IEC 62047-5

Edition 1.0 2011-07

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Semiconductor devices – Micro-electromechanical devices – Part 5: RF MEMS switches

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Dispositifs à semiconducteurs – Dispositifs microélectromécaniques – Partie 5: Commutateurs MEMS-RF

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SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 5: RF MEMS switches

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The text of this standard is based on the following documents:

FDIS	Report on voting
47F/83/FDIS	47F/93/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 62047 series, under the general title *Semiconductor devices – Micro-electromechanical devices*, can be found in the IEC website.

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- withdrawn,
- replaced by a revised edition, or
- amended.

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SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 5: RF MEMS switches

1 Scope

This part of IEC 62047 describes terminology, definition, symbols, test methods that can be used to evaluate and determine the essential ratings and characteristic parameters of RF MEMS switches. The statements made in this standardization are also applicable to RF (Radio Frequency) MEMS (Micro-Electro-Mechanical Systems) switches with various structures, contacts (d.c. contact and capacitive contact), configurations (series and shunt), switching networks (SPST, SPDT, DPDT, etc.), and actuation mechanism such as electrostatic, electro-thermal, electromagnetic, piezoelectric, etc. The RF MEMS switches are promising devices in advanced mobile phones with multi-band/mode operation, smart radar systems, reconfigurable RF devices and systems, SDR (Software Defined Radio) phones, test equipments, tunable devices and systems, satellite, etc.

2 Normative references

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IEC 60747-1: 2006, *Semiconductor devices – Part 1: General*

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IEC 60747-16-1, *Semiconductor devices – Part 16-1: Microwave integrated circuits – Amplifiers*

IEC 60747-16-4:2004, *Semiconductor devices – Part 16-4: Microwave integrated circuits – Switches*

IEC 60749-5, *Semiconductor devices – Mechanical and climatic test methods – Part 5: Steady-state temperature humidity bias life test*

IEC 60749-10, *Semiconductor devices – Mechanical and climatic test methods – Part 10: Mechanical shock*

IEC 60749-12, *Semiconductor devices – Mechanical and climatic test methods – Part 12: Vibration, variable frequency*

IEC 60749-27, *Semiconductor devices – Mechanical and climatic test methods – Part 27: Electrostatic discharge (ESD) sensitivity testing – Machine model (MM)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE In the text of this standard, the term of switch is used instead of RF MEMS switch to improve the readability.

3.1 Switching operation

3.1.1
capacitive switch
switch whereby an RF signal is passed or blocked by a change of impedance ratio caused by the capacitive effect of making contact using a movable metal plate onto a dielectric film presented on a fixed metal plate

3.1.2
d.c. contact switch
switch whereby an RF signal is passed or blocked by a movable metal contact

3.2 Switching configuration

3.2.1
series switch
switch whereby an RF signal applied to the input port is directly passed to the output port when a movable plate makes contact with a fixed plate

3.2.2
shunt switch
switch whereby an RF signal applied to the input port is passed to the ground plane when a movable plate makes contact with a fixed plate

3.3 Actuating mechanism

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3.3.1
electro-statically actuated switch
switch whereby a moving plate is pulled down onto the fixed plate by an electrostatic force caused by the applied d.c. bias voltage, the moving plate returns to its original position when the bias voltage is removed

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NOTE Advantages are virtually zero power consumption, small electrode size, relatively short switching time, and relatively simple fabrication and disadvantage is higher actuation voltage.

3.3.2
electro-magnetically actuated switch
switch whereby a movable plate or armature is pulled down onto a fixed plate by a magnetic force generated by a permanent magnet or an energised electromagnet

NOTE Advantage is a low actuation voltage and disadvantages are complexity of fabrication and high power consumption.

3.3.3
electro-thermally actuated switch
switch whereby a movable plate constructed of two or more differing materials with differential thermal expansion coefficients deflects to contact a fixed plate or electrode

NOTE Advantages are nearly linear deflection-versus-power relations and environmental ruggedness and disadvantages are high power consumption, low bandwidth, and relatively complex fabrication.

3.3.4
piezo-electrically actuated switch
switch whereby a movable plate constructed of piezoelectric materials deflects to contact a fixed plate or electrode

3.4 Switching network configurations

3.4.1
single-pole-single-throw switch
SPST
device with a single input and a single output, which is providing an ON-OFF switching function with switch actuation

3.4.2
single-pole-double-throw switch
SPDT
device with a single input and two outputs, which is transferring the through connection from one output to the other output with switch actuation

3.4.3
single-pole-multi-throw switch
SPMT
device with one input and multiple outputs whereby connection to one or the other of the multiple outputs is determined by switch actuation

3.4.4
double-pole-double- throw switch
DPDT
device with two inputs and two outputs, which is transferring the through connection from one output to the other output with switch actuation

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3.4.5
multi-pole-multi-throw switch
MPMT
device with multi inputs and outputs, which is transferring the through connection from multi outputs to the other multi outputs with switch actuation

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3.5 Reliability (performance)

3.5.1
life time cycles
number of actuating times which the switches are operating with satisfactory electrical performances in the on/off positions

NOTE Unlike the electronic switch, a mechanical switch may fail due to stiction (micro-welding and material transfer) of a moving part and degradation of metal to metal contact used, whereas at electronic RF switches (capacitive switch) the reliability is limited by dielectric charging (charge injection and charge trapping).

3.5.2
cold switching
performed switching where the RF power is not applied during the switch operation

NOTE It is useful for examining the durability of the switch electrode to see if it can withstand the physical stresses of repeated switching.

3.5.3
hot switching
performed switching where the RF power is applied during the switch operation

NOTE The hot-switching tests are indicative of how the switch will survive under actual operating conditions, with current flowing through the device.

3.6 Electrical characteristics

3.6.1
d.c. characteristics

3.6.1.1
actuation voltage
d.c. voltage for the movable electrode (or membrane) of the switch being collapsed down onto the fixed plate and kept securing RF characteristics desired

3.6.1.2
on resistance – DC contact type
electrical resistance which is measured across fully closed contacts at their associated external terminals

3.6.1.3
off resistance – DC contact type
electrical resistance which is measured across fully opened contacts at their associated external terminals

3.6.1.4
on capacitance – Capacitive type
electrical capacitance which is measured in the down-state position (the movable electrode collapsed down on the dielectric layer on top of the fixed electrode) of the switch

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3.6.1.5
off capacitance – Capacitive type
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electrical capacitance which is measured in the up-state position of the switch (before the movable electrode is being actuated)

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3.6.1.6
power consumption
power consumed to pull down and hold the movable plate onto the fixed electrode when the switch is ON

3.6.2
RF characteristics

3.6.2.1
insertion loss
[IEC 60747-16-4:2004, 3.1]

3.6.2.2
isolation
[IEC 60747-16-4:2004, 3.2]

NOTE It is caused by a RF energy leak from one conductor to another by radiation, ionization, capacitive coupling, or Inductive coupling.

3.6.2.3
return loss
[IEC 60747-16-4:2004, 3.3]

3.6.2.4
voltage standing wave ratio
VSWR
ratio of the electrical field strength at a voltage maximum on a transmission line to the electrical field strength of an adjacent voltage minimum

3.6.2.5
resonant frequency
frequency occurred at LC series resonance when the switch is up-state and down-state position, respectively

3.6.2.6
bandwidth
frequency range where the switch has good RF characteristics enough to use in subsystems and system applications

NOTE It is usally expressed as either the frequency or percentage differences between the lower or the upper relative 1 dB points of the frequency response curve.

3.6.2.7
power handling capability
capability of a switch to transmit a given amount of power through the device when the switch is on

3.6.3
Switching characteristics

3.6.3.1
self actuation power
radio frequency power where the switch movable plate is self-actuated without any voltages being applied directly to it

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3.6.3.2
switching time

3.6.3.2.1
turn on time
[IEC 60747-16-4:2004, 3.6]

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3.6.3.2.2
turn off time
[IEC 60747-16-4:2004, 3.7]

3.6.3.2.3
rise time
transition time of the switch from OFF to ON state

NOTE OFF state: 10 % of C_{up} , ON state: 90 % of C_{down}.

[IEC 60747-16-4:2004, 3.8]

3.6.3.2.4
falling time
transition time of the switch from ON to OFF state

[IEC 60747-16-4:2004, 3.9]

4 Essential ratings and characteristics

4.1 Identification and types

General description of the function of RF MEMS switches and their applications should be stated. The statement should include the details of manufacturing technologies about the RF MEMS switches with different operation, configuration, and actuation mechanism. The

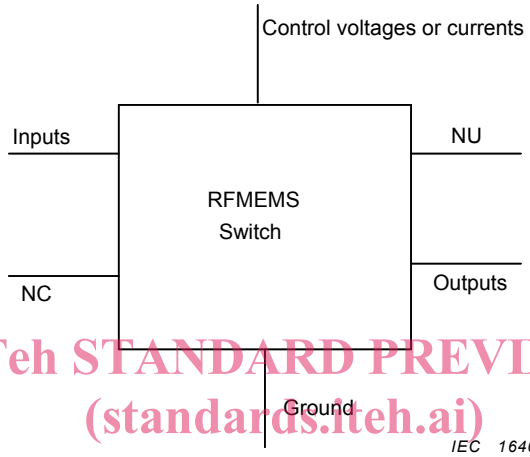
statement should also include packaged form including terminal numbering and package materials.

See 4.1 of IEC 60747-16-4:2004.

4.2 Application and specification description

Information on application of the RF MEMS switch shall be given. Block diagrams of RF MEMS switches and the applied systems should be also given. All terminals should be identified in the block diagram and their functions shall also be stated.

See 4.2 and 4.3 of IEC 60747-16-4:2004.



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NOTE NC is a non-connected terminal and NU is a non-usable terminal.

Figure 1 – Terminals of RF MEMS switch

4.3 Limiting values and operating conditions

This statement should include limiting conditions and values. In particular, electrical limiting values (control voltages or control currents, input power, handling power, power dissipation, etc.) and temperature conditions (operating, ambient, storage, and soldering) shall be given in the statement. These values are indicated within the table including the note.

Parameters (note)	Symbols	Min.	Max.	Unit

See 4.4 and 4.5 of IEC 60747-16-4:2004

4.4 DC and RF characteristics

DC and RF characteristic parameters shall be stated with Min., Nominal, and Max. in a table form.

Characteristics	Symbols	Conditions	Min.	Nominal	Max.	Unit

4.5 Mechanical and environmental characteristics

Any specific mechanical characteristics and environmental ratings applicable shall be stated. The characteristics shall be stated with Symbol, Unit, Min, Nominal, and Max. in a table form.

See 4.6 of IEC 60747-16-4:2004.

4.6 Additional information

Some additional information shall be given such as equivalent input and output circuits (eg. Input/output impedance, d.c. block capacitors, etc.), internal protection circuits against high static voltages or electric fields, handling precautions, and application data/information, etc.

See 4.8 of IEC 60747-16-4:2004.

5 Measuring methods

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5.1 General

This clause prescribes measuring methods for electrical characteristics of RF MEMS switches used at d.c. to microwave frequency bands.

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5.1.1 General precautions

Special care shall be taken to use d.c. supplies, the input RF power supplies, and all bias supply voltages for the measurement of RF MEMS switches. The level of the input and/or output signal shall be specified in either power or voltage.

5.1.2 Characteristic impedances

The input and output characteristic impedances of the measurement systems are 50 Ω. If they are not 50 Ω, they shall be specified.

5.1.3 Handling precautions

See Clause 8 of IEC 60747-1:2006.

5.1.4 Types

RF MEMS switches in this standard are both packaged and chip types, measured using suitable test equipments and fixtures.

5.2 DC characteristics

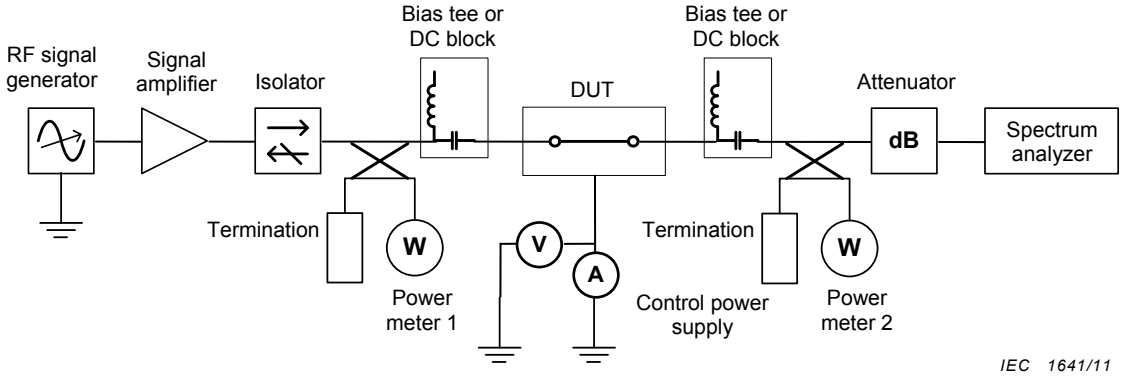
5.2.1 DC actuation voltage

5.2.1.1 Purpose

To measure the optimal control d.c. voltage to satisfy the desired RF characteristics.

5.2.1.2 Circuit diagram

Figure 2 shows a circuit diagram for measuring d.c. actuation voltage and RF characteristics of RF MEMS switches.



Key

Components and meters to monitor		Equipments and supplies	
DUT: device under test	a piece of RF MEMS switches	RF signal generator:	to supply a specified RF signal to a type of the signal amplifier
V:	DC voltage source for operating the DUT	Signal amplifier:	to apply a level of amplified signal to the input port of a piece of DUT through the isolator
A:	DC current source for operating the DUT	Isolator:	to apply the amplified input power to a piece of DUT without being returned to a signal amplifier
W:	power (watt) meter to monitor output power (watt) value of a piece of testing device	Bias tee or d.c. block:	to block a level of d.c. signal between the input and output orts of the DUT
dB:	attenuator to reduce the output power of DUT for protecting the spectrum analyzer	Control power supply:	to apply a specified bias voltage to a piece of DUT
Spectrum analyzer:	to measure the spectrum through the DUT	Termination:	to keep the measured power level steady

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NOTE 1 The control bias for RF MEMS switch is supplied to become ON or OFF between the input and output ports.

NOTE 2 The purpose of the isolator is to enable the power level to the device being measured to be kept constant without considering the mismatched input impedance. Bias tee is used to block the d.c. signal between the input and output ports of device being measured.

Figure 2 – Circuit diagram for measuring d.c. actuation voltage and RF characteristics of RF MEMS switches

5.2.1.3 Principle of measurement

When a control voltage keeps increasing between the driving electrodes (a movable electrode and a fixed electrode), it is measured during the movable plate of the RF MEMS switch being collapsed down onto the fixed plate and kept securing the desired RF characteristics.

5.2.1.4 Measurement procedure

The frequency of the RF signal generator shall be set to the specified value.

An adequate input power shall be applied to the device being measured.