MechaTrans®

Mechano Transformer Corp.

http://www.mechano-transformer.com

Mechano Transformer

Message from President

MechaTrans® is an application name of our piezoelectric actuators, based upon the piezoelectric technology which has been developed and commercialized for the impact dot printers for the first time in the world in 1980's when I worked for NEC. Although the application to printers has afterwards been replaced to the other methods such as ink jet or bubble jet technology, Prof. T. Higuchi of the University of Tokyo has predicted the promise of this actuator and recommended me to expand applications of the piezoelectric technology to the other industrial fields.

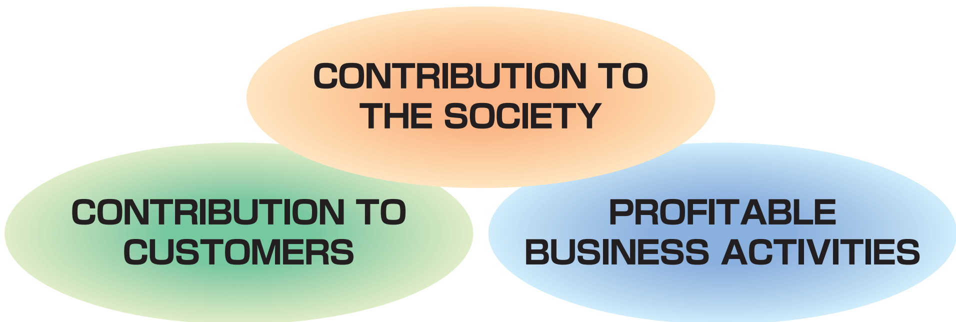
In 2002, a small company has been founded in Tokyo, Japan to develop new applications of piezoelectric actuators with high speed and large displacement. Then, the company name has changed from Denshi-Seiki to Mechano Transformer Corporation since 2005 and also the company location has changed from Tokyo to Kawasaki where is at the suburbs of Tokyo.

Mechano Transformer Corporation has been developing more than 60 different types of piezoelectric actuators and 30 different types of the drive circuits, and those are being used by many customers.

Takeshi Yano

Dr. Takeshi Yano
President of Mechano Transformer Corporation

CORPORATE PROFILE



About Mechano Transformer Corporation

Company Name	Mechano Transformer Corporation
President	Dr. Takeshi Yano
Paid-in capital	10 million Japanese Yen
Location	KBIC, 7-7 Shin-Kawasaki, Saiwai-ku, Kawasaki-shi, Kanagawa 212-0032, Japan
Founded	May 2002

Business Contents

1) Design and manufacturing of MechaTrans® which can expand or reduce mechanically the displacement produced by the piezoelectric device.
2) Technical transfer and consultancy of the piezoelectric device technologies for mass production companies.
3) Development, design, manufacturing, and technical services of other actuator applications and new filtering technologies.

What is MechaTrans® ?

Piezoelectric device generates a required displacement with low voltage. The electrical energy can be converted to mechanical energy at 60% of the conversion efficiency rate. For example, a piezoelectric device of 10mm × 10mm cross section size produces 3,500N(357kgf). However, as the displacement to be generated ranges from a few μm up to 40μm, the application fields should be limited due to the very small displacement. In order to overcome the disadvantage, Mechano Transformer Corporation has developed the displacement enlargement mechanism by using an unique lever principle. The enlarged displacement achieves one hundred times of the piezoelectric device itself. The displacement enlargement mechanism is a kind of a passive structure and no additional energy is required. As the mechanism is similar principle to a transformer which is used in electric circuits, it was called *mechanical transformer* but has been abbreviated to MechaTrans® later on and registered as a trademark in Japan. MechaTrans® was originally named only for the displacement enlargement mechanism but currently it is used as the actuator with a piezoelectric device.

Features of MechaTrans®

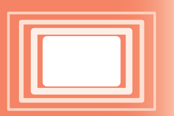
1 High energy efficiency

The conversion efficiency rate of MechaTrans® from the electrical energy to the mechanical energy should be 25%, including the displacement enlargement mechanism. Moreover, the current to retain a certain displacement is very small.

2 High-speed operation

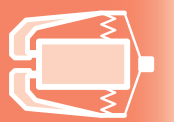
MechaTrans® is capable of high-speed operation compared to the usual actuators such as electromagnetic type. The resonance frequency which means the drive limitation is explained at the paragraph 3 of the technical notes.

3 Effective space utility



MechaTrans® is compact, especially in the thickness dimensions, compared to electromagnetic types of actuators with the same displacement and/or force.

4 Easy to use



MechaTrans® is easy to use because the displacement is proportional to the supply voltage. If it is required to control the displacement more precisely, aside from the hysteresis to be appeared by the input direction of the supply voltage, it is recommended to add a displacement sensor to the system. More details about this are explained at the paragraph 6-1) of the technical notes.

Application fields of MechaTrans®

It is said that “actuator” is a general term for a motion mechanism.

Our MechaTrans® is also a kind of an actuator which is applicable to industrial fields, medical, automotive, consumer products, aircraft, aerospace, agriculture and so on.

MechaTrans® is available for not only straight motion, but also rotary motion.

Technical Notes

1. Displacement and force to be generated

The relation between the displacement and the force to be generated is shown in Fig. 1. The displacement ξ_s at the mechanical output point of MechaTrans® is obtained when 100 [V] of the recommended voltage is supplied onto MechaTrans® without any external load, namely free condition. The force Fs is generated when 100 [V] is supplied and the output point is fixed. The gradient of the line $K_s = F_s/\xi_s$ is represented as the rigidity of MechaTrans® whereas the area of the triangle $0-E_s-\xi_s$ indicates the energy E_s to be produced by MechaTrans® itself.

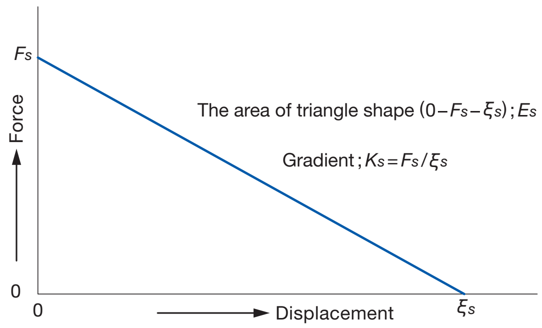


Fig. 1 Relation between the displacement and the force

2. Characteristics under static conditions

The displacement of MechaTrans® to be generated is shown in Fig. 2 when it is used under a static loading condition such as spring constant.

If the load rigidity K_x to MechaTrans® is equal to the rigidity of Mechatrans® K_s, the displacement of MechaTrans® should be half of the free condition. If K_x is larger than K_s, the displacement should be less than half of the free condition, and if K_x is smaller than K_s, the displacement should be more than the half.

The energy of the loading side given by MechaTrans® should be maximized when K_x is equal to K_s and it is a quarter of the total energy of MechaTrans® itself shown as Fig. 1.

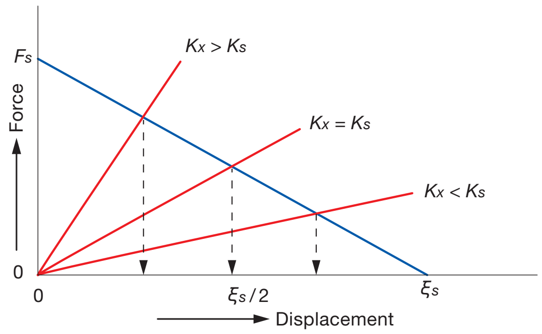


Fig. 2 Relation between load and generated displacement

3. Performance under a dynamic loading force

A mechanical resonance system is made up of both a loading mass M and rigidity of MechaTrans®. The resonance frequency can be calculated from the following equation.

$$f = \frac{1}{2\pi}\sqrt{\frac{K_s}{M}} \qquad (1)$$

Here the units are, f : Hz, K_s : N/m, M : kg.

In this case, the M is very important to the resonance frequency of MechaTrans® itself and the M consists of both the mass at the output point of MechaTrans® and the mass of the loading side. When a step voltage is supplied to MechaTrans®, the maximum kinetic energy to be given to M on the transient phenomenon should be equal to the own energy of the piezoelectric device. That means the energy difference between dynamic conditions and static conditions is not so small. When MechaTrans® is used under dynamic conditions, it is required to receive our technical consultation because MechaTrans® may be damaged in the worst case unless appropriate treatments are given to MechaTrans®. Please refer to paragraph 6-4).

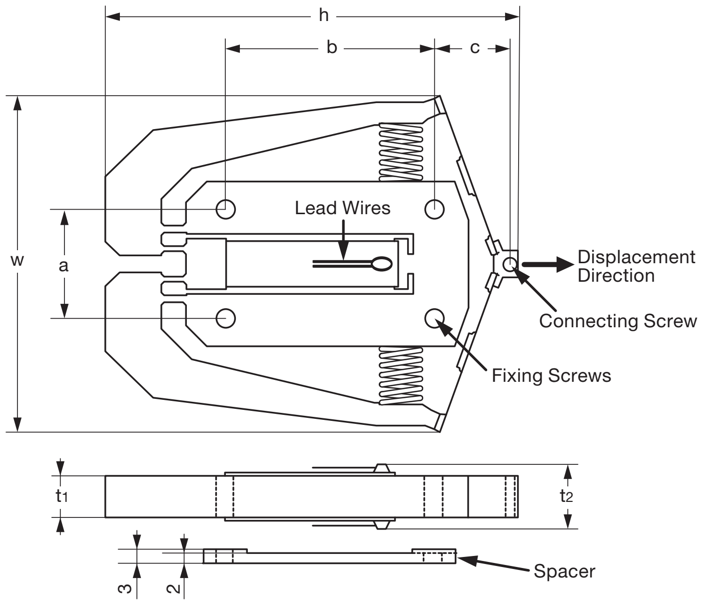


Fig. 3

4. Selection guide for MechaTrans®

The displacement, force, rigidity and capacitance of the existing MechaTrans® are shown in the following table;

These specification data is measured at DC100 volts as recommended by Mechano Transformer.

Fig. 4 is MechaTrans® map which shows the relation between the displacement and the force. It may be useful to select an optimum MechaTrans®.

5. Recommended drive circuits and selection of driving conditions

1) In case of Analog drive circuits; refer to Fig. 5

The current I [Ampere] to the amplifier is calculated by the equation (2), and it should be a key factor for amplifier selection.

$$I = C_d \cdot \frac{dV}{dt} \qquad (2)$$

Cd [F] is the capacitance of the MechaTrans® itself
dV/dt is the voltage change per second of MechaTrans®

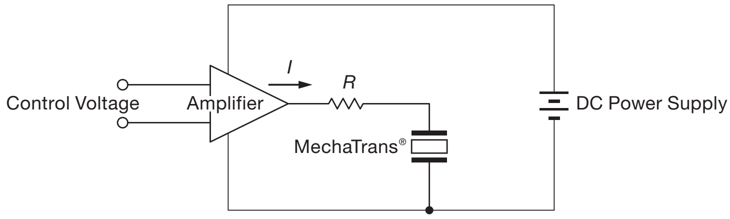


Fig. 5

As the equation (2) does not include the current to the mechanical system, it is recommended to measure the current in prior to selection of the drive circuit.

In order to get an optimum damping factor, the resistance R [Ohm] between the amplifier and MechaTrans® is calculated by the equation (3).

$$R = \frac{1}{C_d}\sqrt{\frac{M}{K_s}} \qquad (3)$$

M [Kg] is a loading mass to be added to MechaTrans®
Ks is rigidity of MechaTrans®

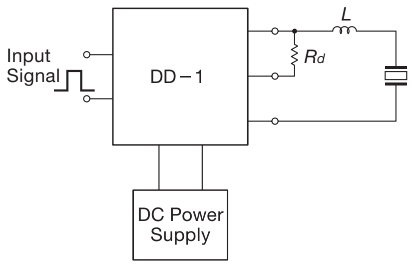


Fig. 6 Schematic of DD-1 connection

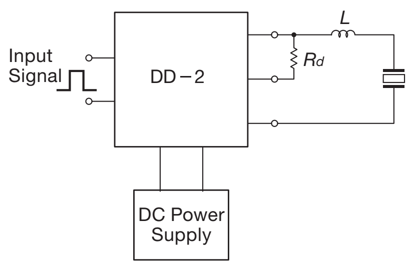


Fig. 7 Schematic of DD-2 connection

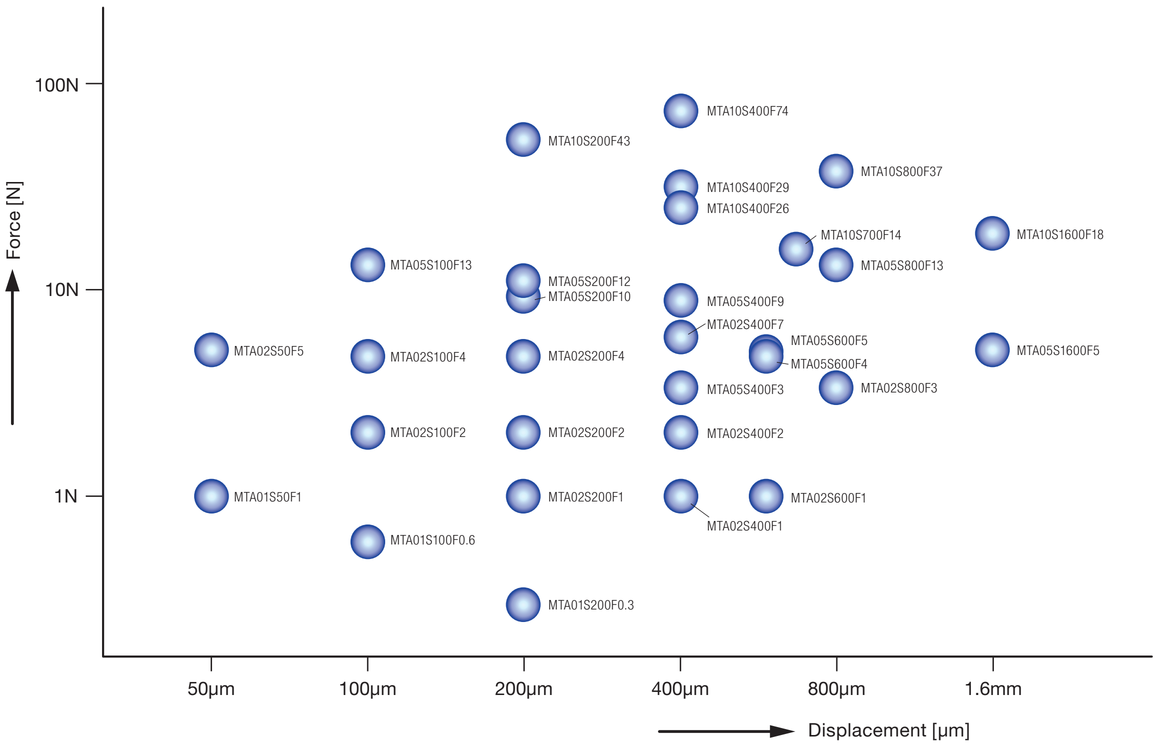


Fig. 4 Map of MechaTrans displacement and force

Type	Size of MechaTrans
MTA01S50F1	1.1×0.8×1
MTA01S100F0.6	
MTA01S200F0.3	
MTA02S50F5	2×3×5
MTA02S100F2	
MTA02S200F1	
MTA02S100F4	2×3×10
MTA02S200F2	
MTA02S400F1	
MTA02S200F4	2×3×20
MTA02S400F2	
MTA02S600F1	
MTA02S400F7	2×3×40
MTA02S600F5	
MTA02S800F3	
MTA05S100F13	5×5×10
MTA05S200F10	
MTA05S400F3	
MTA05S200F12	5×5×20
MTA05S400F9	
MTA05S600F4	
MTA05S400F26	5×5×40
MTA05S800F13	
MTA05S1600F5	
MTA10S200F43	10×10×20
MTA10S400F29	
MTA10S700F14	
MTA10S400F74	10×10×40
MTA10S800F37	
MTA10S1600F18	

2) In case of digital drive circuits; refer to Fig. 6 & 7

Combination both MechaTrans® and a drive circuit is shown on the table 3.

When a step voltage is supplied to MechaTrans® on the digital drive circuit, a large peak current flows both at the step-up point and at the step-down point because of the capacitive device. In order to avoid the peak current, it is necessary to add a resistance *R* or an inductance *L* between the drive circuit and MechaTrans®. It is recommended to add *L* in stead of *R* if a large kinetic energy is required for MechaTrans®. The value of the *L* should be obtained by equation (4) by harmonizing the resonance frequency of the drive circuit with the mechanical resonance frequency.

$$L = \frac{M}{Cd \cdot Ks} \qquad (4)$$

Here *M* [Kg]; Loading mass to MechaTrans®
Cd [F]; Capacitance of MechaTrans® itself (refer to Table 1 as above)
Ks [N/m]; Rigidity of MechaTrans®

(note) Even though L has been decided, a saturation problem may happen due to the coil core material and the air gap.
In that case, please contact us to design and produce the optimum coil.

If a stop motion every input pulse voltage is required, the input pulse signal time *T* [sec] should be determined by the equation (5).

$$T = 2\pi \sqrt{\frac{M}{Ks}} \qquad (5)$$

The optimum *Rd* value on Fig. 6 and 7 can be obtained by actual experiment basis, and in fact, it is expected to be between a few [Ω] to 200[Ω]. It is also important to select the resistance with enough wattage because the driving energy on the circuit is almost consumed by both the coil resistance and *Rd*.

If a slower motion is required for MechaTrans®, another resistance *Rs* is possible to use in stead of the *L* and it is also possible to minimize the physical overshooting amount by controlling the input signal. It is also required to contact us when MechaTrans® is used under dynamic conditions.

(note) In case of the *L* selection, the pulse voltage must be less than 80 [V] because almost twice of the base voltage may be supplied to MechaTrans® as the peak voltage.
In case of the *Rs* selection, the pulse voltage must be less than 130 [V] because the higher peak voltage than the base voltage may be supplied to MechaTrans®.

Table 1

(mm)

ns®	Displacement (μm)	Force (N)	Rigidity (N/m)	Capacitance (nF)
0	50	1.4	28	26
	100	0.6	6	
	200	0.3	1.6	
	50	5	74	90
	100	2	17	
	200	1	4	
	100	4	43	180
	200	2	11	
	400	1	3	
	200	4	17	350
	400	2	5	
	600	1	1.5	
	400	7	17	820
	600	5	8	
	800	3	4	
	100	13	132	750
	200	8	37	
	400	3	7	
	200	12	49	1400
	400	8	21	
	600	4	7	
	400	27	57	3400
	800	16	17	
	1600	5	3	
	200	43	228	5400
	400	28	71	
	700	14	19	
	400	64	148	13600
	800	37	43	
	1600	18	11	

Table 2 The dimensions of each part are as follows.

(mm)

Type	t_1	t_2	h	w	a	b	c	Fixing screw	Driving screw
MTA01S50F1	1	1.9	32	26	10.4	7	9.8	ϕ2	ϕ2
MTA01S100F0.6	1	1.9	32	26	10.4	7	9.8	ϕ2	ϕ2
MTA01S200F0.3	1	1.9	32	26	10.4	7	11.3	ϕ2	ϕ2
MTA02S50F5	2	3.5	28	25	10.4	7	9.7	ϕ2	ϕ2
MTA02S100F2	2	3.5	31	30	10.4	7	9.7	ϕ2	ϕ2
MTA02S200F1	2	3.5	33	35	10.4	7	9.7	ϕ2	ϕ2
MTA02S100F4	2	3.5	46	43	13	14	13	ϕ3	ϕ2
MTA02S200F2	2	3.5	42	43	13	14	13	ϕ3	ϕ2
MTA02S400F1	2	3.5	46	48	13	14	13	ϕ3	ϕ2
MTA02S200F4	2	3.5	63	58	15	24	18	ϕ3	ϕ2
MTA02S400F2	2	3.5	55	58	15	24	13	ϕ3	ϕ2
MTA02S600F1	2	3.5	62	58	15	24	18	ϕ3	ϕ2
MTA02S400F7	2	3.5	81	58	15	44	13	ϕ3	ϕ2
MTA02S600F5	2	3.5	83	58	15	44	13	ϕ3	ϕ2
MTA02S800F3	2	3.5	79	58	15	44	13	ϕ3	ϕ2
MTA05S100F13	4.8	8	53	52	16	19	13.5	ϕ3	ϕ2
MTA05S200F10	4.8	8	51	50	16	19	13.5	ϕ3	ϕ2
MTA05S400F3	4.8	8	55	50	16	19	14	ϕ3	ϕ2
MTA05S200F12	4.8	8.6	65	58	16	26	15	ϕ3	ϕ2
MTA05S400F9	4.8	8.6	61	58	16	26	15	ϕ3	ϕ2
MTA05S600F4	4.8	8.6	65	58	16	26	15	ϕ3	ϕ2
MTA05S400F26	4.8	8.6	86	67	18	44	17	ϕ3	ϕ2
MTA05S800F13	4.8	8.6	86	67	18	44	17	ϕ3	ϕ2
MTA05S1600F5	4.8	8.6	91	77	20	50	15	ϕ3	ϕ2
MTA10S200F43	9.4	14.2	75	75	26	29	17.8	ϕ4	ϕ2
MTA10S400F29	9.4	14.2	75	75	26	29	17.8	ϕ4	ϕ2
MTA10S700F14	9.4	14.2	75	83	26	29	17.8	ϕ4	ϕ2
MTA10S400F74	9.4	14.2	96	77	26	49	17.8	ϕ4	ϕ2
MTA10S800F37	9.4	14.2	96	77	26	49	17.8	ϕ4	ϕ2
MTA10S1600F18	9.4	14.2	97	89	26	49	17.8	ϕ4	ϕ2

6. Operating precautions for MechaTrans®

1) Hysteresis

The displacement of MechaTrans® to be generated by increasing voltage a little bit differs from decreasing voltage. The difference, namely hysteresis comes from the inherent characteristics of piezoelectric devices. If it is required to control the displacement more precisely, it is recommended to add a displacement sensor onto the system.

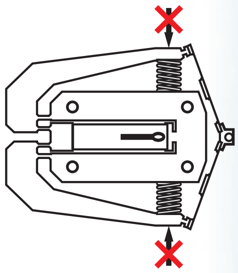
As an example, the hysteresis loop of MechaTrans® MTA02S200F2 is shown in Fig. 8.

2) Continuous DC voltage under high humidity

When DC voltage is supplied to MechaTrans® for a long time under over 60% humid environment, the piezoelectric device may result in an electrical short circuit which is said migration phenomenon. It is recommended to operate MechaTrans® under dry environment such as clean room. But In case of an intermittent operation, possibility of the migration may be very small even though under high humid environment.

3) Avoid excess tensile force against PZT and/or compression force to the arm

An excess outer force to the piezoelectric device and the arm portion must be avoided. Because the piezoelectric device is weak against a tensile force due to not only being made from a ceramic material, also an initial pre-tension force given to the piezoelectric device itself. If an outer force is given to the piezoelectric device through the arm, the force should be amplified by the lever structure.



4) Do not superimpose DC voltage instantaneously

If DC voltage is directly supplied to MechaTrans® by using a switch and unless any resister is added onto MechaTrans® in series, the maximum displacement may be twice, compared to the displacement under static conditions, and then MechaTrans® may be damaged. In that case, it is recommended to add a suitable resister onto MechaTrans®, to increase DC voltage gradually, or to control the voltage less than 80 V.

5) Ambient temperature

If ambient temperature is increased +1 [℃], the displacement at the mechanical output point of MechaTrans® should be the almost same as −1 [V] supply and the displacement direction is opposite to Fig. 3. If MechaTrans® is used under a changeable ambient temperature and its displacement amount cannot be so small to the system. Please contact us for the solution.

6) Polarization

If the polarity of the power supply is opposite to normal, the displacement should have the minus(−) direction up to approximately 20 V. But when the power supply is more than 20 V, the displacement direction changes to plus(+) because of polarization of the piezoelectric device. If an alternating voltage is supplied to MechaTrans® for a long time, the piezoelectric device may be destroyed. The right polarity connection of the power supply should be required except for a special occasion. The red color lead wire is normally connected to the plus(+) polarity.

Table 3 **The combinations of MechaTrans® and a drive circuit are as follows.**

The type of drive circuit	Compatibility of MechaTrans®
DD–1	MTA01S50F1, MTA01S100F0.6, MTA01S200F0.3 MTA02S50F5, MTA02S100F2, MTA02S200F1 MTA02S100F4, MTA02S200F2, MTA02S400F1 MTA02S200F4, MTA02S400F2, MTA02S600F1
DD–2	MTA02S400F7, MTA02S600F5, MTA02S800F3 MTA05S100F13, MTA05S200F10, MTA05S400F3 MTA05S200F12, MTA05S400F9, MTA05S600F4 MTA05S400F26, MTA05S800F13, MTA05S1600F5 MTA10S200F43, MTA10S400F29, MTA10S700F14 MTA10S400F74, MTA10S800F37, MTA10S1600F18

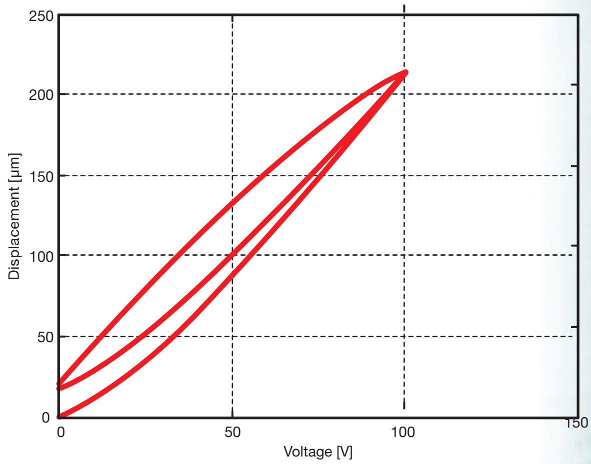


Fig. 8 **MTA02S200F2**

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