04%) are among the acceptable figures being within the 2.7Ω ±2.0Ω range. The difference column (2072Ω ±5364Ω) is greatly influenced by high valued resistor entries of serial 7 through 20 as recorded in Tables 2 and 3.

In a follow up study a number of high precision wire wound resistors were investigated. The resistors are in three categories, namely 0.1 Ω, 0.22Ω and 0.47Ω alongside with a number of 1Ω metal film resistors. Our result shows that only themetal film resistors have their values in ranges defined by the tolerance. The metal film resistors show marked deviations from the rated values. In order to ascertain if the results are consistent with practical reality various digital meters were used in turn to determine their values. The resistors marked 0.1 Ω gave 0.2 Ω, the ones marked 0.22Ω gave 0.4Ω while the ones marked 0.47Ω gave 0.6Ω on average. This goes to suggest that the reliability of this category of components in practical application is questionable.

5.1 Conclusion

Resistor reliability is empirically a function of a number of variables. Certain category of resistors seem to be technically dependable than other categories in terms of rated values. Reliability of a components as empirically determined by a researcher may necessarily be reported with remark on the type of measuring instruments used to ascertain the parameters that led to the reliability figure.

5.2 Recommendation

Copious practical investigation is recommended to establish some findings of this study. The rated values are hereby suggested not to be taken on the face value for practical applications or usage, especially where precision and accuracy are subject of interest.

6.0 Acknowledgement

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