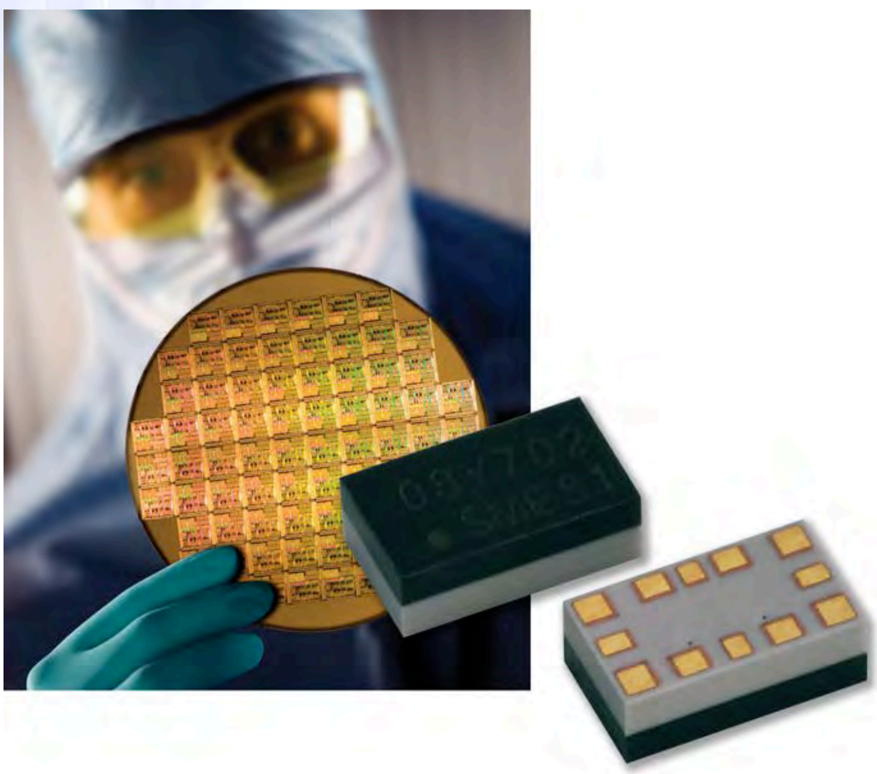
White Paper:

RF MEMS Switching: What You Need to Know

Structure and Usage of OMRON MEMS Switch 2SMES-01



MEMS RF Switch

Type: 2SMES-01

1 Outline

In this application note, the basic operation principle and driving method for OMRON's MEMS switch (2SMES-01), that has an electrostatic actuator, will be described.

2 Features

- Enable mechanical ON/OFF switching with MEMS technology
- Low insertion/return loss and high isolation for GHz signal
- Superb endurance (more than 100M switching operations)
- Small size (5.2 x 3.0 x 1.8 mm, LGA12)
- Low power consumption (less than 10μW)

3 Structure

3.1 Basic Structure of MEMS Switch (SPDT)

OMRON's MEMS switch has a SPDT（**S**ingle **P**ole **D**ouble **T**hrow） contact configuration. Two MEMS chips that have a SPST (**S**ingle **P**ole **S**ingle **T**hrow） contact configuration are installed on the ceramic package using the flip chip bonding method as shown Fig.1.

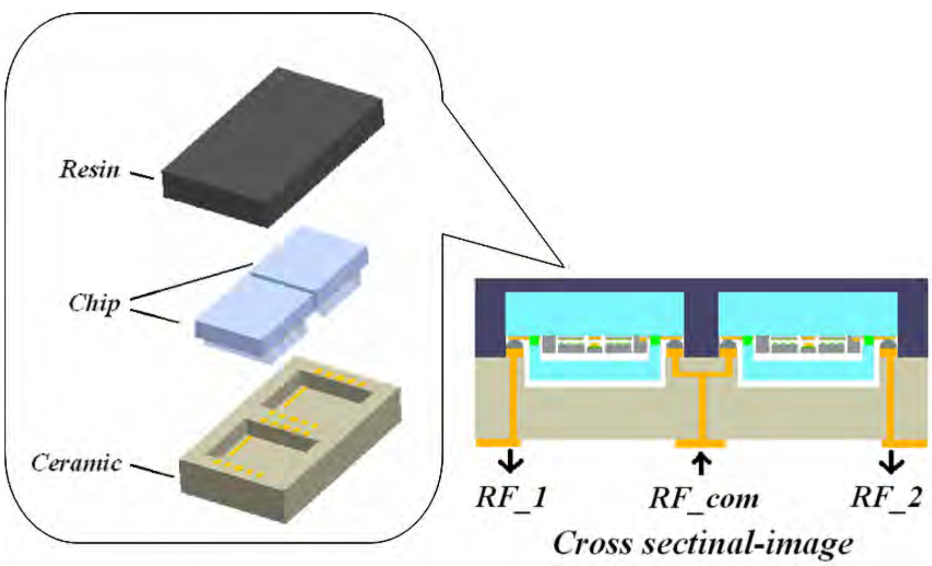


Fig.1 SPDT Package Structure

3.2 Basic Structure of MEMS Switch (bare CHIP)

The basic structure of MEMS switch consists of three layers which are Glass-Silicon- Glass, as shown Fig. 2. It has a SPST contact configuration, “1a”, normally open type. The top glass part is used for protecting the actuator and hermetic sealing. The middle silicon section contains the actuator and movable electrode. A capacitor is built up between the fixed electrode and movable electrode. The signal line and fixed electrode are made on a glass base. When applying the voltage between Fixed Electrode and Movable Electrode, an electrostatic force is generated and it pulls in the Movable Electrode (actuator). When the driving voltage becomes OFF, the electrostatic force will disappear, and then the actuator will go back to the original position because of a self-restoring force. The signal line and the movable contact consist of pure metal wiring, and serve as a mechanical switch which can handle DC to High Frequency signals.

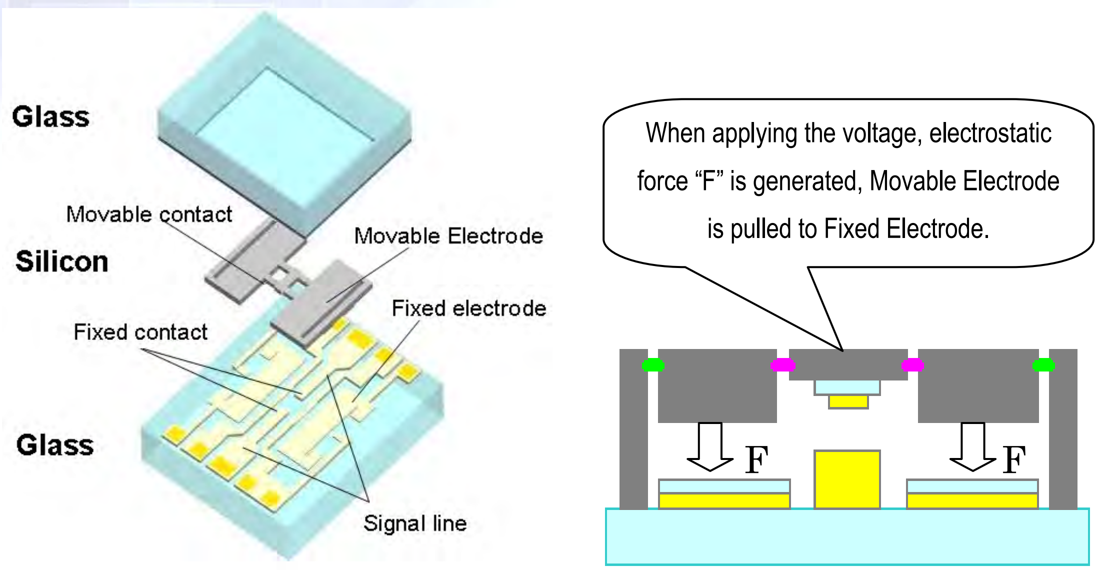


Fig.2 Internal Structure of MEMS Switch (CHIP)

4 Operating Principle

4.1 Operating principle and Structure of Electrostatic Actuator

This electrostatic actuator's basic structure is a parallel plate type capacitor. The electrostatic force generated between the two electrodes is represented by the following equation. Where F is the electrostatic force, ε0 and εr are the dielectric coefficients for a vacuum and a surrounding gas, respectively, and S is the area of the electrode. V is the applied voltage, and d is the average gap between the two electrodes. The MEMS switch can be operated by using this electrostatic force.

$$F = \frac{\varepsilon_0 \varepsilon_r S V^2}{2d^2}$$

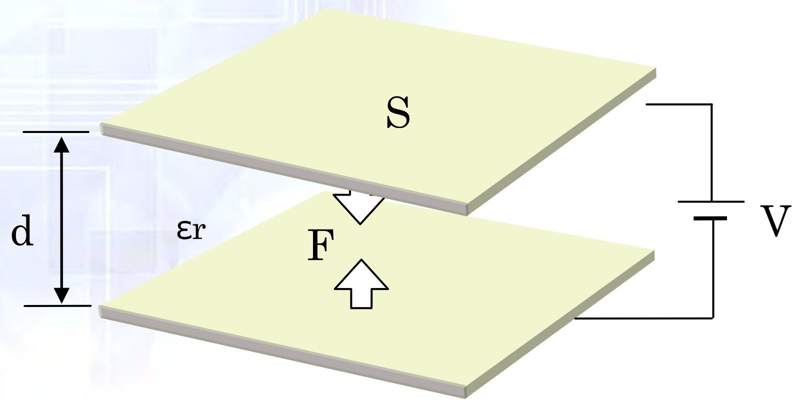


Fig. 3 Parallel Plate Type Capacitor

4.2 Internal Equivalent Circuit of MEMS Switch (SPST)

The internal equivalent circuit of this switch is the combination of the variable capacitor that is made between the movable electrode and fixed electrode and the internal resistance that the silicon actuator has. Those variable capacitor and internal resistance elements are series-connected. The capacitance value between electrodes changes from several pF to 20pF according to the electrode gap at the time of operation. The internal resistance value of actuator is about 10K ohm.

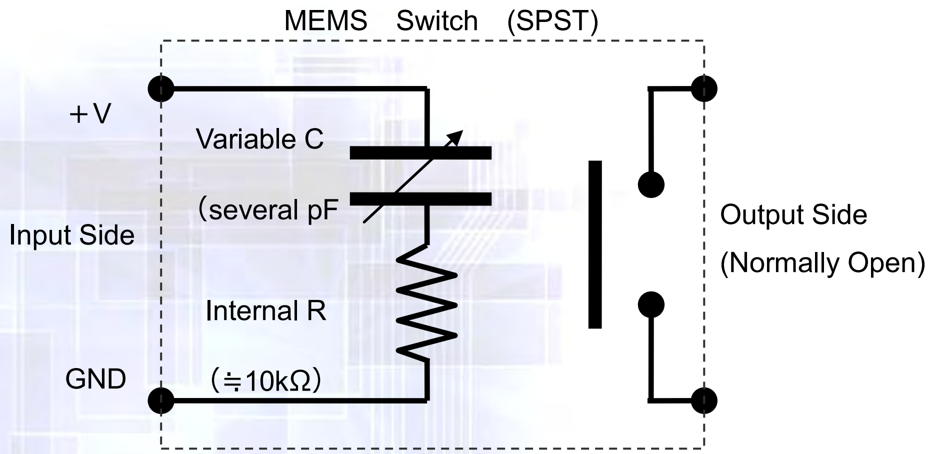


Fig. 4 Internal Equivalent Circuit

The internal equivalent circuit after packaging is a SPDT structure that has a common terminal on input side and output side. Each GND terminal on input side and one half (RF-COM) of the RF ports on output side are connected, as shown Fig. 5.

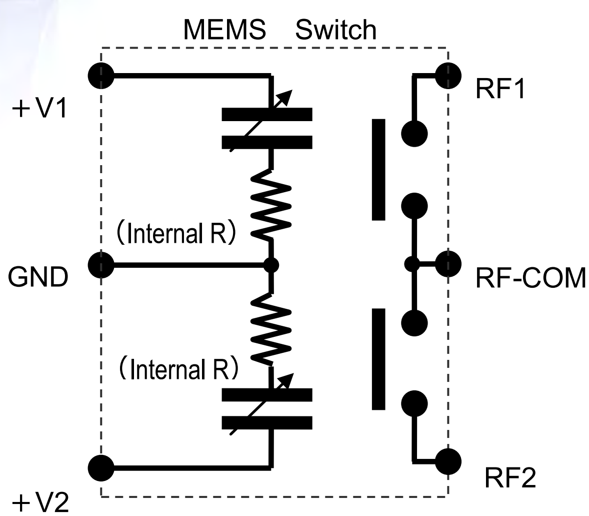
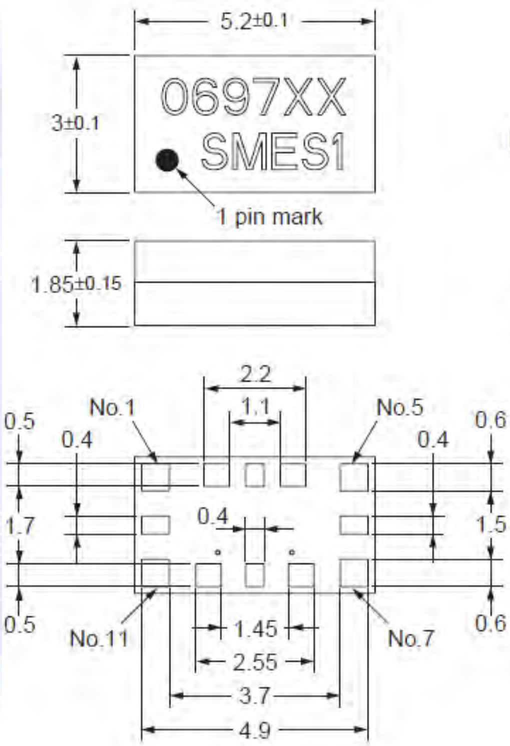


Fig. 5 Internal Equivalent Circuit (SPDT)

5 Dimensions (2SMES-01)



No.	Pin Arrangement
1	GND
2	GND
3	RF_com
4	GND
5	GND
6	RF_2
7	GND
8	Vcont_2
9	GND
10	Vcont_1
11	GND
12	RF_1

6 Specifications

Item		Description
Actuator Ratings (Input Side)	Driving System	Electrostatic Force Driving
	Rated Operating Voltage	34VDC±5%
	Pickup Voltage	90% max. of Rated Voltage
	Release Voltage	10% min. of Rated Voltage
	Absolute Maximum Voltage	40V
	Power Consumption	Max. 10μW
Signal Side (Output Side)	Contact Configuration	SPDT
	Contact Resistance (initial)	Typ. 1.0Ω
	Operating / Release Time	Max. 100μs
	Max. Peak Power	+36dBm
	Max. Carry Power	

	Rated Load	＋30dBm DC0.5V0.5mA / Resistive
High Frequency Performance	Characteristics Impedance Insertion Loss Isolation Return loss -3dB Roll Off Frequency	50Ω Typ. 1.0dB@10GHz Typ. 30dB@10GHz Typ. 10dB@10GHz Min. 12GHz
Durability	Electrical : DC0.5V0.5mA / Resistive	100,000,000 (cycles)

Note. Please confirm most current specifications with the Omron online data sheet.

7 Usage

7.1 Precautions for Driving Circuit Design of MEMS Switch (SPDT)

Please note below when designing the driving circuit for MEMS switch.

DC34V±5%

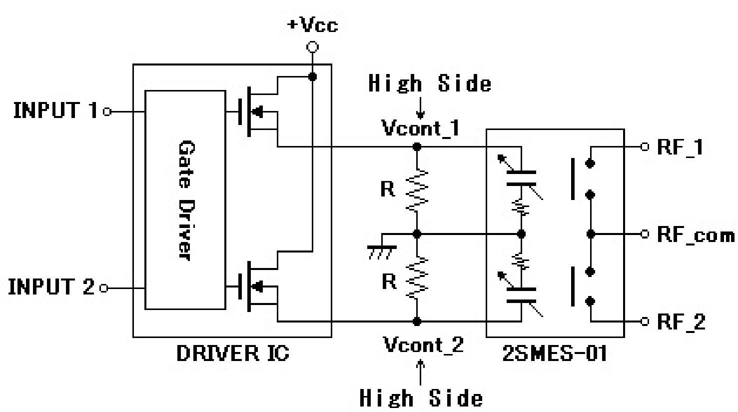


Fig. 6 Example of Drive Circuit for MEMS Switch (SPDT)

(1) This Switch uses an integrated structure for the DC-GND (pin 9) on the input side and the RF-GND (pins: 1, 2,4,5,7, and 11) on the output side. For a relay drive circuit, first be sure to ground the GND pins and then use a high-side switch (Vcont_1 & Vcont_2, not ground) to turn the operating voltage ON and OFF.

(2) This Switch is an electrostatic drive type. To turn OFF the switch, the charge accumulated on the primary side must be discharged. Install a discharge circuit in the switch drive circuit. The resistance value for the discharge circuit must be 1 MΩ or less. If there is no discharge circuit, the switch will not turn OFF. This may result in contact sticking.

(3) This Switch is designed so that the electrostatic actuator operates at a high speed. Because of this, the time constant of the drive waveform may affect the operating characteristics and life performance of the Switch. Therefore, the drive circuit must be designed so that the square wave time constant (τ) in the vicinity of the operating input pins (Vcont_1 and Vcont_2) is greater than 0.5 μs and less than 10 μs.

(4) The operating voltage must be kept in the range of 34V±5% including ripple.

7.2 Precaution for parallel connection of MEMS Switch

As shown in Fig. 7, when connecting N pieces of electrostatic actuators in parallel, set the value of the discharge resistance to 1Mohm/N. When each capacitance of an electrostatic actuator is C, the total capacitance in parallel connection will be "N x C". In this case, if discharge resistance is 1Mohm, the time constant of electric discharge of all the actuators is τ=N x C x1 Mohm, so N times discharge time is needed. The actuation speed of an electrostatic actuator is affected by the electric charge accumulated in the actuator. If the time constant of electric discharge becomes long, actuation speed of an electrostatic actuator becomes slow and contact durability may degrade. Please set the value of discharge resistance so that the time constant of the drive waveform near the input terminal (8pin, 10pin) is between 0.5μs and 10μs.

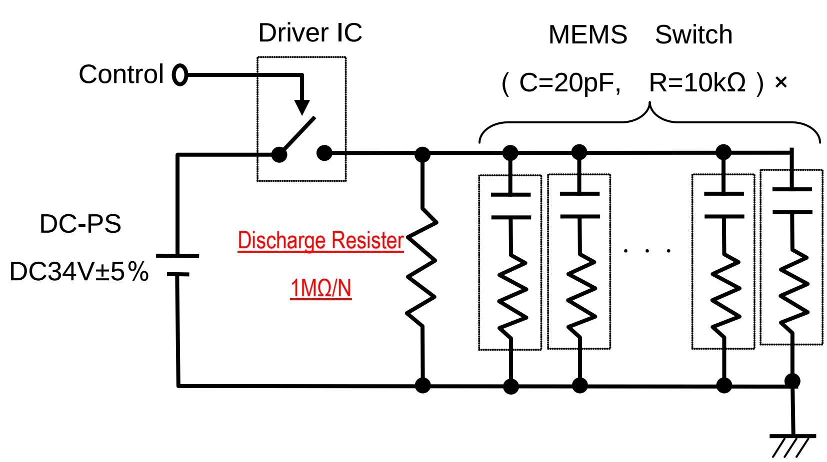


Fig. 7 Equivalent Circuit of Parallel Connection of Electrostatic Actuator

7.3 Circuit Design Example of 34V Power Supply (For Reference)

Figure 8 shows the reference circuit design using LT3494/LT3494A DC-DC converter for making a 34V power supply which is needed to drive the MEMS switch. In addition, please refer to the data sheet from Linear Technology's HP for the detailed specification and the detailed directions for use of LT3494/LT3494A.

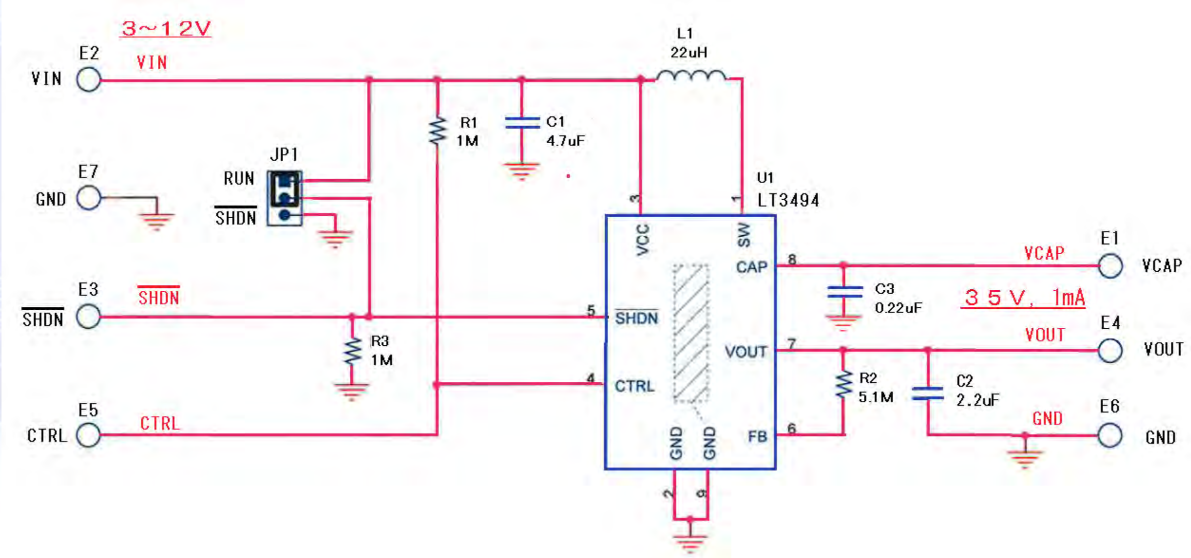


Fig. 8 Circuit Diagram of Step-up Power Supply using LT3494

Table1. Parts List of Step-up Power Supply using LT3494

Part Name		Manufacture	Type name	Specifications
Step-up converter	U1	Linear Technology	LT3494 (LT3494A)	DD8 package, 8-lead plastic DFN
Resistor	R1/R3	Rohm	MCR01	1MΩ, 50V, 1005(0402)
Resistor	R2	Rohm	MCR03	5.1MΩ, 50V, 1608(0603)
Capacitor	C1	TDK	C2012JF1C475Z	4.7uF, 16V, 2125(0805)
Capacitor	C2	TDK	C2012JF1H225Z	2.2uF, 50V, 2125(0805)
Capacitor	C3	TDK	C2012JB1H224Z	0.22uF, 50V, 2125(0805)
Inductor	L1	TDK	GLF1608T200M	22uH, 3Ω, 60mA, 1608(0603)

➢ **Selection Guide of Inductor**

If the following formula is used as a standard in the case of selecting an inductor, the inductor value of the estimate for LT3494 is computable.

$L = (V_{OUT} – V_{IN}(MIN) + 0.5V) \times 0.66$ (μH)

Where V_{OUT} is the needed output voltage, $V_{IN}(MIN)$ is the minimum input voltage. Please use a standard inductor near the calculated value.

➢ **Selection Guide of Input/Output Capacitor**

When the transient response and the stability of this power supply needs to be improved, it is suitable to attach a 4.7μF input capacitor (C1) and a larger output capacitor (C2) from 2.2 μF to 10 μF to the V_{OUT} node. In addition, a capacitor with a sufficient voltage rating should be used. When the power supply circuit using LT3494 is constructed based on the above circuit diagram, as shown in Fig. 9, it generally becomes a mounting space less than a 10mm square. This circuit configuration can output a current of approximately 1mA. NOTE, this is an example of a step up converter design, please be sure to carry out a sufficient initial evaluation for the actual application in use.

Approx. 10 mm x 10mm

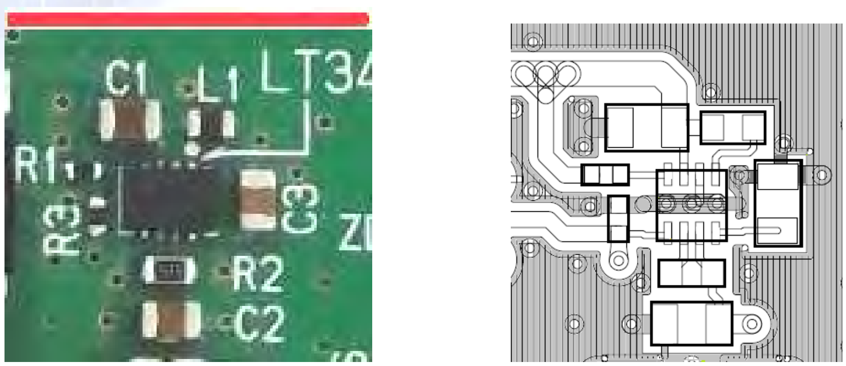


Fig.9 Parts Mounting Image

7.4 Precaution for selection of Driver IC

Please take careful design consideration regarding the “Current Capacity” and “Withstand Voltage” when selecting a suitable Driver IC. As described before, when driving MEMS switch, it has an equivalent circuit of a series connection of Capacitance and Resistance. So, if an electrostatic actuator is turned ON, it needs the electric charge of Q expressed as follows.

$Q=C\times V$ ・・・①

Roughly speaking, since the actual time of inrush current is decided by the time constant “τ” depending on CxR expressed as follows.

$\tau = C \times R$ ・・・②

So, inrush current to Driver IC would be about 3.4mA depending on the ratio of input voltage “V” and internal resistance “R”.

$I = dQ / dt = (CxV) / (CxR) = V / R = 34 / 10k = 3.4mA$ ・・・③

On the other hand, when connecting nth MEMS switches, total inrush current would be **3.4×N (mA)** that is proportionate to the parallel connection number of MEMS switch.

Ex.) N=64 inrush current = 3.4 x 64 = 217.6mA

When selecting a Driver IC, a device with enough current capacity against above inrush current and withstand voltage should be selected. Fig.10 shows the reference circuit design that has a boost converter and several Photo-MOS (ex.G3VM-61PR1) as the Driver IC. Several MEMS switches can be operated by using below configuration.

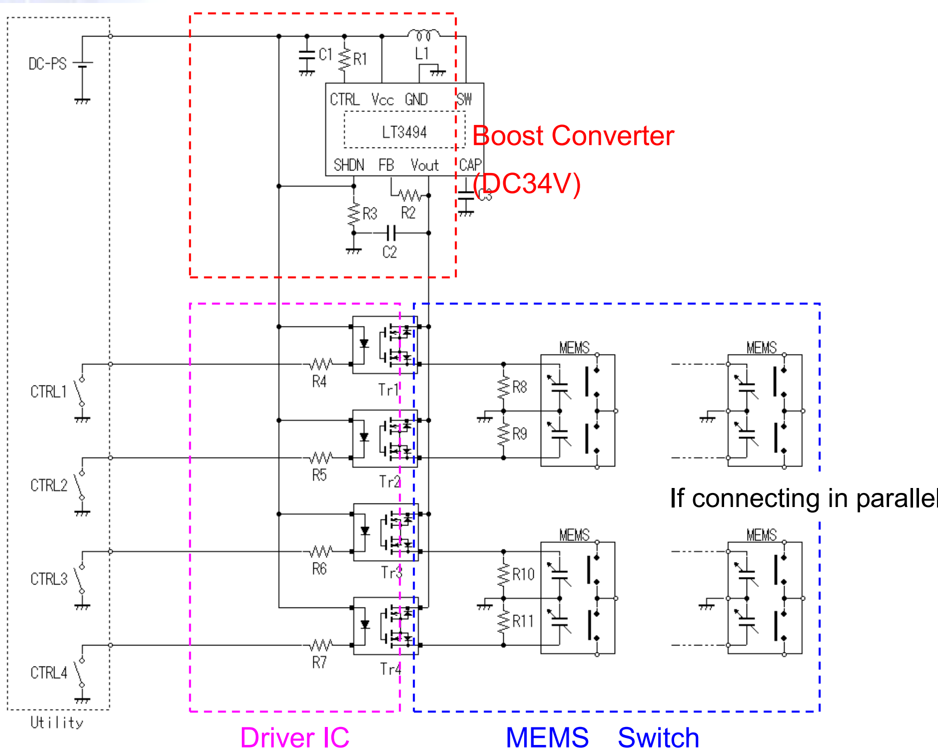


Fig .10 Configuration Example of Boost Converter and Driver IC for MEMS switch

8 Glossary

- **What is MEMS?**

  MEMS is written as "Micro Electro Mechanical Systems", it is the technology of very small devices that are fabricated by semiconductor device fabrication technologies. Some micro scale mechanical components, sensors, actuators or electrical circuits are integrated on one silicon substrate, glass substrate, organic substrate and so on.

- **Electrostatic Force Driving MEMS Switch**

  An ultra-small mechanical switch that has an electrostatic force driving system fabricated by MEMS technologies.

- **Peak Power**

  The maximum amount of power that a device can handle for an instant without damage.

- **Carry Power**

  The maximum amount of power that a device can handle continuously without damage.

- **Rated Load**

  The load conditions for guaranteeing the contact durability. The load is electrically connected to the signal line and ON/OFF switching can be performed in the active state.

- **Insertion Loss**

  The loss of the electric power spread from one terminal to another in a high frequency circuit which consists of 2 terminal-pair networks after the circuit has been closed.
  It is usually expressed in decibels (dB).

- **Isolation**

  The loss of the electric power spread from one terminal to another in a high frequency circuit which consists of 2 terminal-pair networks after the circuit has been opened.
  It is usually expressed in decibels (dB).

- **Return Loss**

  The ratio between the input power and the reflected power at one terminal in the high frequency circuit.
  It is usually expressed in decibels (dB).

- **Cut-off Frequency**

  The frequency of the point that the insertion loss usually falls by 3 dB rather than the nominal value in the high frequency circuit.

More Information

- **OMRON Electronic Components Web**
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- **Contact Us**
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