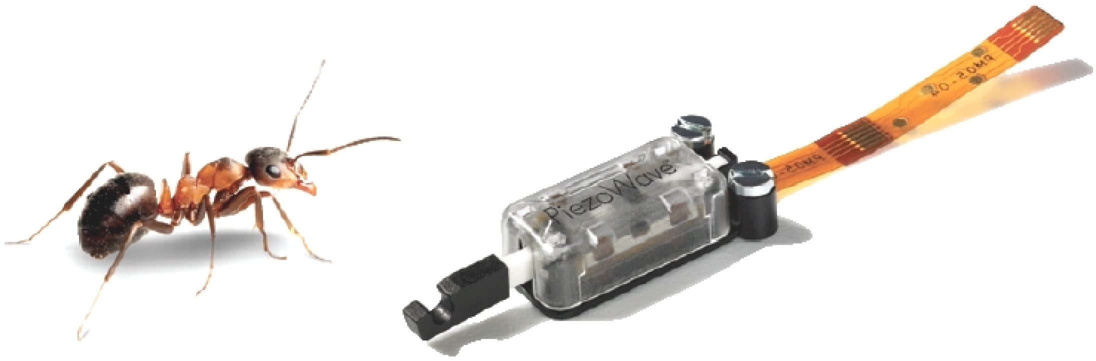
The PiezoWave™ motor



General description

The PiezoWave™ motor has been developed to meet the needs in e.g. portable consumer electronics where miniature size, speed, precision and power consumption are essential features. The part count is very low and all components in the motor are manufactured with existing mass-fabrication technology. The electronics interface is extremely simple – two low voltage signals of essentially arbitrary shapes can be used and the demands on frequency control is extremely low. The PiezoWave™ motor can easily be tailored for various customer applications.

The motor consists of a few parts, Fig. 1. When activated electrically the piezo elements will oscillate at an ultrasonic frequency. The drive pads, which are used for transferring the movement from the elements to the drive rail, will move in an elliptical fashion due to the flexural (bending) waves in the piezo element. The drive pad is only in contact with the drive rail during half the cycle and the drive rail will therefore move one step forward or backward for each electrical cycle. The spring is used to create the friction force between the drive pad and the drive rail.

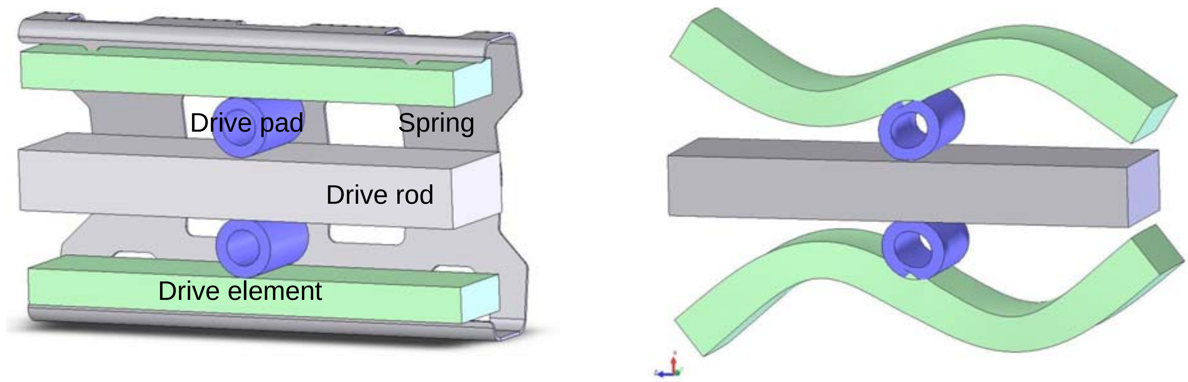


Fig. 1 The essential parts of the PiezoWave motors (left) and one of the flexural vibration modes of the Piezo elements (right).

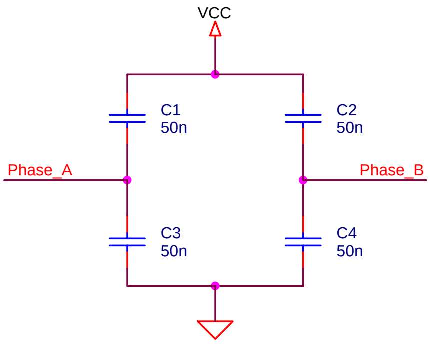


Fig. 3 The PiezoWave motor from an electrical point of view

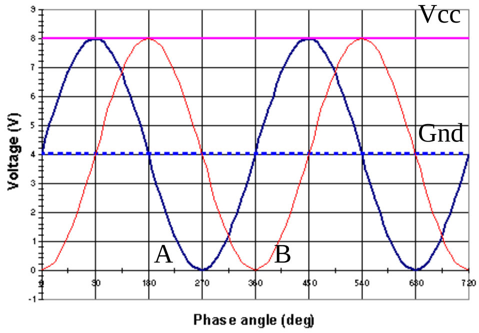


Fig. 4 Definitions of the voltages.

Electrical description

Each Piezo element consists of two independent halves and can be seen as two capacitors electrically, Fig. 3. A complete motor has two elements and they are essentially in parallel with each other from an electrical standpoint. Typically two 90° phase-shifted signals are applied to the piezo element. The phase relation between the two signals will determine the movement direction of the drive rail. The motor moves forward, i.e. the mechanical connector on the drive rod moves away from the motor housing, when phase A is +90° shifted relative phase B, Fig. 4. To change direction the phase difference should be reversed.

Typical voltages for both phases, Vcc and Gnd, for driving in one direction are given in Fig. 4. It is important that the peak phase voltages should not be higher than 2 V above the Vcc voltage level and less than 2 V lower than the Gnd voltage level. The shape of the waveform for the phase voltages does not strongly influence the motor operation.

The motor flexible circuit board (FPC)is prepared for a 6 pin connector: CviLux CF21 Series ZIF #CF21061U0R0, Fig 5. Pin assignment is given below. Dual Connectors: the FPC has two connector areas, Fig 6, which are identical. It is possible to cut the FPC to get a shorter FPC.

Absolute min./max. ratings

Phase voltage, U_{pp}	0 - +9	V
Voltage difference U_{max} - Vcc	< +2	V
Voltage difference U_{min} - Gnd	> -2	V
Frequency	90 - 98	kHz

Typical electrical characteristics

Phase Voltage, peak-peak	8	V
Phase voltage, DC level	4	V
Phase shift A-B	±90	°
Vcc (DC voltage)	8	V
Capacitance/phase	100	nF
Frequency	91 - 93	kHz

Pin assignment

Pin #	1	2	3	4	5	6
Signal		Vcc	Gnd	A	B	

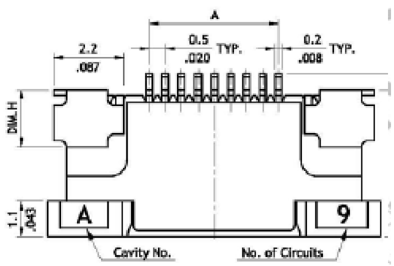


Fig. 5 The CviLux CF21 Series ZIF #CF21061U0R connector

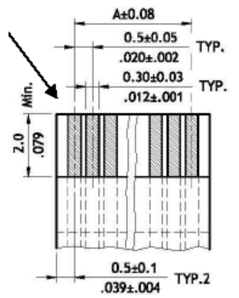


Fig. 6 Dimensions of the connector areas on the FPC.

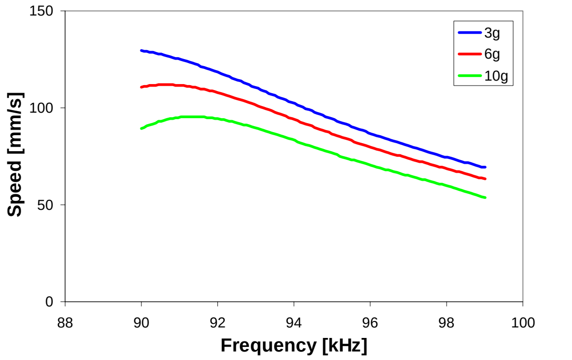


Fig. 7 Typical speed as a function of frequency for different loads at 8 V and 20 °C

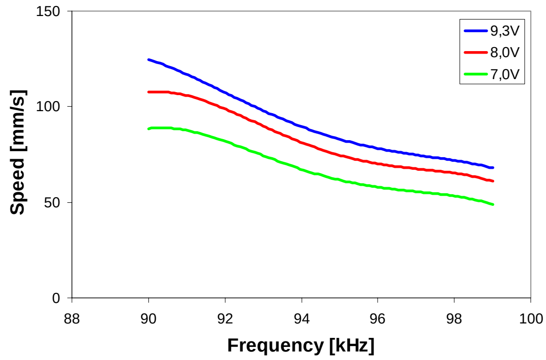


Fig. 8 Typical speed as a function of frequency for different voltages at 0.1 N and 20 °C

Typical motor characteristics

Speed @ no load[1]	150	mm/s
Speed @ 0.1 N load[1]	50	mm/s
Stall force[1]	0.15	N
Holding force	0.30	N
Stroke	8	mm
Step length, average	0.5 –1	µm
Life time[1], cycles 8 mm	>100.000	

Absolute min./max. ratings

Force, drive direction	0.5	N
Force, transverse direction	0.3	N
Temperature	-10 - +50	°C

Typical motor performance for some various driving conditions are shown in Figs. 7-9. The speed variation between individual motors is typically ±10%. The motor operation can be unstable at frequencies lower than 90 kHz and these conditions are therefore not recommended.

The motor is not designed to carry load in directions transverse to the driving direction. The moveable part in the applications should have its own guiding system and the mechanical connection to the drive rail should not result in large torques and transverse forces. The mechanical connector allows for angular errors of up to ± 2°.

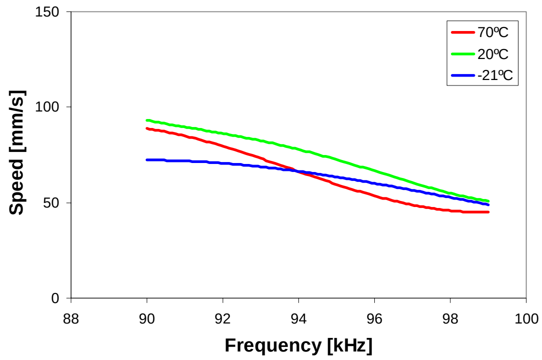


Fig. 9 Typical speed as a function of frequency for different temperatures at 8 V and 0.1 N

Mechanical data

Motor dimensions	14x7.2x4.4	mm
Motor mass	0,6	g
Drive element size	8x1,4x0,6	mm

1 $U_{peak\text{-}peak}$=8V, + 20 °C, frequency 92 kHz

Application examples

The simplest way to drive the motor is to send a pulse train, e.g. a square wave, via an inductor to the piezo element which creates an LC circuit and sine wave voltage across the piezo element, Fig. 10. The assumption is that the amplitude of the pulses in the pulse train is the same as VCC.

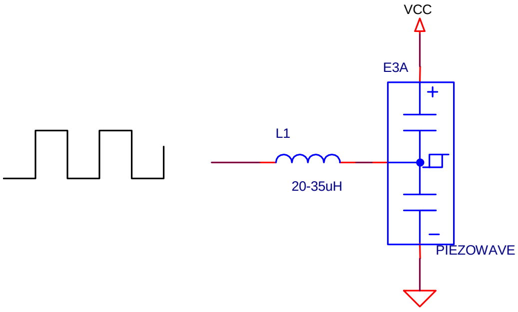


Fig. 10 Drive principle with an inductor in series with the motor phase.

Drive Stage Examples

Two different drive stage examples are presented below. Both are of the resonant type.

The first example, Fig. 11, is utilizing simple TTL-circuitry, 74AC14. This is a very simple driver and can be used in applications that do not require very high efficiency. The control signals are square wave pulse trains with a 90°phase difference. The movement direction is switched by reversing the phases. See details about voltages, frequencies and phase relationships in Typical Electrical Characteristics and Absolute Min./Max. Ratings.

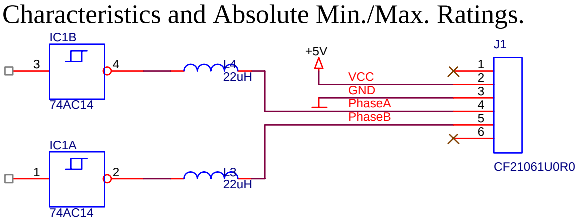


Fig. 11 A simple driver circuit suitable for the PiezoWave motor.

The second example, Fig. 12 is a circuit with higher efficiency that can run with supply voltages in the range 2.7 – 3.3V. This makes it ideal for hand held, battery operated applications.

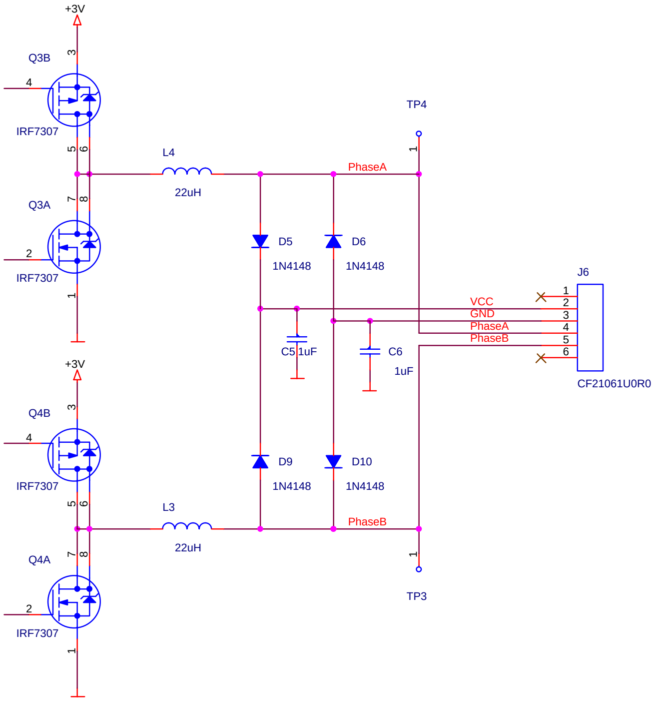


Fig. 12 A low voltage driver for the PiezoWave motors

In switching designs it is very important to allow enough “dead time” in between switching on/off the high and low side switches. The design above is using virtual GND and VCC generated by the phase voltages. A similar design can of course be used together with the TTL-based driver. Both of the designs presented are based on a resonant LC-circuit. It is of course possible to run the motor with a sine wave generated by a different circuitry. The power consumption will however increase if a non-resonant driver is used.