DATA SHEET

Order code	Manufacturer code	Description
06-0770	n/a	SMART WIRE 0.004IN DIAMETER PER METRE RE
06-0768	n/a	SMART WIRE 0.006IN DIAMETER PER METRE RE

Revision A
20/02/2007

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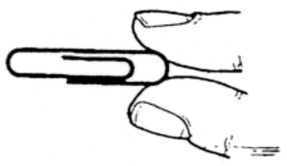
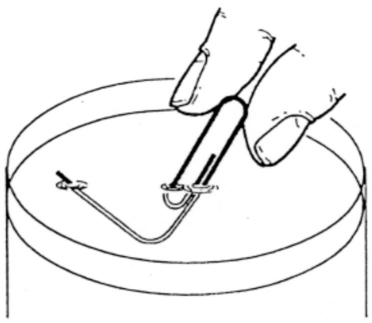
SMART WIRE

The following is abridge from the TEP publication: "Smart Wire & its applications" version 1

Shape Memory Alloy (SMA)

SMA is a "smart" material which, as its name suggests, has a memory. The most common SMA is an alloy (mixture of metals) of nickel and titanium - called **nitinol.** By means of special heat treatment, a piece of SMA can be made to 'remember' a shape. For example, a length of wire can be made to remember that it should be straight at temperatures above 70°C. If you bend this wire at normal room temperature into the shape of a paper clip, it stays bent and will continue acting as a paper clip. However, if you place it in a glass of water whose temperature is above 70°C, it immediately straightens out! When cool, it remains straight until it is bent again.





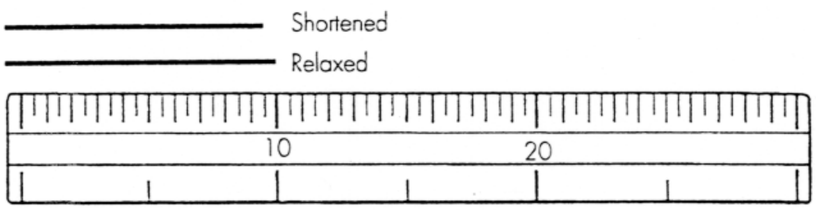
This cycle of bending and then straightening when heated can be continued millions of times. The temperature at which SMA 'remembers' its original form is called the *transition* temperature and when this point is reached, it changes shape.

SMA has a relatively high electrical resistance and can be heated to its transition temperature by passing an electrical current through it.

Smart Wire

A common form of SMA is wire available in different diameters. This ranges, for example, from 5 mm diameter down to 50 microns (1 micron = 1/1000 millimetre). The SMA wire sample provided with this book is Nitol with a diameter of 100 microns. It is heat treated to 'remember' that it has a shorter length when heated above its transition temperature (70°-80°C) than below it. (See study File 2)

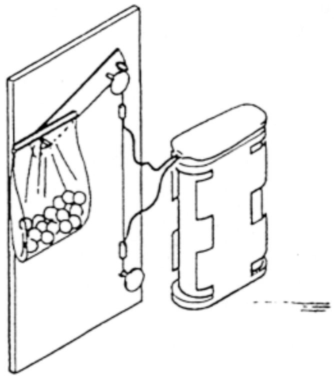
If the sample length of wire is held between two points it has a length of approximately 10 cm. When heated to between 70° and 80°C, it shortens by about 5% or 1/20 and exerts a useful pulling force. (The wire becomes shorter and it gets slightly fatter.) When the wire cools down, it relaxes to its longer length of 10 cm.



The 5% change in length is constant for any length or diameter of SMA wire. This results in quite small movements for shorter lengths of wire. However, the movement can be increased by increasing the length of wire. To work out the amount of movement for a given piece of wire, you simply multiply its length by 5%.

For example, for a wire 150 mm in length, the shortening is:

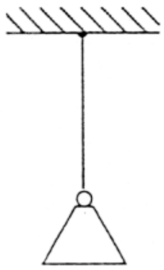
$150/1 \times 1/20 = 150/20 = 7.5$ mm



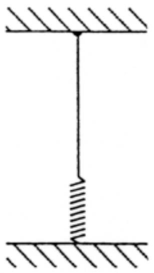
The 5% shortening of SMA can also be turned into a much larger movement using simple lever systems.

SMA wire has to be stretched or biased to return to its longer length. The force required to do this is much smaller than the pulling force that the wire exerts when it shortens. There are two main ways of biasing:

- Using a weight
- Using a spring

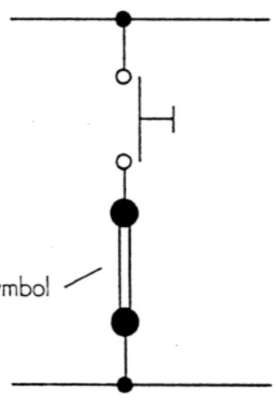


Using a weight



Using a spring

Because SMA has a relatively high electrical resistance, it can be heated to its transition temperature simply by passing current through it. This opens up many possibilities for providing mechanical actuation (movement) without any moving parts other than those the SMA is attached to! Also, for smaller diameter wires, the currents needed are quite small and can be provided from smaller batteries.



In a practical design using SMA wire, you need to know what force to use to bias it, and what force it will exert when it shortens. If you are heating it with electric current, you also need to know how much current to pass without overheating and damaging it.

All these figures (for 100 micron wire) are provided in the table below:

Bias force Pulling force	0.3 N 1.5 N
Resistance Max. current Max. power	150 ohms per metre 180 milliamps 5 Watts per metre
Shortening time Relaxation time	0.1 second 1.0 second
Recommended extension Minimum bend radius	5% 5 mm
Effective transition temperature	70°Centigrade
Pulling starts at Pulling finishes at Relaxation starts at Relaxation finishes at	68°C. 78°C. 52°C. 42°C.

Explanation of the Table

The table tells us that at normal room temperature the wire needs to be stretched with a bias force of 0.3 newtons - which is roughly equivalent to hanging a weight of approximately 30 grams on the end. When heated to the transition temperature of between 70° to 80°C, the wire shortens about 5% in length and will exert a pulling force of 1.5 newtons - roughly equivalent to lifting a weight of 150 grams.

The speed at which the wire shortens when it reaches the transition temperature is about 0.1 seconds. It takes longer to relax or stretch back to its longer length - about 1 second. The table also tells us that when heated, the wire actually starts changing length at 68°C and finishes at 78°C. When it cools, however, the stretching or relaxation does not take place until it has reached 52°C. (The difference between the higher transition temperature and the relaxation temperature is called hysteresis (see Study File 2).

The figures given in the table are the recommended ones for 100 micron nitol; if they are exceeded, the useful life of the wire will be reduced.

The supply needed to heat the wire can be determined using Ohm's Law. This states the relationship between voltage (V), current (I) and resistance (R). Ohm's Law states that:

$$V = I \times R$$
$$I = V/R$$
$$R = V/I$$

The table gives us the resistance of the wire and also states the maximum current. Using Ohm's Law, we can therefore work out the voltage needed.

For example, what is the voltage needed to pass the maximum safe current through the 10 cm length of 100 micron sample wire provided with this book?

Step 1
The resistance of the wire is 150Ω per metre.
Divide by 100 = 1.5Ω per cm.
10 cm of wire = 1.5Ω × 10 = 15Ω.

Step 2
The maximum current is 180 mA or 0.18 A.
(1 milliamp = 1/1000 Amp.)

Step 3
V = I × R. Substituting the figures above gives:
V = 0.18 A. × 15Ω = 2.7 volts.

A 3 volt battery (two AA cells in series) can be used to power this length of wire because as current is drawn, its voltage will reduce slightly.

To check that the power rating (the rate of doing work) is not exceeded, we can use the power equation W = I × V.

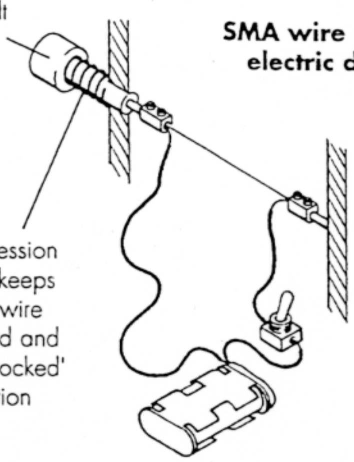
If we substitute the above figures W = 0.18 × 2.7 = 0.49 Watts for a 10 cm length of wire and 10 × 0.49 = 4.9 for a metre length. This is the maximum figure given in the table.

What voltage would be needed to supply a 15 cm length of 100 micron SMA wire?

How many times per minute could a length of 100 micron SMA wire go through a complete shortening and relaxation cycle?

Practical Applications of SMA Wire

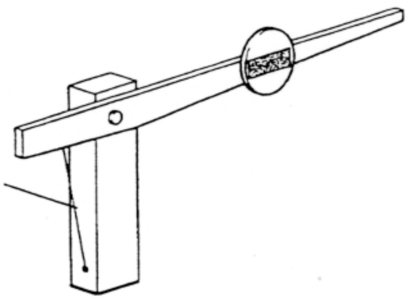
Linear actuation
SMA wire is most easily used to provide linear or straight line movement. The example shown uses SMA wire to pull a bolt in a simple lock. In this application very little linear movement is needed. If its length can be accommodated, SMA wire can often be used in place of a more expensive solenoid. A free-standing actuator can be made by containing the wire in a plastic tube.



SMA wire used in an electric door lock

- **Angular actuation**

In many practical applications of SMA wire, a mechanical system is used to amplify movement. The barrier prototype model illustrated uses the lever principle to move and



Further supplies can be obtained from Middlesex University Teaching Resources:

Teaching Resources Centre
Middlesex University
Trent Park
Oakwood
London N14 4YZ

TEL : 0181 447 0342
FAX : 0181 447 0340

100μm Smartwire	- PAC SW4 - £6.00
150μm Smartwire	- PAC SW1 - £6.00
Booklet	- BBS 030 - £2.50

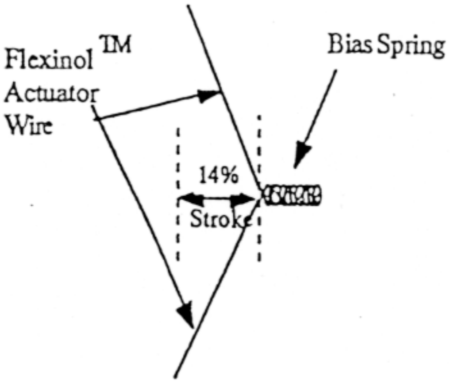
Section 2. Electrical Guidelines

If Flexinol™ actuator wire is used within the guidelines then obtaining repeatable motion from the wire for tens of millions of cycles is reasonable. If higher stresses or strains are imposed, then the memory strain is likely to slowly decrease and good motion may be obtain for only hundreds or a few thousands of cycles. The permanent deformation which occurs in the wire during cycling is heavily a function of the stress imposed and the temperature under which the actuator wire is operating. Flexinol™ wire has been specially processed to minimize this straining, but if the stress is too great or the temperature too high some permanent strain will occur. Since temperature is directly related to current density passing through the wire care should be taken to heat, but not overheat, the actuator wire. The following charts give rough guidelines as to how much current and force to expect with various wire sizes.

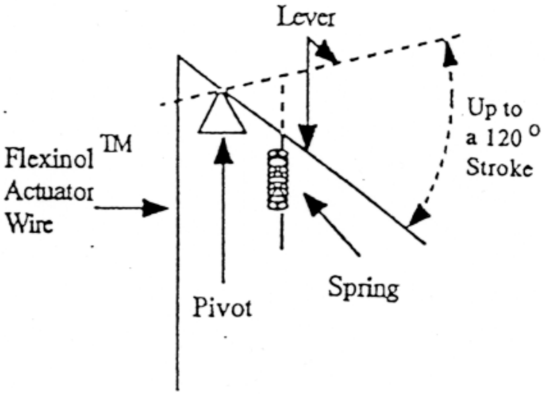
	Wire Diameter Size	Resistance Ohms Per Inch	Maximum Pull/Force	Approximate* Current at Room Temperature	Contraction Time	Off Time 70 C Wire	Off Time 90° C Wire
	0.0015"	21	17 gm	30mA	1 sec.	.25sec	.09sec
	0.002"	12	35 gm	50mA	1 sec.	.3 sec	.1 sec
	0.003"	5	80 gm	100mA	1 sec.	.5 sec	.2 sec
SW4	0.004"	3	150 gm	180mA	1 sec.	.8 sec	.4 sec
	0.005"	1.8	230 gm	250mA	1 sec.	1.6 sec	.9 sec
SW1	0.006"	1.3	330 gm	400mA	1 sec.	2 sec	1.2 sec
	0.008"	0.8	590 gm	610mA	1 sec.	3.5 sec	2.2 sec
	0.010"	0.5	930 gm	1000mA	1 sec.	5.5 sec	3.5 sec
	0.012"	0.33	1250 gm	1750mA	1 sec.	8 sec	6 sec
	0.015"	0.2	2000 gm	2750mA	1 sec.	13 sec	10 sec

* The contraction time is directly related to current input. the figures used here are only approximate since room temperatures, air currents, and heat sinking of specific devices vary. currents which heat the wire in 1 second can be left on without overheating it. both heating and cooling can be greatly changed, see "Section 3 Cycle Time".

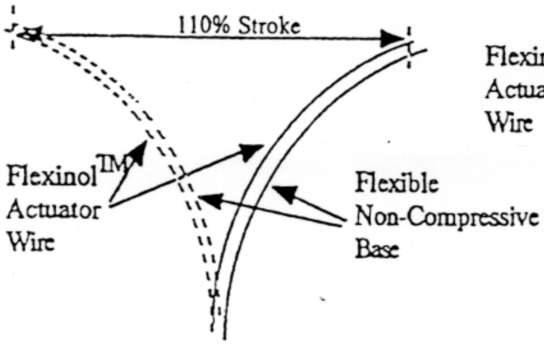
Right Angle Pull



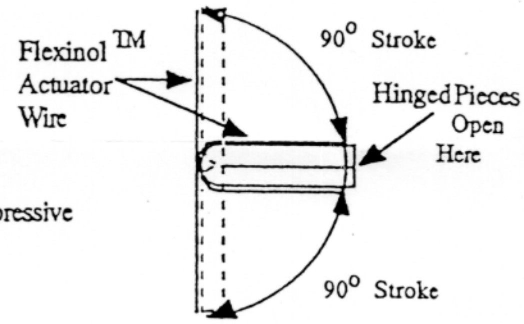
Simple Lever



Adjusting Curvature



Clam Shell



Stroke and Available Force Table

100 µm   150 µm

	Approx. Stroke	.001" Wire	.002" Wire	.003" Wire	.004" Wire	.005" Wire	.006" Wire	.008" Wire	.010" Wire
Normal Bias Spring	3%	7gms	35gms	80gms	150gms	230gms	330gms	590gms	930gms
Dead Weight Bias	4%	7gms	35gms	80gms	150gms	230gms	330gms	590gms	930gms
Leaf Spring Bias	7%	7gms	35gms	80gms	150gms	230gms	330gms	590gms	930gms
Right Angle Pull	14%	2gms	9gms	20gms	38gms	56gms	83gms	148gms	232gms
Simple Lever *	30%	1gms	5gms	11gms	22gms	31gms	47gms	84gms	133gms
Adjusting Curvature	110%	.2gms	1.2gms	3gms	5gms	8gms	12gms	22gms	34gms
Clam Shell	100%	.2gms	1.4gms	3.2gms	6gms	9gms	13gms	24gms	37gms

* Assumes a lever ratio of 6:1