A Novel Design Methodology for MEMS Micro Cantilever Triode Switch

Pamuleti Challa, Lal Kishore Kondepudi, Satyam Mandavilli

Abstract: *This paper describes a novel methodology for designing a MEMS (micro electromechanical systems) triode switch made up of a cantilever for a given set of performance parameters viz minimum pull-in voltage, on-time and off-time. These performance parameters are associated with MEMS triode switch structural parameters such as length, width, thickness, cross sectional area, initial gap between the electrodes and are found using MATLAB. A relational database using MS Access is created with the performance parameters and corresponding structural parameters. The switch(es) which satisfy the given specifications are retrieved based on data mining principle. An algorithm is written for mining the data from the database. A software package is developed for this algorithm in JAVA language for data mining. The designer can choose the switch(es) as per design constraints. This approach reduces the design cycle time of the MEMS triode switches.*

Keywords : *control electrodes, contact electrodes, DC voltage, MEMS triode switch, on-time, off-time, pull-in voltage, initial design, substrate, gap, electrostatic force, mechanical force, spring constant, bending moment, slope, deflection, mass, damping coefficient, relational database.*

I. INTRODUCTION

MEMS switches are being used now days in electronic circuits and systems as key elements for switching [1][2]. Some of the switches have been favorably used for digital mirrors, Radio frequency (RF) switches, MEMS fundamental logic gates, multi-bit logic circuits and memories [3][4][5]. There are several computer aided design (CAD) tools like Intellisuite, Coventor, Comsol multiphysics and Ansys multiphysics etc. to assist in the designing of MEMS devices including triode switches [2][6][7][8][9][10]. In CAD tools one suggests a set of structural parameters as an initial set and evaluate the performance parameters like pull-in voltage, on-time and off-time. Based on the difference between the required performance parameters and the performance parameters obtained for the switch to be analyzed, the second set of structural parameters are suggested and this process is iterative, continues till the performance parameters obtained which are close to the required one. One has to carry out several iterations before arriving at a single MEMS switch which meets the specifications like minimum pull-in voltage, on-time and off-time. This involves a considerable amount of time to realize the design of a single switch. In view of this an attempt has been made to develop a design methodology which is based on creating a database containing several MEMS triode architectures (different dimensions) and their performance specifications. A search process is used to select the switches with the required performance parameters from the database. The design parameters that are obtained from the database will help to establish a semi-initial design and are very close to the parameters that are finally used for fabrication of MEMS triode switches. The initial design represented in this paper, will be the starting point for further design aspects. After the initial design represented here one has to modify the design parameters slightly, taking the process constraints in to account. This method enables the design of switches which satisfy the designer's specifications almost instantaneously. This initial design may be considered as another tool along with the rest of the tools. This paper aims at reporting the various aspects like formulating the equations, their computations using MATLAB software for device performance, creating the database of the MEMS triode switches and mining or searching (using Java Software) of the switches with the given performance [8][9][11]. These switches are operated with ultra-low actuation voltages ranging from 0.5 volts to 3.5 volts and are used in the design of MEMS logic gates and memories[1][2][6][7][8][9][12].

II. METHODOLOGY

MEMS triode switch is basically a micro cantilever which has a movable arm suspended over the substrate by an anchor [5]. It consists of two sets of electrodes called control electrodes and contact electrodes, attached on bottom surface of the cantilever and top surface of the substrate [8]. Control electrodes are used for the actuation of the cantilever and contact electrodes are used for switching of the device (Fig.1a). When the actuation (DC) voltage is applied between the control electrodes, the electrostatic force arising between the control electrodes results in bending of the movable arm [4][12]. When the bias voltage reaches pull-in voltage (v_{pi}) contact is made at the free end [3][7][8][13]. In this paper, pull-in voltage is taken as the voltage required for the deflection given by

$$\delta(I, t) = (\ y_0/4) \tag{1}$$

from the top where y_0 is the initial gap between the control electrodes [10][12][14].

The switch gets released abruptly when the voltage between the control electrodes becomes zero. The MEMS triode switch is specified by pull-in voltage, on-time and off-time [13]. A methodology of designing MEMS triode

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switches for a given pull-in voltage, on-time and off-time based on data mining principles is reported in this paper. This paper describes

a) the mathematical equations used for device performance

b) calculating numerical values of performance parameters using MATLAB

c) the creation of the database of calculated performance parameters and the corresponding structural parameters

d) the method of using this data base for design of MEMS triode switches (retrieval of the switches)

III. STRUCTURE AND PRINCIPLE OF OPERATION

The structure of MEMS triode switch is shown in Fig. 1a which is a cantilever (**AB**) of uniform rectangular cross section with an extension arm (**BC**) of length (l_e) µm.

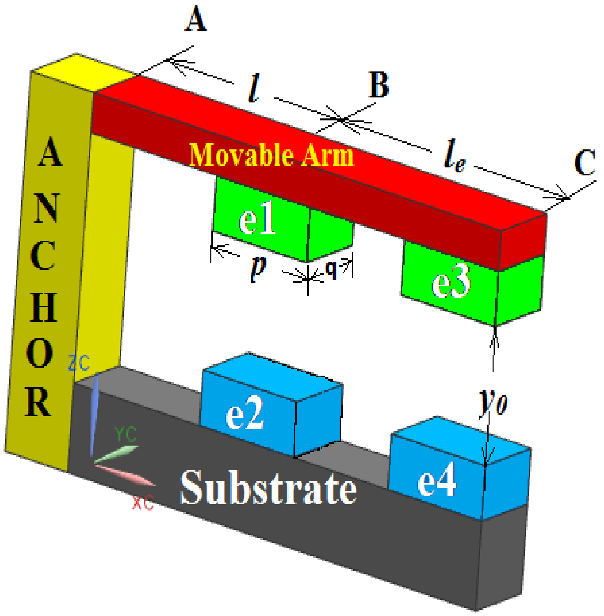


Fig.1(a) Sturucture of MEMS Triode Switch

It is made of a thin elastic material like polysilicon of modulus of elasticity (*E*) and stiffness (*K*). It is fixed at **A**, free at **C** and suspended at a height (y_0) µm (total initial gap) over the substrate [7][10]. The physical dimensions of the cantilever are: length (*l*), width (*w*), thickness (*t*). The control electrodes are denoted as {e_1, e_2} and the contact electrodes are denoted as {e_3, e_4}; whose physical dimensions are length (*p*) and width (*q*). The electrodes (e_1) and (e_3) are mounted on the bottom surface of the cantilever at **B** and **C**; and the electrodes (e_2) and (e_4) are mounted on the top surface of the substrate exactly below (e_1) and (e_3). In this investigation the gap between the electrodes (y_0) and their thickness are considered as 1µm, 1.5µm and few angstrom's respectively to cover various ranges of switch parameters [2]. When DC voltage is applied between the electrodes (e_1) and (e_2), the cantilever is bent as shown in the Fig. 1b. Upon sufficient actuation of the cantilever in downward direction, the electrode (e_3) makes contact with(e_4) [3][7].

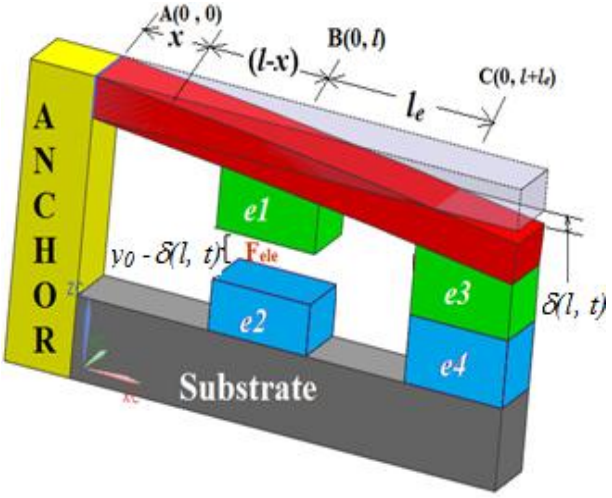


Fig.1(b) MEMS Triode ON Switch

IV. CALCULATION OF PERFORMANCE PARAMETERS

The performance parameters viz minimum pull-in voltage, on-time and off-time of the MEMS triode switch are calculated as follows:

A. *Pull-in voltage* (v_{pi})

When a step voltage ($V_{applied}$) is applied between the electrodes (e_1) and (e_2), an electrostatic force F_{ele} is developed between them which pull the cantilever towards (e_2) [3][7][10].The magnitude of electrostatic force F_{ele} generated between (e_1) and (e_2) is equal to the gradient of the stored electrical energy with respect to the gap between the electrodes is given by[7][8][11][13][14]

$$F_{ele} = \left|\frac{\partial U}{\partial[y_0 - \delta(l,t)]}\right| = \frac{\epsilon p q V_{applied}^2}{2[y_0 - \delta(l,t)]^2} \qquad (2)$$

Where U is the electric energy stored, ϵ is the dielectric constant of the free space between the electrodes (e_1) and (e_2) [7][10] [11]. The force F_{ele} bends the cantilever there by decreasing the gap. This gives rise to the mechanical restoring force F_{mech} in the cantilever. F_{mech} is developed due to the stiffness of the cantilever (*K*) is given by [13]

$$F_{mech} = K\delta(l,t) \qquad (3)$$

On the application of the DC voltage between the electrodes (e_1) and (e_2) of the cantilever, it is bent in negative y-direction as shown in the Fig. 1b [7]. The bending of the cantilever is described by bending moment equation is given by

$$EI\frac{d^2y}{dx^2} = F_{ele}(l - x) \qquad (4)$$

where '*I*' is the Moment of Inertia and '*E*' is the Young's Modulus or Modulus of elasticity of the cantilever.The solutions for Eq. (4) (for the boundary conditions: at *x=0*, both the deflection and the slope are being zero) are given by

$$\frac{dy}{dx} = \frac{F_{ele}}{EI}\left(lx - \frac{x^2}{2}\right) \tag{5}$$

$$y = \frac{F_{ele}}{EI}\left(\frac{lx^2}{2} - \frac{x^3}{6}\right) \tag{6}$$

where $\frac{dy}{dx}$ and 'y' are the slope and deflection at any section 'x' of the cantilever. Let the slope and deflection at **B** be i_b, $\delta(l)$ respectively and are given by

$$i_b = \frac{F_{ele}(l^2)}{2EI} \tag{7}$$

$$\delta(l,t) = \frac{F_{ele}(l^3)}{3EI} \tag{8}$$

The Moment of Inertia of the cantilever (of rectangular) cross-section is given by [3]

$$I = \frac{wt^3}{12} \tag{9}$$

The stiffness (K) of the cantilever is characterized by a term called the spring constant is given by [3][5][7][8][9]

$$K = \frac{F_{ele}}{\delta(l,t)} \tag{10}$$

From Eq. (8), (9) and (10)

$$K = \frac{1}{4}Ew\left(\frac{t}{l}\right)^3 \tag{11}$$

Under static equilibrium condition, the mechanical restoring force (F_{mech}) and electrostatic force F_{ele} are equal in magnitude but opposite in direction is given by [7][8][14]

$$F_{ele} = -F_{mech} \tag{12}$$

$$\left|\frac{\varepsilon pqV_{applied}^2}{2[y_0-\delta(l,t)]^2}\right| = |K\delta(l,t)| \tag{13}$$

From Eq. (13), the voltage at which the cantilever makes the deflection $\delta(l,t)$ is given by

$$V_{applied} = \sqrt{\frac{2K}{\varepsilon pq}\delta(l,t)[y_0 - \delta(l,t)]^2} \tag{14}$$

where, $K = \frac{1}{4}Ew\left(\frac{t}{l}\right)^3$ and assuming $p = q = w$.

pull-in voltage (v_{pi}) is the voltage at which cantilever has traversed 1/4 of the gap from the top or 3/4 of the gap from the bottom at **B** and make a contact at the free end **C** with slope (i_b) [5][16]. The pull-in voltage (v_{pi}) can be obtained by substituting $\delta(l,t) = \left(\frac{1}{4}y_0\right)$ in Eq. (14) is given by [7][8]

$$v_{pi} = \sqrt{\frac{9Et^3y_0^3}{128\varepsilon wl^3}} \tag{15}$$

With the slope (i_b) and deflection $[y_0 - \delta(l,t)]$, (l_e) is calculated as [7]

$$l_e \cong \frac{[y_0-\delta(l,t)]}{i_b} \cong \frac{(3/4)y_0}{i_b} \tag{16}$$

Where, $i_b = \frac{F_{ele}l^2}{2EI}$ and $F_{ele} = \frac{\varepsilon w^2 v_{pi}^2}{2(3/4)y_0^2} = \frac{2\varepsilon w^2 v_{pi}^2}{3y_0^2}$

$\left(at\ \delta(l,t) = \left(\frac{1}{4}y_0\right), V_{applied} = v_{pi}\right)$

The slope $(i_b)$for the deflection at $\delta(l,t) = \left(\frac{1}{4}y_0\right)$ is given by

$$i_b = \frac{2\varepsilon w^2 v_{pi}^2}{3y_0^2}\frac{l^2}{2EI} = \frac{\varepsilon w^2 v_{pi}^2}{3y_0^2}\frac{l^2}{EI}$$

Therefore l_e is given by

$$l_e \cong \frac{(3/4)y_0}{\left[\varepsilon w^2 v_{pi}^2/3y_0^2\right][l^2/EI]} \cong \frac{9y_0^3EI}{4\varepsilon w^2 v_{pi}^2 l^2} \tag{17}$$

B. On-time (t_{on})

Application of the DC voltage between the control electrodes, gives rise to the deflection $\delta(l,t)$ of the cantilever and its dynamics to be modeled is given by [8][15]

$$m\ddot{\delta}(l,t) + b\dot{\delta}(l,t) + K\delta(l,t) = F_{ele} \tag{18}$$

where 'b' is the damping coefficient, $m = 0.35(lwt)\rho$ is the effective mass, 'ρ' is the density of the polysilicon cantilever used. From Eq. (2), F_{ele} is identified as $F_{ele} = \frac{\varepsilon pqV_{applied}^2}{2[y_0-\delta(l,t)]^2}$

The Eq. (18) is a non-linear second order differential equation and finite difference method is used to solve this equation. From Eq. (2) and Eq. (18) we get

$$m\frac{d^2\delta(l,t)}{dt^2} + b\frac{d\delta(l,t)}{dt} + K\delta(l,t) = \frac{\varepsilon pqV_{applied}^2}{2\left(y_0-\delta(l,t)\right)^2} \tag{19}$$

which may be written in the form of difference equation

$$m\left[\frac{\delta(l,t)_{n+1}-2\delta(l,t)_n+\delta(l,t)_{n-1}}{\Delta t^2}\right] + b\left[\frac{\delta(l,t)_{n+1}-\delta(l,t)_{n-1}}{\Delta t}\right] +$$

$$K\delta(l,t)_n = \frac{\varepsilon pqV_{applied}^2}{2(y_0-\delta(l,t)_n)^2} \quad (20)$$

$m[\delta(l,t)_{n+1} - 2\delta(l,t)_n + \delta(l,t)_{n-1}] + b[\delta(l,t)_{n+1} -$

$\delta l,tn-1\Delta t+K\delta l,tn\Delta t2=\varepsilon pqVapplied22y0-\delta l,tn2\Delta t2$

(21)

$$\delta(l,t)_{n+1} =$$

$$\frac{\delta(l,t)_n\left(2m-K\Delta t^2\right)}{m+b\Delta t} + \frac{\varepsilon pqV_{applied}^2\left(\Delta t^2/2(y_0-\delta(l,t)_n)^2\right)}{m+b\Delta t} -$$

$$\frac{\delta(l,t)_{n-1}(m-b\Delta t)}{m+b\Delta t} \tag{22}$$

where *n* is a time index which represents the deflection at *n*th point. The initial conditions at $t = 0$ are,

$$(i)\delta(l,t)_{-1} = 0\ (ii)\delta(l,t) = 0\ (iii)\dot{\delta}(l,t) = 0.$$

on-time (t_{on}) is the time needed for the tip **C** to reach the equilibrium position (y_0) corresponding to the minimum pull-in voltage (v_{pi}). The solution of the Eq. (22) can be used to calculate the on-time.

C. Off-time (t_{off})

off-time (t_{off}) is the time needed for the tip **C** to reach to its initial position from the bottom electrode (e_4) when the voltage $V_{applied}$ is made zero, i.e. $F_{ele} = 0$. The switch off-time is calculated using the Eq. (23)

$$\delta(l,t)_{n+1} = \frac{\delta(l,t)_n\left(2m-K\Delta t^2\right)}{m+b\Delta t} - \frac{\delta(l,t)_{n-1}(m-b\Delta t)}{m+b\Delta t} \tag{23}$$

The initial conditions are $F_{ele} = 0$, at $t = -1$ and $t = 0$ the deflection is $\left(-\frac{1}{4}\right)y_0$. These calculations are made using MATLAB software.

V. RELATIONAL DATABASE

The performance parameters *i.e.* minimum pull-in voltage, switch-on and switch-off times for the cantilevers of dimensions in the range of $l = 20\mu m$ to $80\mu m$, $w = 5\mu m$ to $40\mu m$, $t = 0.1\mu m$ to $0.4\mu m$, $y_0 = 1\mu m$ and $y_0 = 1.5\mu m$ are calculated from Eqs. (15), (22), (23) [8][10][12][13]. The range of the structural parameters used for these calculations are given in the Table 1**.** The performance parameters of 2483 switches along with the structural parameters are stored in the database in tabular form as shown in the Table 2 [2][6]. These switches are arbitrarily chosen to obtain a reasonable size of the database.

TABLE 1: The Range Of The Structural Parameters And Constants Used

SNO	Symbol	Structural Parameters	1st Set (μm)	2nd Set (μm)	3rd Set (μm)	4th Set (μm)
1	*l*	Length	20-54	45-55	55-65	60-80
2	*w*	Width	5-17	5-17	25-35	20-40
3	*t*	Thickness	0.1	0.1	0.1	0.1- 0.4
4	*p*	Lengths of e_1, e_2, e_3, e_4	5-17	5-17	25-35	20-40
5	*q*	Widths of e_1, e_2, e_3, e_4	5-17	5-17	25-35	20-40
6	y_0	Gap between $\{e_1, e_2\}$, $\{e_3, e_4\}$	1	1.5	1.5	1
	Constants used					
7	*E*	Young's Modulus	120×10^9 N/m^2			
8	ε_0	Dielectric constant of the free space between the electrodes	8.854×10^{-12} F/m			
9	ρ	density of the polysilicon cantilever	2300 Kg/m^3			

TABLE 2:Experimental Results stored in Microsoft Access Database

SNO	***l*** (μm)	***w*** (μm)	***t*** (μm)	***p*** (μm)	***q*** (μm)	y_0 (μm)	***le*** (m)	v_{pi} (volts)	t_{on} (sec)	t_{off} (sec)
1	20	5	0.1	5	5	1	4.00×10^{-05}	4.88098123978291	1.70×10^{-06}	8.00×10^{-07}
2	20	6	0.1	6	6	1	4.00×10^{-05}	4.45570587964772	1.70×10^{-06}	8.00×10^{-07}
3	20	7	0.1	7	7	1	4.00×10^{-05}	4.1251820620526	1.70×10^{-06}	8.00×10^{-07}
4	20	8	0.1	8	8	1	4.00×10^{-05}	3.85875448356661	1.70×10^{-06}	8.00×10^{-07}
5	20	9	0.1	9	9	1	4.00×10^{-05}	3.63806861635193	1.70×10^{-06}	8.00×10^{-07}
6	20	10	0.1	10	10	1	4.00×10^{-05}	3.45137493349482	1.70×10^{-06}	8.00×10^{-07}
7	20	11	0.1	11	11	1	4.00×10^{-05}	3.2907568805473	1.70×10^{-06}	8.00×10^{-07}
8	20	12	0.1	12	12	1	4.00×10^{-05}	3.15065984247167	1.70×10^{-06}	8.00×10^{-07}
9	20	13	0.1	13	13	1	4.00×10^{-05}	3.0270560630569	1.70×10^{-06}	8.00×10^{-07}
10	20	14	0.1	14	14	1	4.00×10^{-05}	2.9169442097065	1.70×10^{-06}	8.00×10^{-07}
11	20	15	0.1	15	15	1	4.00×10^{-05}	2.81803583269818	1.70×10^{-06}	8.00×10^{-07}
12	20	16	0.1	16	16	1	4.00×10^{-05}	2.72855146226395	1.70×10^{-06}	8.00×10^{-07}
13	20	17	0.1	17	17	1	4.00×10^{-05}	2.64708373737595	1.70×10^{-06}	8.00×10^{-07}
14	21	5	0.1	5	5	1	4.20×10^{-05}	4.53652375996625	1.80×10^{-06}	8.00×10^{-07}
15	21	6	0.1	6	6	1	4.20×10^{-05}	4.14126065998611	1.80×10^{-06}	8.00×10^{-07}
16	21	7	0.1	7	7	1	4.20×10^{-05}	3.83406235741249	1.80×10^{-06}	8.00×10^{-07}
17	21	8	0.1	8	8	1	4.20×10^{-05}	3.58643693524108	1.80×10^{-06}	8.00×10^{-07}
18	21	9	0.1	9	9	1	4.20×10^{-05}	3.38132516960916	1.80×10^{-06}	8.00×10^{-07}

VI. SEARCH METHOD

Software has been developed through which structural parameters of the MEMS triode switches can be retrieved according to the specifications followed by a flow chart as shown in Fig. 3. One of the performance parameter v_{pi}, its range denoted by p_1 can be entered in a given narrow range of r_1 and thereby the structural parameters of the triode switch/switches corresponding to the r_1 can be searched. The program narrows down its search further in the group r_1 for the device structures with the performance parameter t_{on} in the range denoted by p_2,in a given narrow range of r_2 and the process can be repeated with p_3 for t_{off}. The search at the end, results in MEMS triode switch(s) which satisfy both p_1, $p_2$and p_3 for one which the designer can choose/select the switch/switches as per his/her design constraints.

A. *Algorithm*

Procedure:

(i). Create the database in terms of *l*, *w*, *t*, *p*, *q*, l_e, y_0 and v_{pi}, t_{on}, t_{off} for 2483 sets of MEMS triode switches.

(ii). Design search process for retrieval of *l*, *w*, *t*, *p*, *q*, y_0, l_e for the ranges of v_{pi} or t_{on} or t_{off} or with the ranges of v_{pi} and t_{on} or v_{pi} and t_{off} or t_{on} and t_{off} or all.

Step 1: Create a database using MS-ACCESS relational database for 2483 switches.

Step 2: Read the ranges of values of v_{pi} (denote this range by p_1), t_{on} (denote this range by p_2), t_{off} (denote this range by p_3) from the GUI.

Step 3(decision box denoted by a_1): If nothing is entered then retrieve and display all records (rectangular box denoted by b_1) and stop. Else continue.

Step 4(decision box denoted by a_2): If any one of the performance parameters i.e. v_{pi} or t_{on} or t_{off} are entered in the narrow range(from p_1 or p_2 or p_3) denoted by r_1 or r_2 or r_3 then retrieve and display all records(rectangular box denoted by b_2) corresponding to that performance parameter and stop. Else continue.

Step 5(decision box denoted by a_2): If any two of the performance parameters are entered in the narrow range(from p_1 and p_2 or p_1 and p_3 or p_2 and p_3) denoted by r_1 and r_2 or r_1 and r_3 or r_2 and r_3 then retrieve and display all records (rectangular box denoted by b_3) corresponding to those performance parameters and stop. Else continue.

Step 6(decision box denoted by a_3): If all of the performance parameters are entered in the narrow range(from p_1 and p_2 and p_3) denoted by r_1 and r_2 and r_3 then retrieve and display all records (rectangular box denoted by b_4) corresponding to those performance parameters and stop. End of algorithm.

In order to carry out the process efficiently a graphical user interface (GUI) named 'performance analysis table' has been developed for the flow chart and is shown in Fig.4a and Fig.5a.The performance analysis table consists of an input panel and a data panel. The data panel (shown in Fig.4a andFig.5a) displays the available ranges of performance parameters of 2483 MEMS triode switches.

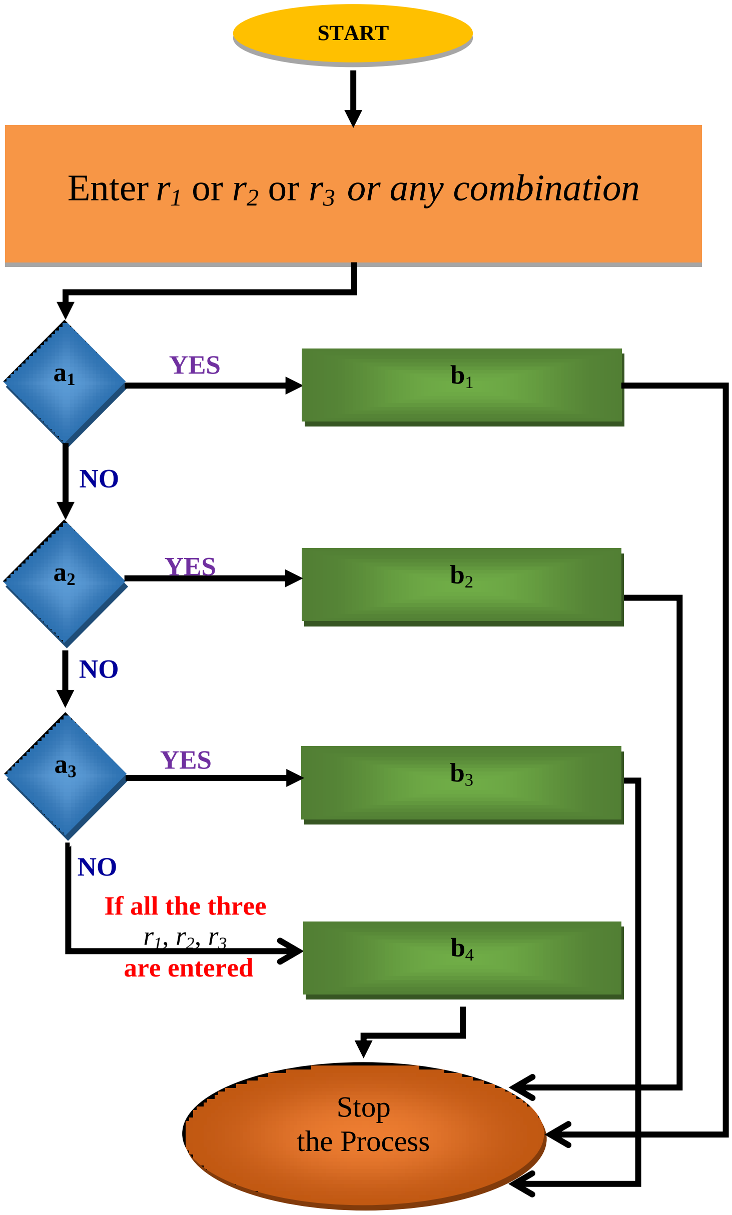
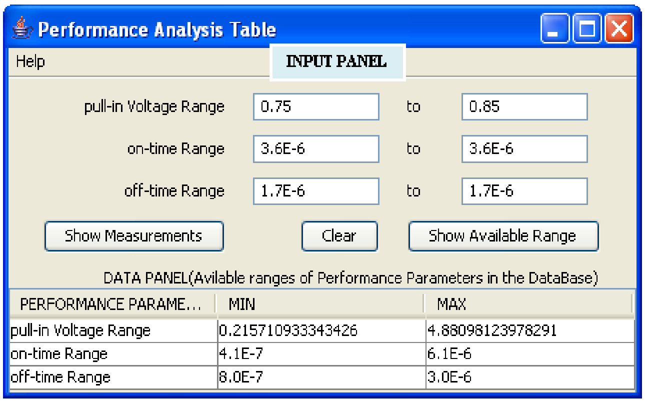


Fig.3 Flow chart

VII. RESULTS AND DISCUSSION

With this GUI the designer/user can enter the performance parameters of his/her choice in the input panel and carry out the search as shown in Fig.4a to Fig.5b. Based on the information provided by the data panel, search for MEMS triode switches can be narrowed down (by clicking on show Available Range button) till the process is complete. The input panel displays a single set of performance parameters of the data panel that are entered in the narrow ranges i.e. r_1, r_2 and r_3 (as shown in Fig.4a and Fig.5a).

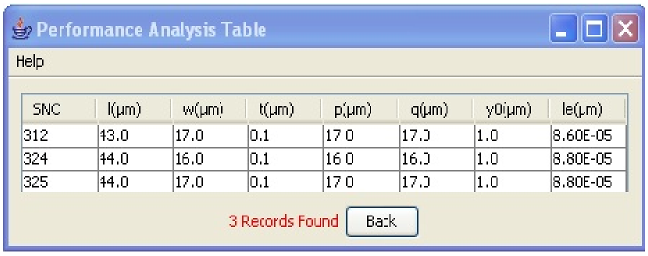


pull-in Voltage Range: 0.75 to 0.85
on-time Range: 3.6E-6 to 3.6E-6
off-time Range: 1.7E-6 to 1.7E-6

DATA PANEL(Avilable ranges of Performance Parameters in the DataBase)

PERFORMANCE PARAME...	MIN	MAX
pull-in Voltage Range	0.215710933343426	4.88098123978291
on-time Range	4.1E-7	6.1E-6
off-time Range	8.0E-7	3.0E-6

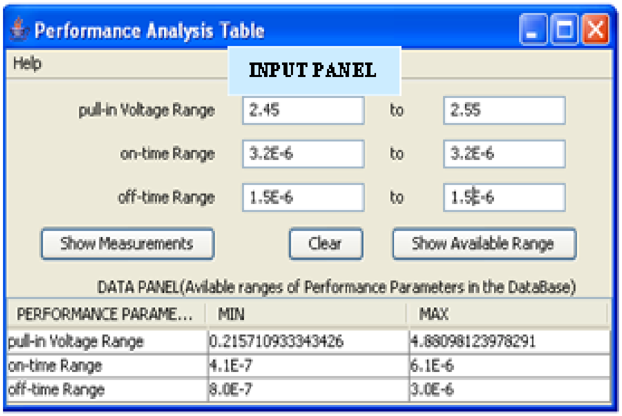
Fig.4a performance analysis table for examining test case-1



SNC	l(μm)	w(μm)	t(μm)	p(μm)	q(μm)	y0(μm)	le(μm)
312	43.0	17.0	0.1	17.0	17.0	1.0	8.60E-05
324	44.0	16.0	0.1	16.0	16.0	1.0	8.80E-05
325	44.0	17.0	0.1	17.0	17.0	1.0	8.80E-05

3 Records Found

Fig.4b structural parameters retrieved from the database

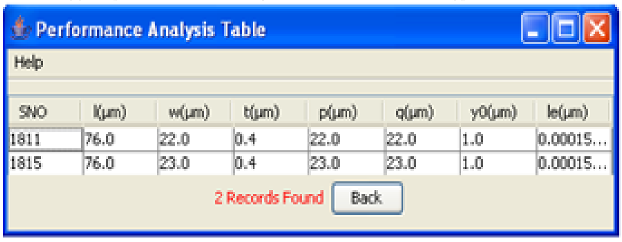


pull-in Voltage Range: 2.45 to 2.55
on-time Range: 3.2E-6 to 3.2E-6
off-time Range: 1.5E-6 to 1.5E-6

DATA PANEL(Avilable ranges of Performance Parameters in the DataBase)

PERFORMANCE PARAME...	MIN	MAX
pull-in Voltage Range	0.215710933343426	4.88098123978291
on-time Range	4.1E-7	6.1E-6
off-time Range	8.0E-7	3.0E-6

Fig.5a performance analysis table for examining test case-2



SNO	l(μm)	w(μm)	t(μm)	p(μm)	q(μm)	y0(μm)	le(μm)
1811	76.0	22.0	0.4	22.0	22.0	1.0	0.00015...
1815	76.0	23.0	0.4	23.0	23.0	1.0	0.00015...

2 Records Found

Fig.5b structural parameters retrieved from the database

The structural parameters corresponding to the performance parameters entered in the input panel are retrieved and displayed (by clicking on show measurements button) as shown in Fig.4b and Fig.5b.

If the ranges are to be narrowed based on the MEMS switches suggested by the search process, one may decide to narrow down the range and repeat the process. The structural parameters are varied in small steps and performance is calculated for the MEMS triode switch in each case. A relational tablature is given which consists of all the switches ranging from l = 20 μm to 80 μm, w = 5 μm to 40 μm, t = 0.1 μm to 0.4 μm. The proposed method is implemented to carry out the search process with the given performance parameters. Many test cases have been examined and the desired triode switches have been obtained from the database. From these test cases it is clear that MEMS triode switches can be designed reasonably well with the information available in the database and search process provided. It has been found that by using the proposed method the design of a triode switch can be completed within a few seconds. This includes the start of the search process, entering the specifications and retrieving the structural parameters corresponding to the specifications. The actual time taken by the computer is minimal. If the specifications are not within the range of the database it indicates that no records found. From the background literature such a fast design approach of MEMS triode switch is not available.

VIII. CONCLUSION

In this paper, the mathematical equations used for device performance are derived. Numerical values for the performance parameters viz minimum pull-in voltage, on-time and off-time are calculated using MATLAB. The database for the calculated performance parameters and the corresponding structural parameters is created using MS-Access database management system. A search method for retrieval of the switches from this data base for design of MEMS triode switches is developed in JAVA language. In this investigation the MEMS switches are designed with 1μm and 1.5μm gap between the electrodes and their thickness is in angstroms respectively. With this method the design of a MEMS Triode switch can be completed within a few seconds based on the relational database of pre-calculated values and a search process. This database is restricted to certain range of parameters. It can be further extended beyond these calculated values which may cover wider specifications. The design cycle time of MEMS triode switches is considerably reduced by this methodology and real time decision making becomes easy and fast.

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