SF6901

Fast Turn-off Intelligent Controller

December 2015

GENERAL DESCRIPTION

The SF6901 is a Low-Drop Diode Emulator IC that, combined with an external switch replaces Schottky diodes in high-efficiency, Flyback converters. The chip regulates the forward drop of an external switch to about 70mV and switches it off as soon as the voltage becomes negative. FS6901 is offered in a space saving SOT23-6 package.

FEATURES

- Works with both Standard and Logic Level FETS
- Compatible with Energy Star, 1W Standby Requirements
- V_{CC} Range From 4.5V to 32V
- Fast Turn-off Total Delay of 20ns
- Max 400kHz Switching Frequency
- < 1mA Low Quiescent Current
- Supports CCM, DCM and Quasi-Resonant Topologies
- Supports High-side and Low-side Rectification
- Power Savings of Up to 1.5W in a Typical Notebook Adapter

APPLICATIONS

- Industrial Power Systems
- Distributed Power Systems
- Battery Powered Systems
- Flyback Converters

TYPICAL APPLICATION CIRCUIT

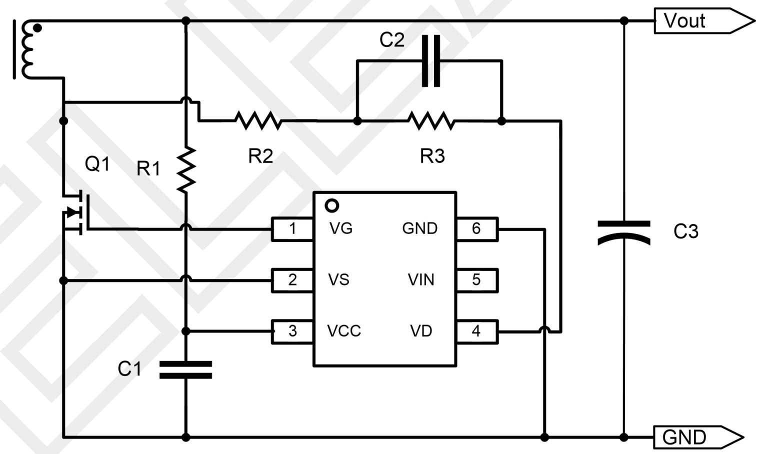
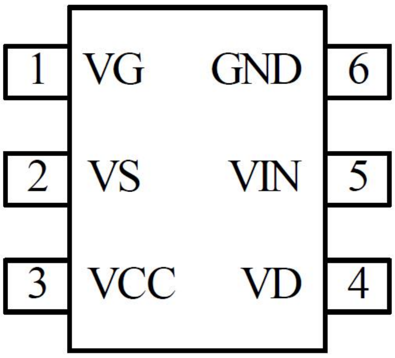


Figure 1 Typical Application Circuit (Vout > 5V)

PIN CONFIGURATION

Package	Pin Configuration (Top View)
SOT23-6	

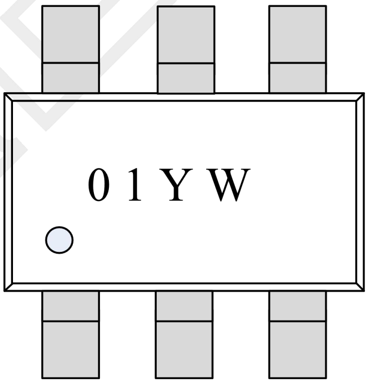
PIN DESCRIPTION

No.	Pin	Description
1	V_G	Gate drive output
2	V_S	Ground, also used as reference for VD
3	V_{CC}	Supply voltage
4	V_D	FET drain voltage sense
5	V_{IN}	Auxiliary supply voltage
6	GND	Power Ground, return for driver switch

ORDERING INFORMATION
Industrial Range: -40°C to +125°C

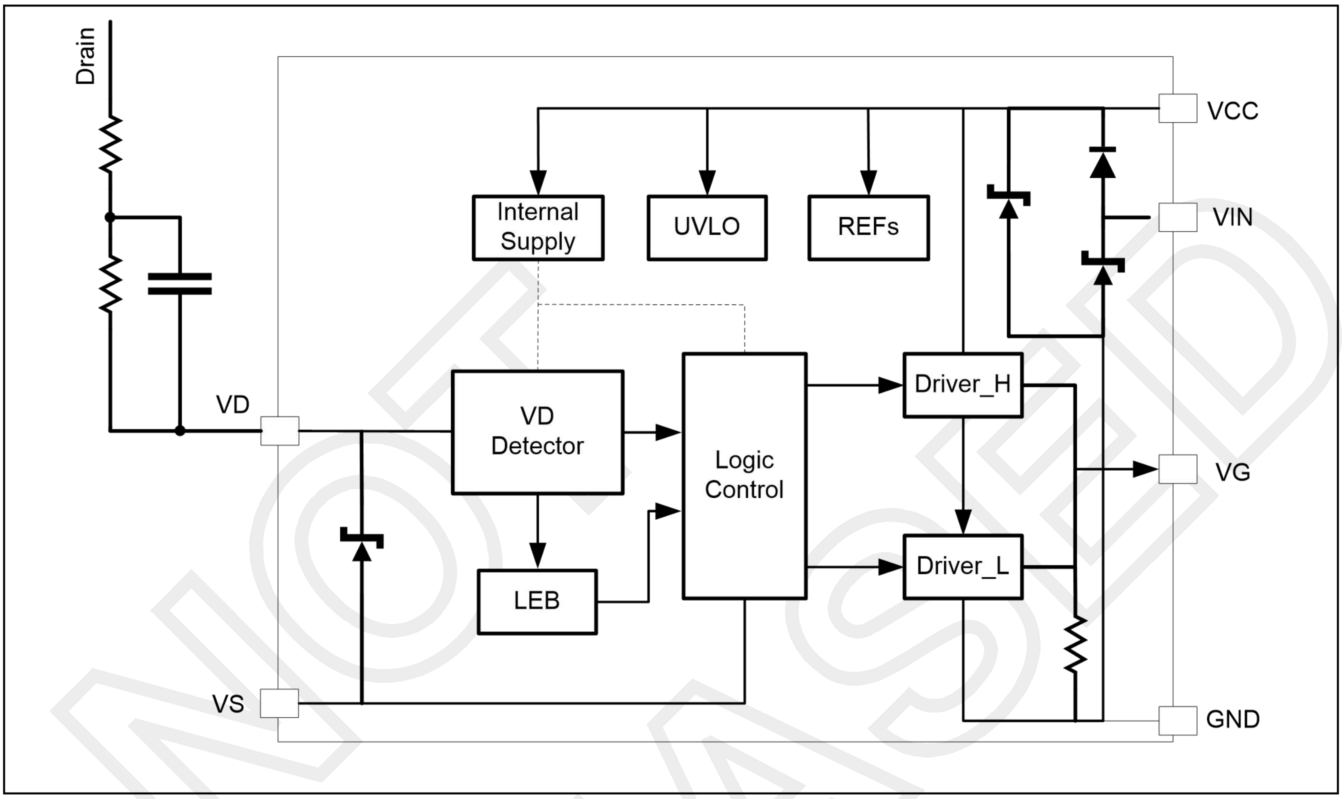
Order Part No.	Package	Unit Weight (g)	QTY
SF6901LGT	SOT23-6, Pb-Free	0.015	3000/Reel

Marking Information



Dot: Pin1 Mark
01:Part number SF6901
YW: Year&Week Code

FUNCTIONAL BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

V_{CC} to V_S Voltage		-0.3V ~ 45V
GND to V_S Voltage		-0.3V ~ 0.3V
V_G to V_S Voltage		-0.3V ~ 25V
V_D to V_S Voltage		-0.7V ~ 5.7V
V_{IN} to V_S Voltage		-0.3V ~ 45V
Operation frequency		400 kHz
Operating temperature range, T_A		-40°C~+110°C
Storage temperature range, T_{STG}		-55°~+150°C
Package Thermal Resistance (SOT23-6)	Junction to Ambient, $R_{th\text{-}JA}$	220 °C/w
	Junction to Case, $R_{th\text{-}JC}$	110 °C/w
ESD (HBM)		3000 V

Note:
Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other condition beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

Test condition is T_A = 25°C, V_{CC} = 12V, unless otherwise specified.

Parameter	Condition	Min.	Typ.	Max.	Unit
Supply Voltage (V_{CC}) Section					
V_{CC} Supply Voltage Operation Range		4.5		32	V
V_{CC} UVLO Rising			4.2		V
V_{CC} UVLO Falling			4.3		V
V_{CC} Clamper Voltage			35		V
Operation Current	C_{load} = 5nF, F_{SW} = 100kHz		6	10	mA
Quiescent Current	No Switching			1	mA
Shutdown Current	V_{CC} = 4V		100	150	uA
Thermal Shutdown Temperature			150		°C
Thermal Shutdown Hysteresis			15		°C
Control Circuitry Section					
VS to VD Forward Volrage, V_{FWD}		55	70	85	mV
Turn-on Delay	C_{LOAD} = 5nF		75		ns
	C_{LOAD} = 10nF		100		ns
Pull-Down Resistance of VG Pin			200k		Ω
Input bias Current on VD pin	MOSFET off		5.5		uA
	MOSFET on		2.5		uA
Minimum 'ON' time			1.6		us
Gate Driver Section					
V_G (Low)	I_{LOAD} = 1mA		0.05	0.5	V
V_G (High)	V_{CC} > 17V	12	13.5	15	V
	V_{CC} < 17V	V_{CC}–2.2			V
Turn-off Threshold		10	15	20	mV
Turn-off Propagation Delay	V_D = V_S, R_{GATE} = 0ohm		15		ns
Turn-off Total Delay	V_D = V_S, C_{LOAD} = 5nF, R_{GATE} = 0ohm		20	35	ns
	V_D = V_S, C_{LOAD} = 10nF, R_{GATE} = 0ohm		40		ns
Pull Down Impedance			1	2	Ω
Pull Down Current		2			A

OPERATION DISCRIPTION

The SF6901 supports operation in CCM, DCM and Quasi-Resonant topologies. Operating in either a DCM or Quasi-Resonant topology, the control circuitry controls the gate in forward mode and will turn the gate off when the MOSFET current is fairly low. In CCM operation, the control circuitry turns off the gate when very fast transients occur.

Blanking

The control circuitry contains a blanking function. When it pulls the MOSFET on/off, it makes sure that the on/off state at least lasts for some time. The turn on blanking time is ~1.6us, which determines the minimum on-time. During the turn on blanking period, the turn off threshold is not totally blanked, but changes the threshold voltage to ~+50mV (instead of -20mV). This assures that the part can always be turned off even during the turn on blanking period. (Albeit slower, so it is not recommended to set the synchronous period less than 1.6us at CCM condition in flyback converter, otherwise shoot through may occur)

Under-Voltage Lockout (UVLO)

When the V_{CC} is below UVLO threshold, the part is in sleep mode and the Vg pin is pulled low by a 10kΩ resistor.

Thermal Shutdown

If the junction temperature of the chip exceeds 150°C, the Vg will be pulled low and the part stops switching. The part will return to normal function after the junction temperature has dropped to 115°C.

Turn-on Phase

When the synchronous MOSFET is conducting, current will flow through its body diode which generates a negative Vds across it. Because this body diode voltage drop (<-500mV) is much smaller than the turn on threshold of the control circuitry (-70mV), which will then pull the gate driver voltage high to turn on the synchronous MOSFET after about 100ns turn on delay.

As soon as the turn on threshold (-70mV) is triggered, a blanking time (Minimum on-time: ~1.6us) will be added during which the turn off threshold will be changed from -15mV to +50mV. This blanking time can help to avoid error trigger on turn off threshold caused by the turn on ringing of the synchronous MOSFET.

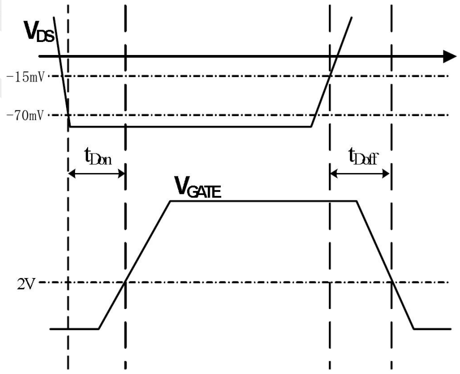


Figure 2 Turn-on and Turn-off Delay

Conducting Phase

When the synchronous MOSFET is turned on, Vds becomes to rise according to its on resistance, as soon as Vds rises above the turn on threshold (-70mV), the control circuitry stops pulling up the gate driver which leads the gate voltage is pulled down by the internal pull-down resistance (10kΩ) to larger the on resistance of synchronous MOSFET to ease the rise of Vds. By doing that, Vds is adjusted to be around - 70mV even when the current through the MOS is fairly small, this function can make the driver voltage fairly low when the synchronous MOSFET is turned off to fast the turn off speed (this function is still active during turn on blanking time which means the gate driver could still be turned off even with very small duty of the synchronous MOSFET).

Turn-off Phase

When Vds rises to trigger the turn off threshold (- 15mV), the gate voltage is pulled to low after about 20ns turn off delay (defined in Fig.2) by the control circuitry. Similar with turn-on phase, a 200ns blanking time is added after the synchronous MOSFET is turned off to avoid error trigger.
Fig.3 shows synchronous rectification operation at heavy load condition. Due to the high current, the gate driver will be saturated at first. After Vds goes to above -70mV, gate driver voltage decreases to adjust the Vds to typical -70mV.
Fig.4 shows synchronous rectification operation at light load condition. Due to the low current, the gate driver voltage never saturates but begins to decrease as soon as the synchronous MOSFET is turned on and adjust the Vds.

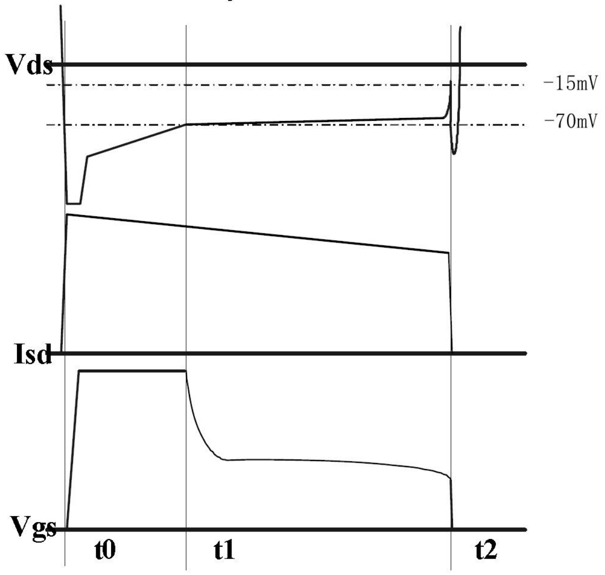


Figure 3 Synchronous Rectification Operation at heavy load

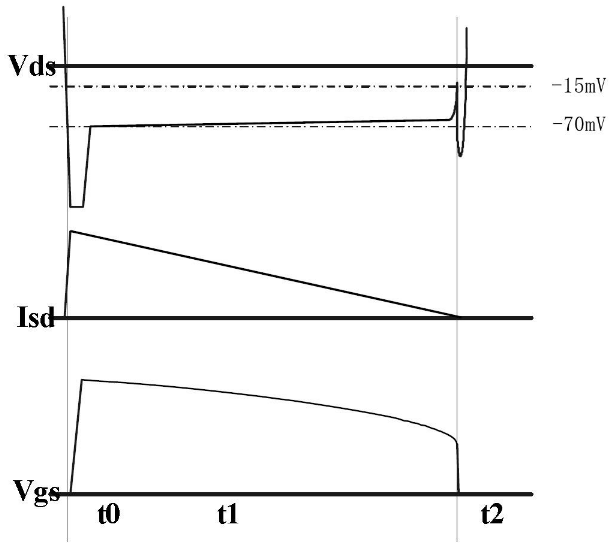


Figure 4 Synchronous Rectification Operation at light load

SR Mosfet Selection and Driver ability

The Power Mosfet selection proved to be a trade off between Ron and Qg. In order to achieve high efficiency, the Mosfet with smaller Ron is always preferred, while the Qg is usually larger with smaller Ron, which makes the turn-on/off speed lower and lead to larger power loss. For SF6901, because Vds is regulated at ~-70mV during the driving period, the Mosfet with too small Ron is not recommend, because the gate driver may be pulled down to a fairly low level with too small Ron when the Mosfet current is still fairly high, which make the advantage of the low Ron inconspicuous.
Fig.5 shows the typical waveform of QR flyback. Assume 50% duty cycle and the output current is IOUT.
To achieve fairly high usage of the Mosfet's Ron, it is expected that the Mosfet be fully turned on at least 50% of the SR conduction period:
Vds = −Ic ×Ron = −2 · IOUT ×Ron ≤ −Vfwd
Where Vds is Drain-Source voltage of the Mosfet and Vfwd is the forward voltage threshold of SF6901, which is ~70mV.
So the Mosfet's Ron is recommended to be no lower than ~35/IOUT (mΩ). (For example, for 5A application, the Ron of the Mosfet is recommended to be no lower than 7mΩ)
Fig.6 shows the corresponding total delay during turn-on period (t_{Total}, see Fig.2) with driving different Qg Mosfet by FS6901. From Fig.6, with driving a 120nC Qg Mosfet, the driver ability of FS6901 is able to pull up the gate driver voltage of the Mosfet to ~5V in 300ns as soon as the body diode of the Mosfet is conducting, which greatly save the turn-on power loss in the Mosfet's body diode.

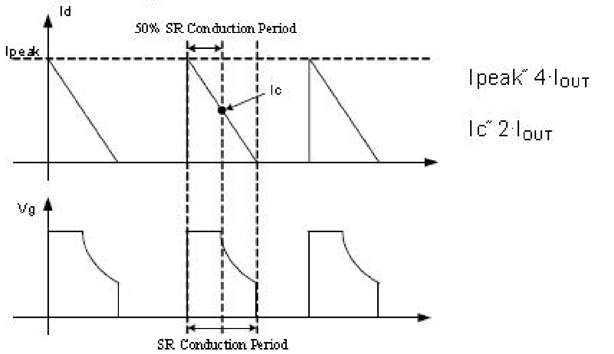


Figure 5 Synchronous Rectification typical waveforms in QR Flyback

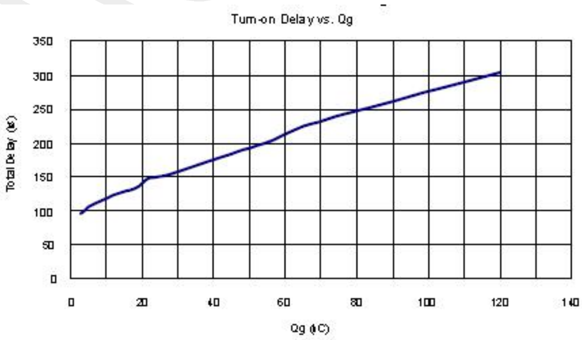


Figure 6 Total Turn-on Delay vs. Qg

CLASSIFICATION REFLOW PROFILES

Profile Feature	Pb-Free Assembly
Preheat & Soak Temperature min (Tsmin) Temperature max (Tsmax) Time (Tsmin to Tsmax) (ts)	150°C 200°C 60-120 seconds
Average ramp-up rate (Tsmax to Tp)	3°C/second max.
Liquidous temperature (TL) Time at liquidous (tL)	217°C 60-150 seconds
Peak package body temperature (Tp)*	Max 260°C
Time (tp)** within 5°C of the specified classification temperature (Tc)	Max 30 seconds
Average ramp-down rate (Tp to Tsmax)	6°C/second max.
Time 25°C to peak temperature	8 minutes max.

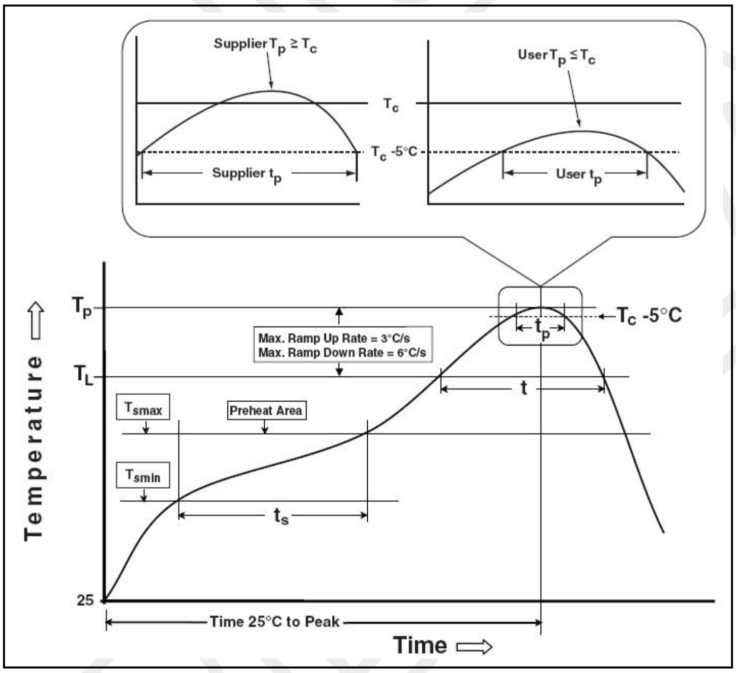
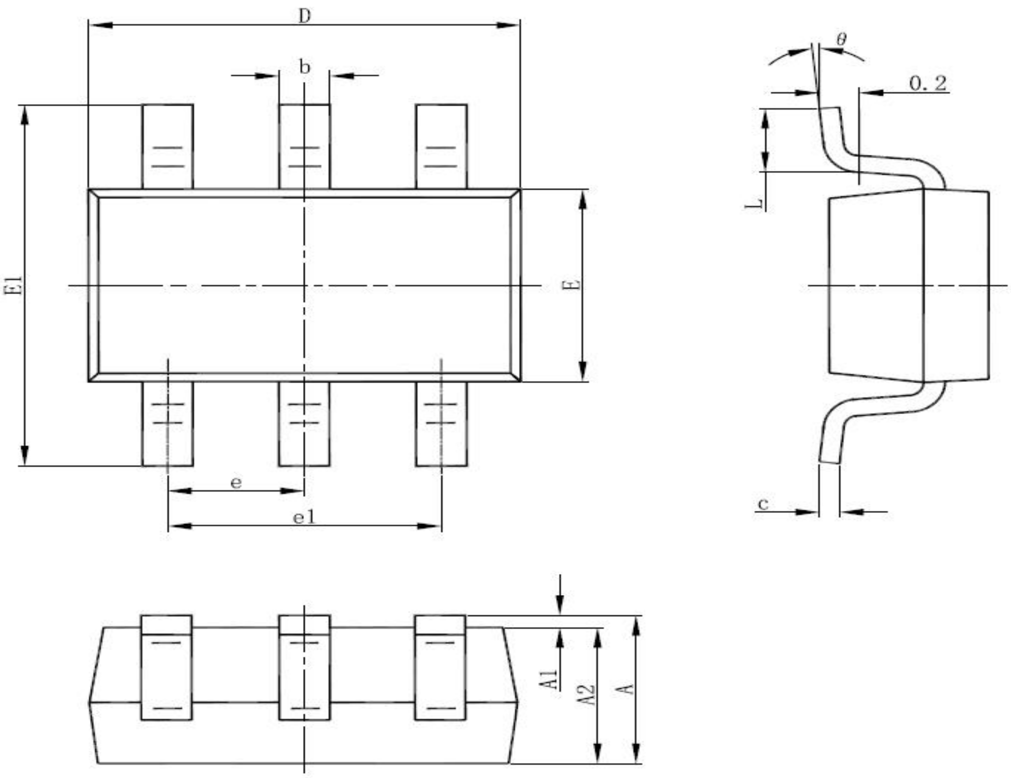


Figure 2 Classification Profile

PACKAGE INFORMATION

SOT-23-6L PACKAGE OUTLINE DIMENSIONS



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	**Max**	**Min**	**Max**
A	1.000	1.300	0.039	0.051
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.800	3.020	0.110	0.119
E	1.500	1.700	0.059	0.067
E1	2.600	3.000	0.102	0.118
e	0.950 (BSC)		0.037 (BSC)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0º	8º	0º	8º