

## Characterization

The TM6604 is a haptic feedback driver designed to address common obstacles in driving linear vibration motor (LRA) haptic feedback elements. The TM6604 is also used to provide drive power for drivers commonly used in portable devices with low latency, very high efficiency, and large drive strength. LRA drivers typically have a narrow frequency band in which they have a full haptic feedback response. This frequency window is typically around  $\pm 2.5$  Hz, so it can be a challenge to drive an LRA driver.

The TM6604 solves this problem by employing automatic resonance tracking, which automatically detects and tracks the optimal commutation frequency. This means that any PWM frequency in the input range (10kHz to 250kHz) will automatically produce the correct resonant output frequency. As an added benefit, the TM6604 is able to perform optimized braking algorithms to stop LRA ringing, leaving the user with a clear sense of tactile feedback. There is also a power supply correction function to ensure constant vibration strength when no power supply is regulated, thus allowing connection to a high efficiency DC battery. This product has excellent performance and reliable quality.

## Functional features

- Flexible touch feedback /vibra driver
  - LRA (linear vibration motor)
- Automatic resonance tracking for LRA
  - No frequency calibration required
  - Automatic drive commutation
  - Automatic braking algorithm
  - Wide input pulse width modulation (PWM) frequency range
- Continuous vibration intensity exceeds the scope of supply
- Automatic input level conversion
- 0% to 100% duty cycle control range
- Wide supply voltage range from 2.7V to 5.2v
- 1.8V compatible, 5V tolerance digital pin
- Package form: SOT23-6, dfn6le
- Application fields: mobile phones, tablet computers, touch enabled devices

## Pin arrangement

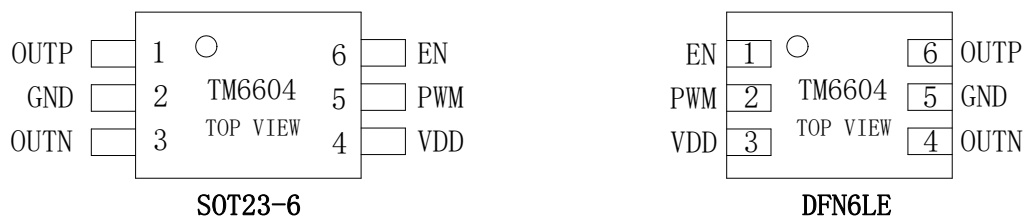


Figure 1

## Pin function

Pin name	Pin serial number		I/O	Function description
	SOT23-6	DFN6LE		
OUTP	1	6	-	Positive tactile driver differential output
GND	2	5	-	land
OUTN	3	4	-	Negative tactile driver differential output
VDD	4	3	-	Power input
PWM	5	2		Input signal
EN	6	1	--	Enable, highly effective

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Integrated circuits are electrostatic sensitive devices, which are prone to generate a large amount of static electricity when used in dry seasons or dry environments. Electrostatic discharge may damage integrated circuits. Titan Micro Electronics recommends taking all appropriate integrated circuit preventive measures and improper operations

Welding may cause ESD damage or performance degradation, and the chip cannot work normally.

## Electrical characteristics

### Extreme working conditions

Parameter name	Parameter symbols	Limit value	Unit
working voltage	V <sub>dd</sub>	-0.3~6.0	V
input voltage	V <sub>in</sub>	-0.3~V <sub>DD</sub> +0.3	V
Ambient temperature range	T <sub>a</sub>	-40~85	°C
Junction temperature	T <sub>j</sub>	-40~150	°C
Storage temperature range	T <sub>stg</sub>	-65~150	°C
ESD	HBM (manikin)	±2	KV
	Mm (machine model)	±500	V

(1) If the chip works under the above limit parameters for a long time, the reliability of the device may be reduced or permanently damaged. Tianmicroelectronics does not recommend that any parameter reach or exceed these limits in actual use.

(2) All voltage values are tested relative to the system ground.

### Recommended working conditions

Under the test conditions of v <sub>dd</sub> =5v and t <sub>a</sub> =+25 °C			TM6604			Unit
Parameter name	Parameter symbols	Test conditions	minimum value	Typical value	Maximum value	
supply voltage	V <sub>dd</sub>	V <sub>DD</sub>	2.7		5.2	V
PWM input frequency	F <sub>pwm</sub>		10		250	kHz
Load impedance	R <sub>l</sub>	V <sub>DD</sub> =5.2V	8			Ω
Support LRA frequency	F <sub>0</sub>	Self resonance tracking range of LRA	140		220	Hz
Digital input low voltage	V <sub>il</sub>	EN, PWM			0.6	V
Digital input high voltage	V <sub>ih</sub>	EN, PWM	1.2			V
Ambient temperature range	T <sub>a</sub>		-40		85	°C
Junction to ambient thermal resistance	R <sub>θja</sub>			153.7		°C/W
Junction to box (top) thermal resistance	R <sub>θjc(top)</sub>			86		°C/W
Thermal resistance of contact plate	R <sub>θjb</sub>			70.4		°C/W
Connect to top characterization parameter	ψ <sub>jt</sub>			1.3		°C/W
Point to plate characteristic parameters	ψ <sub>jb</sub>			70.4		°C/W

## Electrical characteristics

Under the test conditions of v <sub>dd</sub> =5v and t <sub>a</sub> =+25 °C			TM6604			Unit
Parameter name	Parameter symbols	Test conditions	minimum value	Typical value	Maximum value	

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Digital input low current	I <sub>IL</sub>	EN,PWM,VDD=5.0V,VIN =0V			1	μA
Digital input high current	I <sub>IH</sub>	EN=VDD=5.0V,VIN=VDD			6	μA
		PWM,VDD=5.0V,VIN=VDD			3	μA
Closing current	I <sub>SD</sub>	VEN = 0 V	0.3		3	μA
Quiescent current	I <sub>DDQ</sub>	V <sub>en</sub> = VDD, ERM mode, 50% duty cycle input cycle, no load	1.7		2.5	mA
Output impedance during shutdown	R <sub>OUT</sub>	OUT+ to GND, OUT- to GND	15			kΩ
Start time	t <sub>SU</sub>	Time from en high to output signal	1.3			ms
PWM output frequency	f <sub>SW</sub>		19.5	20.3	21.5	kHz
Average battery current during normal operation	I <sub>BAT,AVG</sub>	Duty cycle = 100%, LRA mode, load = 25 Ω LRA	55			mA
Drain source resistance, high side	R <sub>DS-HS</sub>		1.05			Ω
Drain source resistance, low side	R <sub>DS-LS</sub>		0.85			Ω
Differential output voltage	V <sub>OUT</sub>	Duty cycle = 100%, LRA mode, load = 25 Ω LRA	2.2			VRMS
Thermal threshold			145			
Thermal hysteresis			18			

## Parameter measurement

### Test setup diagram

The output waveform of tm6604 can be checked by connecting oscilloscope. The output signal contains high-frequency PWM components and basic driving components that cause motion. In order to measure or observe the basic driving elements, a low-pass filter must be used to eliminate the PWM component. The digital filtering function of digital oscilloscope is used in other typical digital oscilloscopes. A first-order low-pass filter between 1 kHz and 3.5 kHz is recommended. If there is no digital oscilloscope with digital filtering, the first-order low-pass RC filtering network can be used instead, as shown in the dotted box in Figure 2. Be careful not to use too low filter impedance. This will interfere with the back EMF of the driver action and destroy the operation of the automatic resonance function.

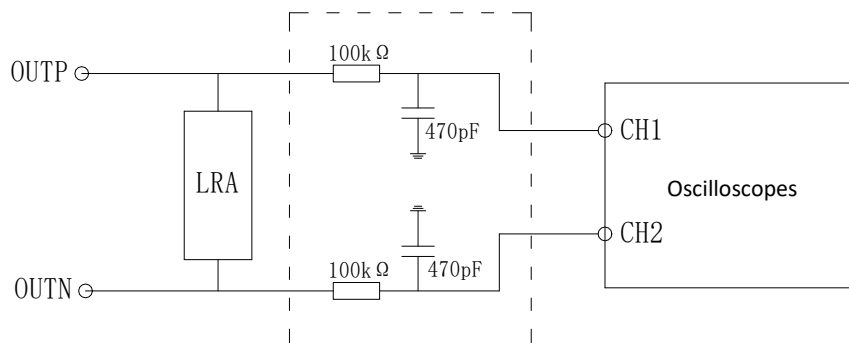


Figure 2

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## Function description

### 1. Power supply voltage suppression and PWM input logic level for constant vibration intensity

Tm6604 has power feedback, so it does not need external power regulation. If the power supply voltage is consumed over time (for example, due to battery discharge), as long as there is enough power supply voltage to maintain the required output voltage, the vibration intensity will remain unchanged. The tm6604 can be connected directly to the battery. As long as the PWM port input voltage meets the VIH and VIL levels, the vibration intensity will remain unchanged even if the digital levels are different.

### 2. Over temperature and over-current protection

Tm6604 chip over temperature protection will shut down the device to prevent internal overheating. For typical over temperature threshold, please refer to the electrical specification table. At the same time, it also has overcurrent protection to prevent damage under short-circuit conditions. This overcurrent protection monitors the current from VDD, GND, out+ and out-. Refer to the electrical specification sheet for typical overcurrent thresholds.

### 3. Edge rate control

Tm6604 output driver realizes edge rate control (ERC). This ensures that the rising and falling characteristics of the output driver do not release radiation levels that may interfere with other circuits in mobile and portable platforms. Due to ERC, no output filter or inductance is required.

### 4. Scope of automatic resonance tracking

Linear vibration motors, or LRAs, only vibrate effectively at their resonant frequencies. LRAs has high-precision frequency response characteristics, and its vibration performance drops sharply when it deviates from the response frequency by 2 to 3 Hz. Many factors will cause the resonant frequency of the driver to change or drift, such as temperature, aging, the product quality of LRA installation, and the way it is fixed in portable products. In addition, when the driver is driven to its maximum allowable voltage, many LRAs will move a few hertz in frequency due to mechanical compression. All these factors are real-time. Tracking self resonance algorithm is very important in driving LRA to achieve consistent and optimized performance. Tm6604 self resonant driver tracks the resonance frequency of LRA in real time. If the resonant frequency moves in the middle of the waveform of a factor, the driver will track its period. The automatic resonance engine achieves this by continuously monitoring the back EMF of the LRA. The frequency tracking range of tm6604 is 140 Hz to 220 Hz.

## Application information

### 1. Application introduction

Tm6604 chip is used to drive LRA motor of tactile feedback. LRA drivers can be used in many tactile feedback applications, including vibration alarm, advanced vibration for touch surface or screen communication, button replacement, and tactile feedback.

The output of tm6604 is controlled by PWM input. The duty cycle of PWM determines the amplitude of the output waveform. By changing the duty cycle, you can create advanced tactile modes and programs, such as clicks, bumps, pulses, slopes, and so on. 100% input duty cycle provides the strongest vibration intensity, and the vibration intensity of 0% to 50% input duty cycle is 0. The automatic resonance detection algorithm is responsible for the rectification of the physical layer signal and the linear vibration motor. Tm6604 realizes closed-loop operation by a simple feedback loop. If the back EMF feedback tells the device that the vibration input duty cycle is relatively low, tm6604 will increase the vibration intensity. If the back EMF feedback tells the equipment that the vibration of the phase input duty cycle is too high, tm6604 automatically enforces the braking algorithm. When the input duty cycle is 0% to 50%, the chip will always be forced to brake until the LRA no longer vibrates.

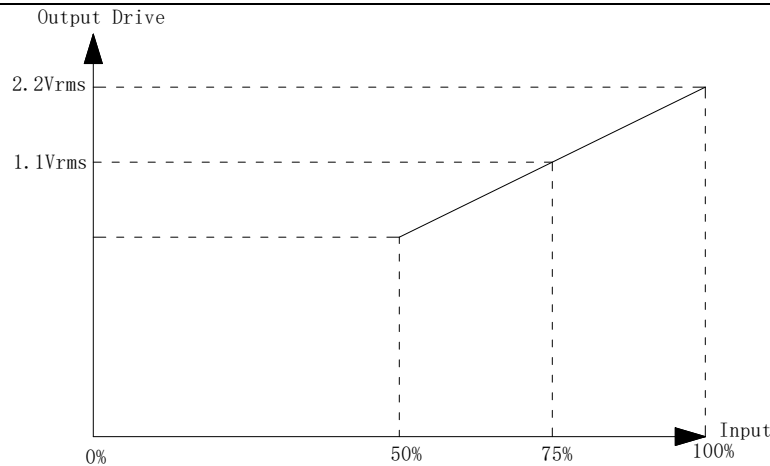


Figure 3

The accurate full-scale output voltage depends on the physical structure of the LRA itself. Some LRA devices give a small amount of back EMF during the strongest vibration, while other LRA devices give a larger back EMF. The nominal full-scale output value is 2.2 VRMS, but it can usually vary + / - 10%, depending on the physical design of the actuator. When the input duty cycle is 50% - 100%, the output voltage can be approximately calculated by the following formula:

$$V_{OUT(RMS)} = V_{OUT(FULL-SCALE)} \left[ \frac{Input\ Duty\ Cycle\ \%}{50} - 1 \right]$$

Since tm6604 includes a constant output drive power supply voltage and an adjustable output PWM duty cycle, the above formula is correct no matter how the power supply voltage changes.

If the PWM port is unavailable, the PWM pin of tm6604 can be controlled by GPIO; At this time, tm6604 will only be used as a switch. In LRA mode, when GPIO is high, the output is 100%. When GPIO is low, the driver will automatically brake to stop the motor vibration.

## 2. Typical applications

The following figure shows the LRA application configuration.

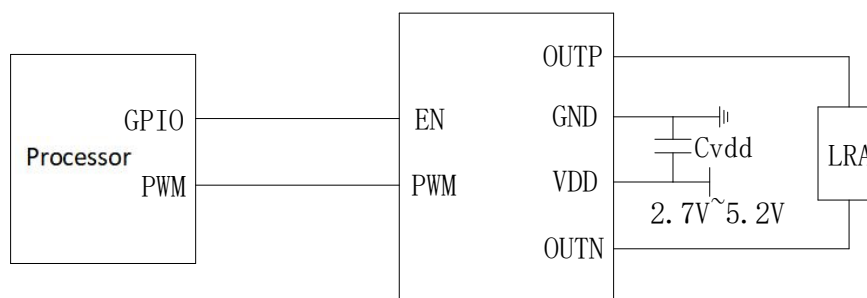


Figure 4

### 2.1 detailed design steps

#### 2.1.1 driver selection

Many factors should be taken into consideration when selecting the driver, including cost, shape factor, vibration intensity, power consumption requirements, tactile acuity, reliability and audible noise performance. The choice of driver is one of the most important design considerations of tactile system, so driver should be the first component to be considered when designing the system. The following can be used to select the minimum supply voltage required.

1. Find the rated / maximum working voltage in the driver data sheet; Some drive data sheets may only list the rated voltage.
2. Using a larger rated value and maximum working voltage plus 250Mv is the minimum operating voltage. The addition of 250Mv provides operating margin for internal drive losses.
3. Check the power supply voltage to ensure that the expected output is achieved. It is also necessary to

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calculate the minimum supply current according to the load. Compare the driving capacity of the battery or voltage to ensure sufficient power to drive the load in the driver data sheet.

#### 2.1.2 power supply selection

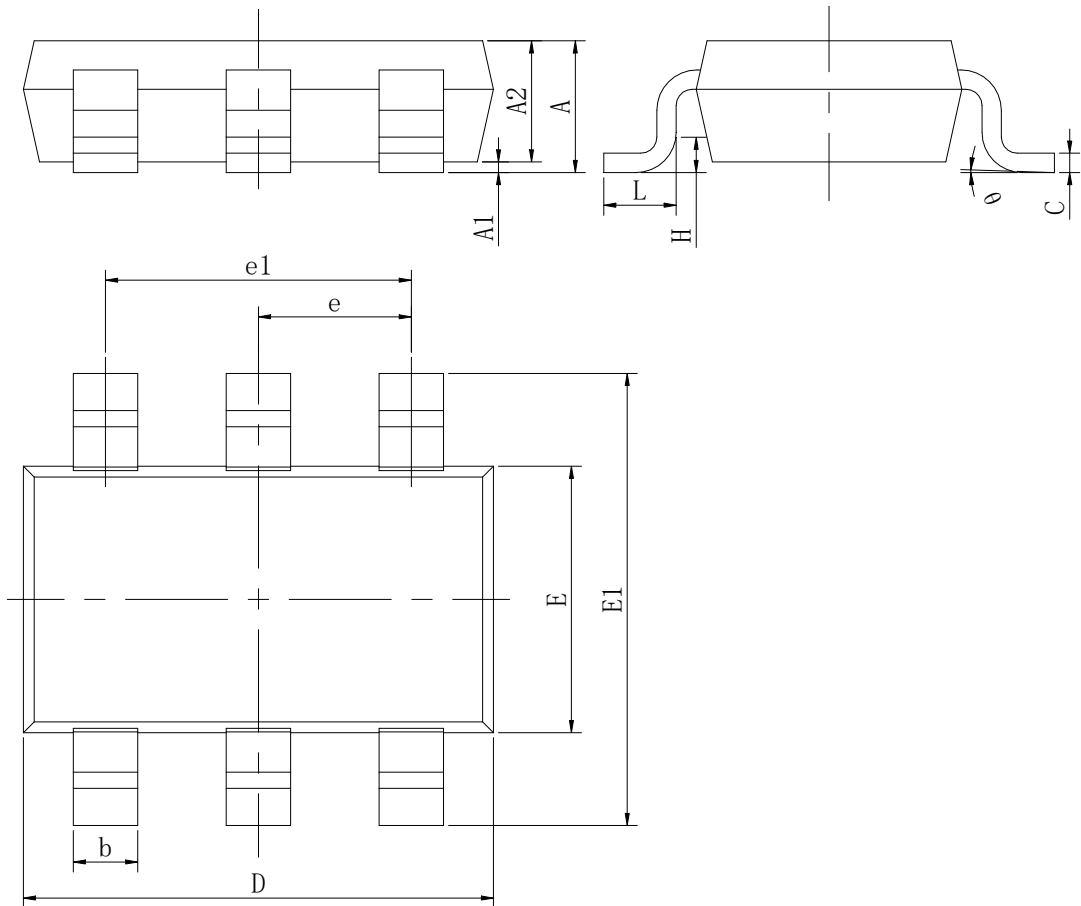
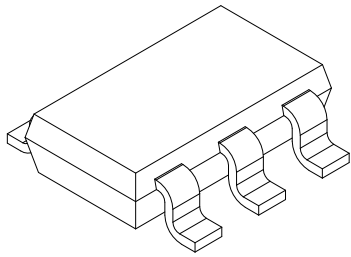
Tm6604 supports power supply voltage from 2.7V to 5.2v. Tm6604 can be directly connected to various types of batteries, including ordinary batteries, such as lithium ion and lithium polymer. The power suppression feature eliminates the need for a voltage regulator between the battery and VDD for the tm6604.

#### 2.1.3 send tactile effect

Sending tactile effects with tm6604 is very simple. The best performance is achieved through the following steps.

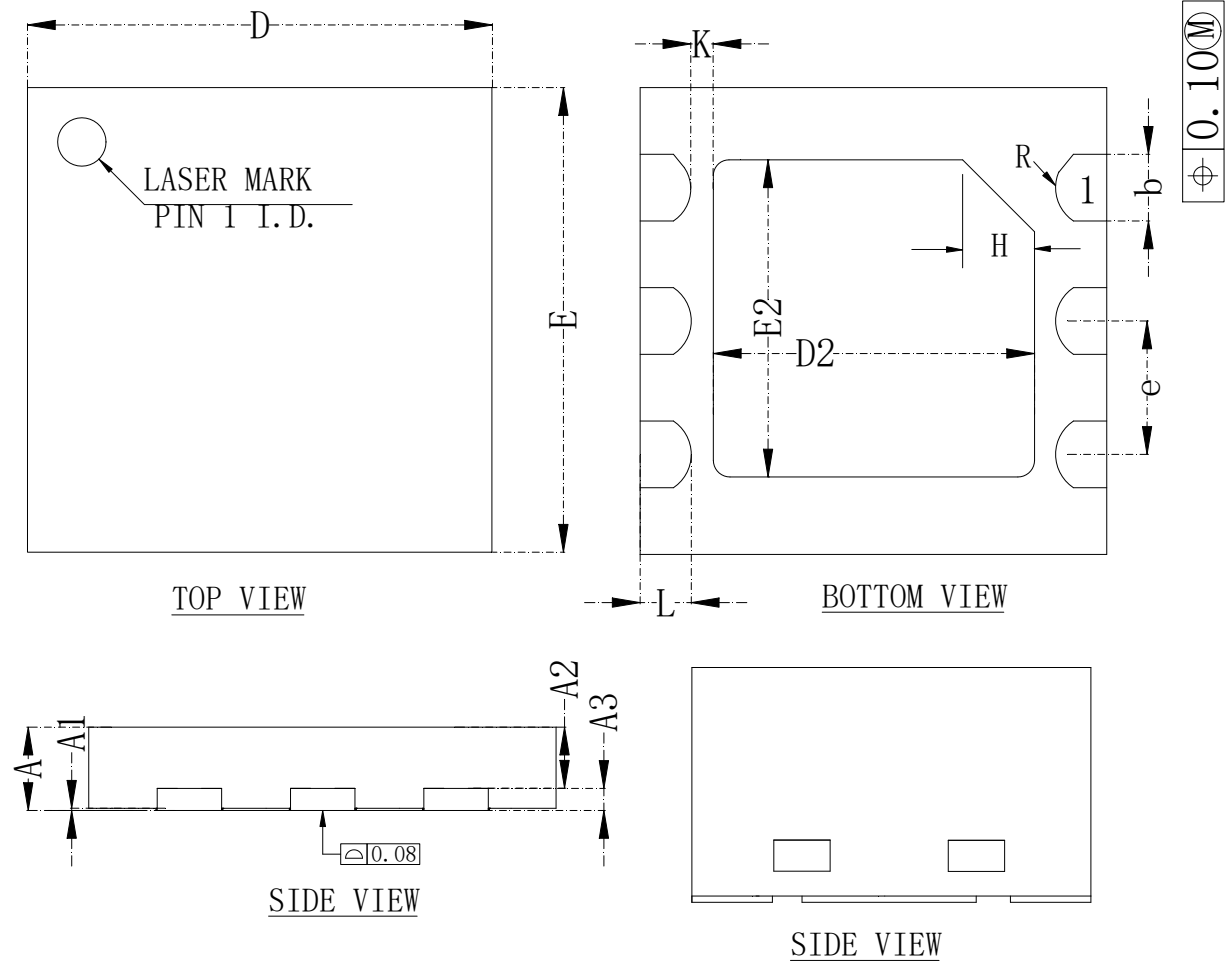
1. At or near the same time, the EN pin is pulled high and the PWM input waveform. Generally, the driver produces tactile effect within 20 ms to 50 ms of instantaneous driving. Refer to the specifications of the drive for the best overdrive characteristics.
2. When the tactile effect is completed, if braking is required, set the PWM duty cycle to 0%, and the EN pin must be kept high. When the braking is completed, set the EN pin to low to end the tactile effect. When braking LRA, the automatic resonance engine will automatically drive the driver to zero vibration, so there will be no obvious reverse vibration.

Packaging diagram (SOT23-6)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700	0.900	0.028	0.035
A1	0.000	0.100	0.000	0.004
A2	0.700	0.800	0.028	0.031
b	0.350	0.500	0.014	0.020
c	0.080	0.200	0.003	0.008
D	2.820	3.020	0.111	0.119
E	1.600	1.700	0.063	0.067
E1	2.650	2.950	0.104	0.116
e	0.95 (BSC)		0.037(BSC)	
e1	1.90 (BSC)		0.075(BSC)	
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

(DFN6LE)



Symbol	Dimensions In Millimeters		
	Min	NOM	Max
A	0.70	0.75	0.80
A1	0.00	0.02	0.05
A2	0.50	0.55	0.60
A3	0.20REF		
b	0.20	0.25	0.30
D	1.90	2.00	2.10
E	1.90	2.00	2.10
D2	0.70	0.80	0.90
E2	1.20	1.30	1.40
e	0.55	0.65	0.75
H	0.25REF		
K	0.20	--	--
L	0.30	0.35	0.40
R	0.11	--	--

All specs and applications shown above subject to change without prior notice.

## Version revision history

edition	Issue date	Introduction to revision
V1.0	2018-5-25	First edition release
V1.1	2018-11-21	Adjust and modify the circuit group
V1.2	2018-11-29	Correct the wrong unit and correct some descriptive words