DESCRIPTION

PT2513 is an integrated three-phase sensorless BLDC motor driver chip with advanced protection functions, including soft-start circuit, thermal shutdown, lock on protection and output current protection. PT2513 uses sine wave current control to reduce electromagnetic noise during operation, and is suitable for fan motor drives that require high efficiency. On the speed control interface, it supports PWM or VSP (DC) commands, so that the motor can be controlled smoothly from low speed to high speed.

PT2513 adopts the BCD process, only a single VDD power supply is needed for use, and only a few parts are needed around it. The chip is packaged as HTSSOP16, HTSSOP20 and QFN20 with bottom heat dissipation, which can achieve excellent energy efficiency, making it compact, low-cost, and Ideal solution for sensor BLDC motor drive.

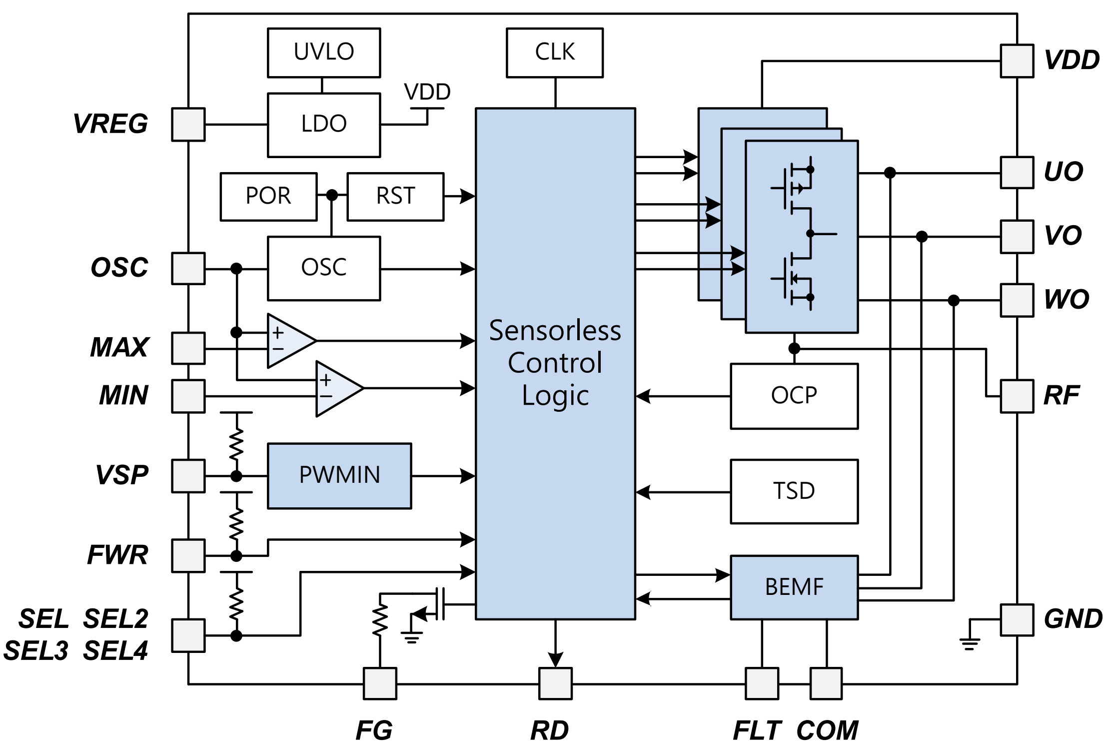
FEATURES

- Three-phase sensorless driver IC
- 6V ~ 16V voltage operating range
- 180 degree sine wave current operation
- Soft start control function
- PWM or VSP (DC) input speed control
- Maximum and minimum duty cycle limit settings
- Lock on and over-temperature protection
- Current limit protection function
- FG or 1/2FG speed signal output

APPLICATIONS

- Three phase sensorless BLDC driver
- CPU,GPU, or server cooling fan
- Refrigerator fan

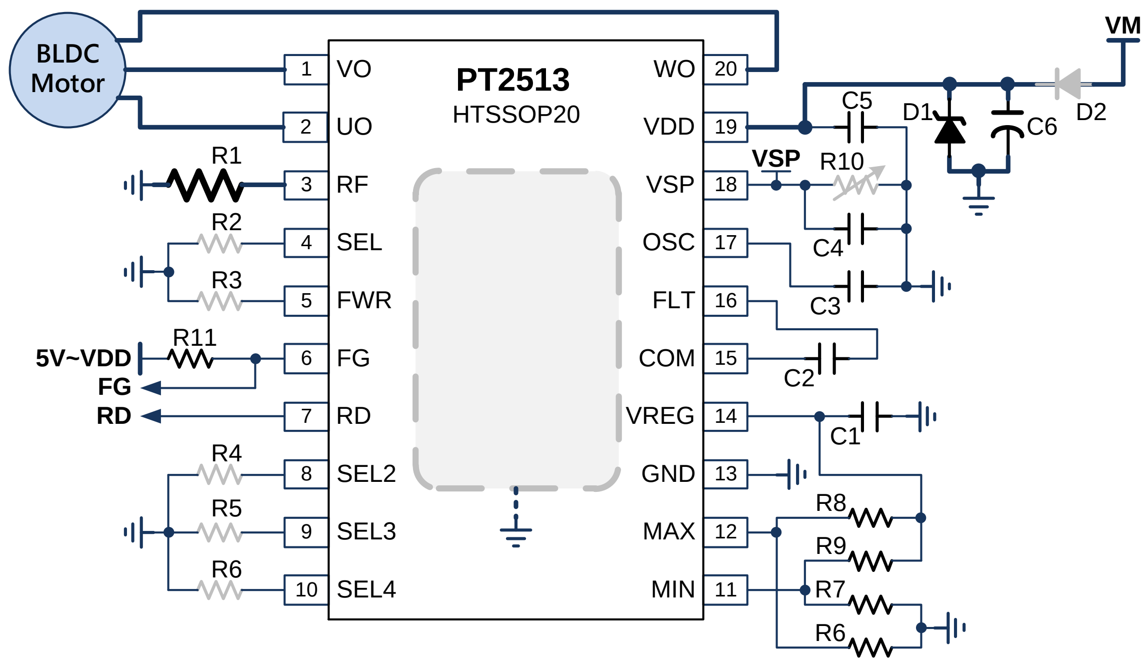
BLOCK DIAGRAM



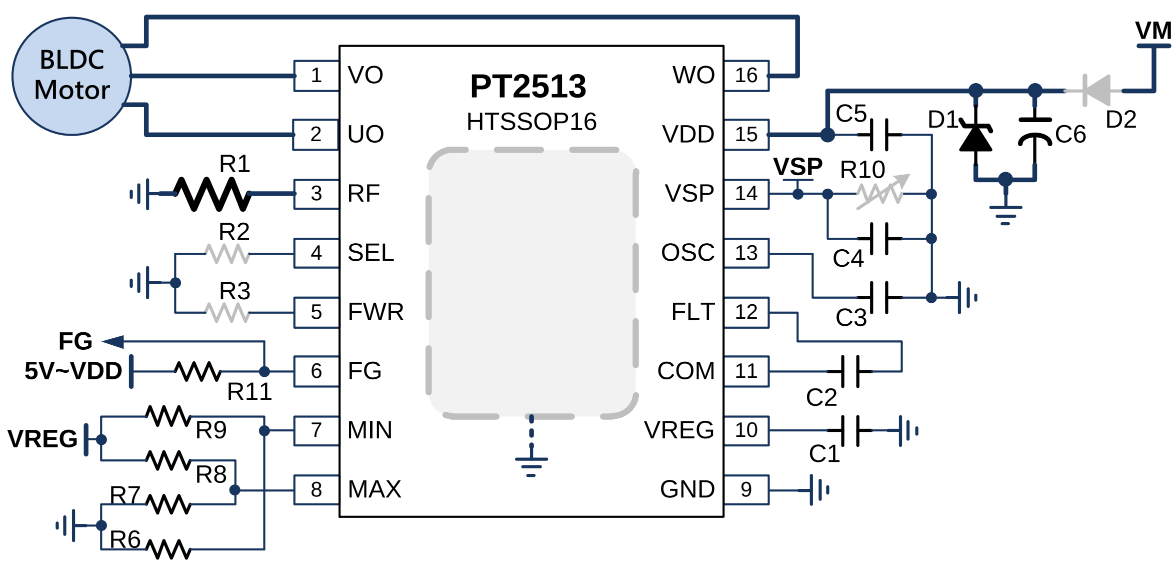
ORDER INFORMATION

Valid Part Number	Package Type	Top Code
PT2513-HT	16-PIN, HTSSOP, 173MIL	PT2513-HT
PT2513	20-PIN, HTSSOP, 173MIL	PT2513
PT2513-QF	20-PIN, QFN	PT2513-QF

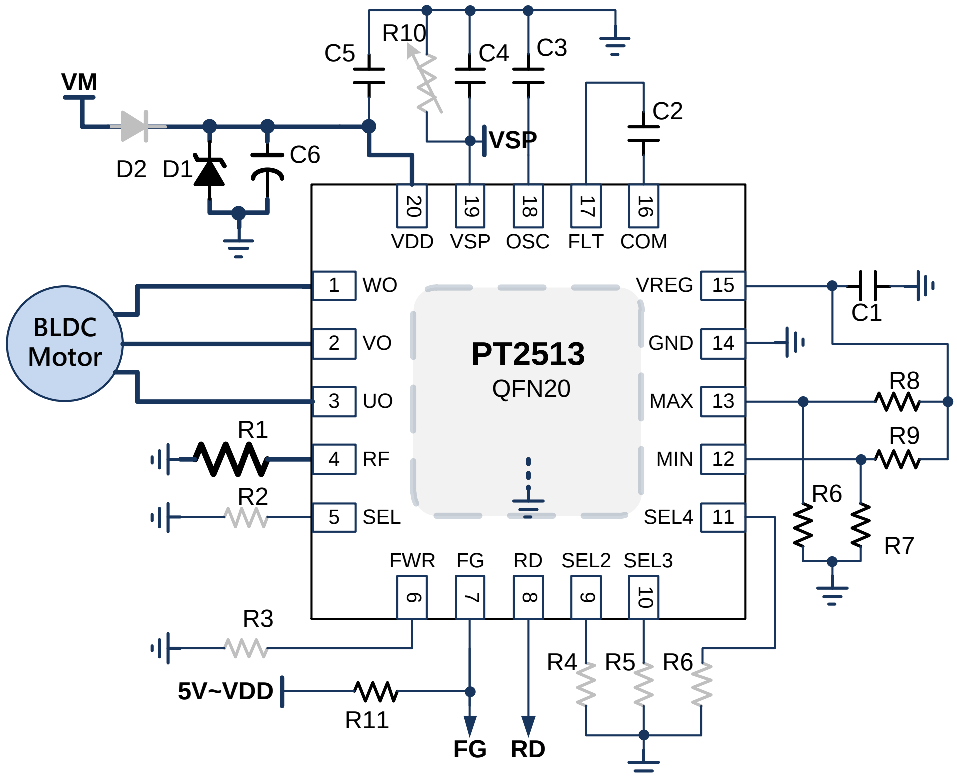
HTSSOP20 APPLICATION CIRCUIT



HTSSOP16 APPLICATION CIRCUIT



QFN20 APPLICATION CIRCUIT

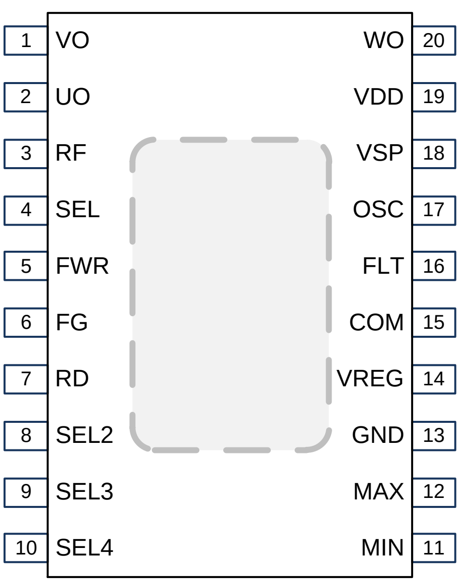


APPLICATION CIRCUIT BOM

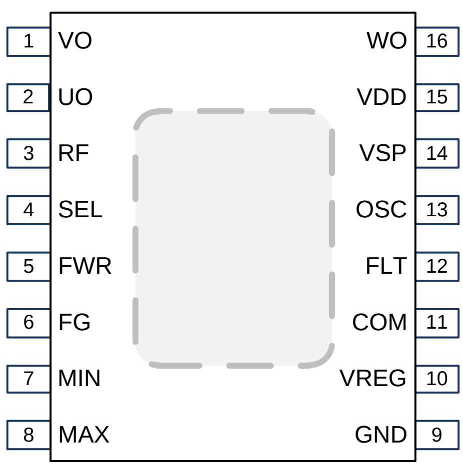
Parts	Value	Unit	Description
R1	0.1 ~ 0.5	Ω	Motor phase current limit reference, use more than 1206, type and power> 1/4W, if the temperature rise is too high, it can be paralleled or enlarged
R2/R4/R5/R6	0/~250K/ NC	Ω	SEL setting, please refer to the pin description, SEL=H can be kept floating, SEL=L can be short to GND, SEL=M, can be connected 220KΩ ~ 270KΩ to GND.
R3	0~10K/ NC	Ω	Forward and reverse settings, when not in use, it can be kept floating or short to GND
R6/R7/R8/R9	0~100K	Ω	MAX and MIN settings. It is recommended that the resistance value of R6+R8 or R7+R9 is between 100KΩ ~ 500KΩ, and it can also be set by external input voltage.

R10	0 ~ 1M	Ω	When a potentiometer is needed to adjust the speed, a 1MΩ adjustable resistor can be connected. Or connect >100KΩ three-terminal adjustable resistance to VREG/GND. It is no needed when using external VSP or PWM input
R11	10K	Ω	FG Open Drain pull high resister
C1	100n	F	VREG bypass capacitor
C2	10p ~ 10n	F	ZC detection filter capacitor
C3	10p ~ 10n	F	Startup capacitor, Set start step and acceleration /deceleration
C4	1n ~ 100n	F	VSP input bypass capacitor
C5	~100n	F	DC power input high frequency (like PWM switching) rejection capacitor
C6	22u ~ 47u	F	DC power input voltage stabilized capacitor, use >25V electrolytic capacitor. In addition to voltage stabilization, it can also reduce abnormal voltage bounce when the motor is decelerated or locked.
D1	15 ~ 18	V	Zener diode to prevent excessive back-EMF or voltage surge
D2	50	V	Anti-voltage reverse connection diode, used when needed, it will consume power and generate heat

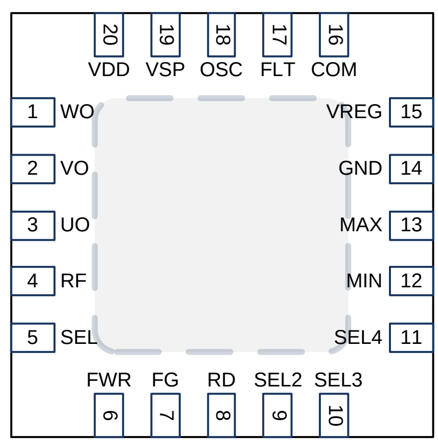
PIN DESCRIPTION



PT2513
HTSSOP20



PT2513
HTSSOP16



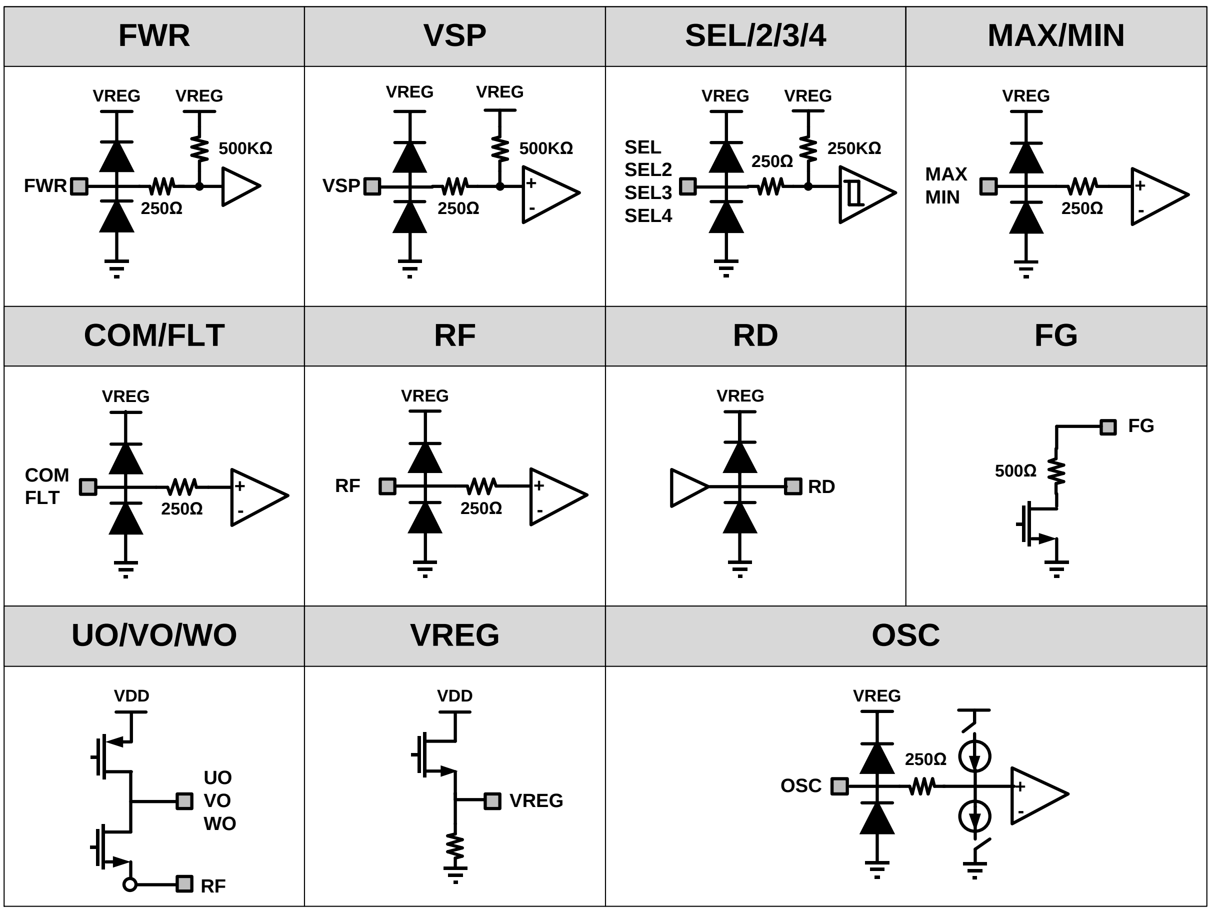
PT2513
QFN20

PIN DESCRIPTION

<table>
<tr><th rowspan="2">Pin Name</th><th rowspan="2">I/O</th><th rowspan="2">Description</th><th colspan="3">Pin No.</th></tr>
<tr><th>HTSSOP -16</th><th>HTSSOP -20</th><th>QFN -20</th></tr>
<tr><td>VO</td><td>O</td><td>V phase output</td><td>1</td><td>1</td><td>2</td></tr>
<tr><td>UO</td><td>O</td><td>U phase output</td><td>2</td><td>2</td><td>3</td></tr>
<tr><td>RF</td><td>O</td><td>U, V, W three-phase low side source parallel output.
Connect an external resistor to GND as a reference potential for current limiting or overcurrent detection</td><td>3</td><td>3</td><td>4</td></tr>
<tr><td>SEL</td><td>I</td><td>FG output and ZC detection Hi-Z window setting:
SEL=H, FG output & single Hi-Z window detection
SEL=M, 1/2FG output & single Hi-Z window detection
SEL=L, FG output & six Hi-Z windows detection
The H, M, L levels are defined as follows:
H=VREG (keep floating, internal equivalent 250KΩ connected to VREG),
M=1/2VREG (external 250KΩ grounding)
L=GND (external grounding)
SEL, SEL2, SEL3, SEL4 have the same level definition</td><td>4</td><td>4</td><td>5</td></tr>
<tr><td>FWR</td><td>I</td><td>Forward or reverse rotation select input pin. 500KΩ pull high internally.</td><td>5</td><td>5</td><td>6</td></tr>
<tr><td>FG</td><td>O</td><td>FG signal output；open drain structure，it can be set as FG or 1/2 FG output via SEL pin</td><td>6</td><td>6</td><td>7</td></tr>
<tr><td>RD</td><td>O</td><td>RD signal output; motor status indication, general logic level, low level for normal operation, high level output for over current, stall or over temperature protection</td><td>-</td><td>7</td><td>8</td></tr>
<tr><td>SEL2</td><td>I</td><td>ZC detection window(Hi-Z) setting：
SEL2=H & M, Hi-Z window = 9º (default)
SEL2=L, Hi-Z window =10.5º</td><td>-</td><td>8</td><td>9</td></tr>
<tr><td>SEL3</td><td>I</td><td rowspan="2">Maximum speed (Hz) settings, exceed the value will enter lock protection mode。PWM frequency & test mode settings。
1. SEL3/4 = H/H; Max. 200Hz , PWM 40KHz (默认)
2. SEL3/4 = M/M; Max 400Hz, PWM 40KHz
3. SEL3/4 = H/L; Max. 697Hz, PWM 80KHz
4. SEL3/4 = L/H; Max. 1025Hz, PWM 80KHz
5. SEL3/4 = L/L; Max. 100Hz, PWM 80KHz
6. SEL3/4 = M/H; Max. 170Hz, PWM 160KHz
7. SEL3/4 = M/L; Max. 400Hz, PWM 20KHz, square wave.
8. SEL3/4 = H/M, Max.450Hz, square wave control. PWM output directly (w/o smoothly)
9. SEL3/4= L/M, test mode, disable some protection functions. (over current, lock on, over speed)</td><td>-</td><td>9</td><td>10</td></tr>
<tr><td>SEL4</td><td>I</td><td>-</td><td>10</td><td>11</td></tr>
<tr><td>MIN</td><td>I</td><td>Minimum output duty setting, pull high (VREG) for disable</td><td>7</td><td>11</td><td>12</td></tr>
<tr><td>MAX</td><td>I</td><td>Maximum output duty setting, pull high (VREG) for disable
Pull low (GND) will disable MAX function and enable IPD function</td><td>8</td><td>12</td><td>13</td></tr>
</table>

GND	P	System ground	9	13	14
VREG	IO	5V Regulator, connect a bypass capacitor to ground.	10	14	15
COM	I	Motor middle point connection for BEMF detection	11	15	16
FLT	I	BEMF signal filter input pin	12	16	17
OSC	I	External capacitor for start-up step &acceleration setting	13	17	18
VSP	I	Speed command input pin (DC or PWM signal). Keep floating for full speed operation.	14	18	19
VDD	P	High voltage power supply pin	15	19	20
WO	O	W phase output	16	20	1
Heatsink	P	Backside heat sink is for heat dissipation.	Backside heat plate		

PIN EQUIVALENT CIRCUIT



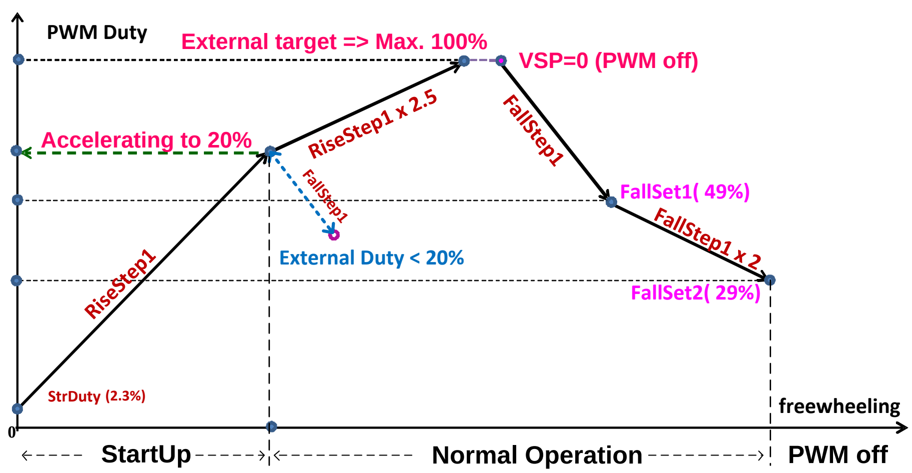
FUNCTION DESCRIPTION

Power Supply

PT2513 supports VDD power supply voltage range from 6V to 16V operation. VDD is the output stage MOS power supply and provides the internal voltage regulator VREG input voltage. VREG provides 5V for analog and digital circuits. Since the application end load is a motor coil with inductive characteristics, when the motor starts to rotate, large current and voltage surges may be induced. Choose a suitable bypass capacitor and be as close as possible to the VDD pin. In addition, the use of externally increased electrolytic capacitors and Zener diode with larger capacitance will help suppress excessive BEMF voltage generated when the motor is decelerated or locked.

VSP Input Control

PT2513 can accept external input DC voltage or PWM signal from VSP pin to adjust motor speed. When using PWM input, the high voltage potential needs to be greater than 3.3V; and the low voltage potential needs to be less than 0.3V. The recommended PWM input frequency is between 1K and 50KHz. When using analog DC voltage input, the voltage control range should be between 0.5V and 3.2V. When the VSP pin is not connected, it is internally pulled to a high potential, and the motor runs at full speed with 100% PWM duty cycle. After VSP (PWM) is input, the control program will accelerate and decelerate according to the situation, as shown in the figure below.

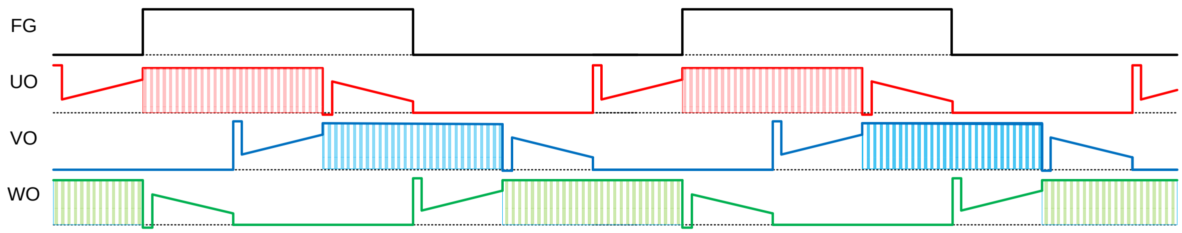


PT2513 has two settings (MIN and MAX) for minimum and maximum PWM duty cycle limitation. When using PWM or VSP control, the minimum/maximum duty cycle will be limited by the MIN_MAX setting. The working range of MIN & MAX is 0.5V to 3.2V. It is not allowed to set MIN>MAX. When this situation occurs, MIN=MAX will be forced. For some applications, the PWM duty cycle can be limited to a narrow range by setting MIN & MAX.

PT2513 does not have speed closed-loop control, the speed information will be output by FG, to adjust VSP and monitor FG signal could achieve the required speed control.

Startup

The most difficult part of sensorless control is the start-up process, because the rotor position is unknown and the BEMF signal is weak or undetectable. The starting method of PT2513 is the increase of initial alignment and gradual control voltage (or increase of PWM duty cycle) to realize the excitation and rotation of the motor. The initial alignment may cause the rotor to randomly rotate forward or backward for one electrical cycle when starting. Unclear ZC signal will cause the motor to fail to start. If the motor does not start successfully within a certain period of time, the PT2513 will enter the lock protection mode and restart after a period of time. PT2513 adopts square wave PWM control mode during the startup process. At this time, there is a larger BEMF detection interval to reduce the probability of startup failure, as shown in the figure below.



During the startup process , 120° square wave PWM control mode is adopted

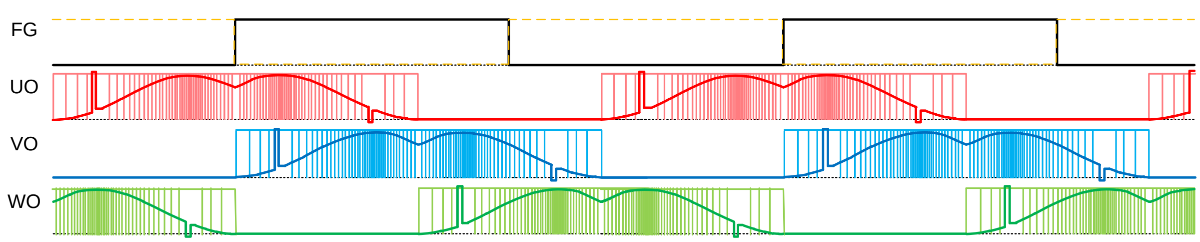
In order to adapt to the load requirements of different motors, the starting capacitor of the OSC pin can be adjusted to make the motor start smoothly. The range of OSC capacitance is about 10pF~10nF. Lighter and faster motors generally require smaller capacitance values, and heavier and slower motors generally require larger capacitance values.

Sensor-less Control

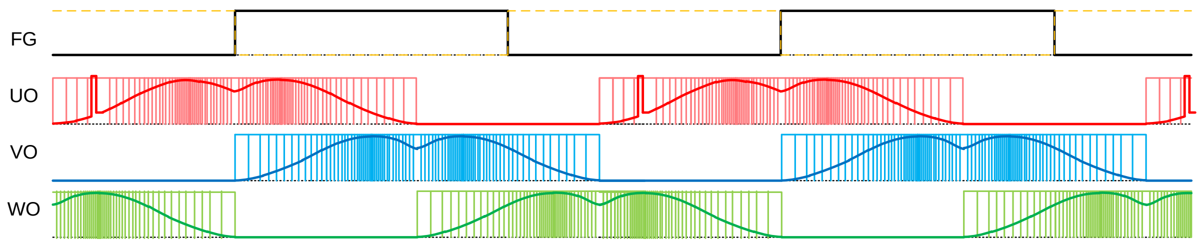
The PT2513 control scheme is based on a sensorless sinusoidal current waveform. The feedback of sensorless control is mainly realized by measuring the induced electromotive force (BEMF) of the motor wire when the motor is rotating. U-phase is used to open a narrow window at the beginning of the commutation interval to detect the zero-crossing signal, thus realizing sensorless control.

PT2513 reduces the UVW phase voltage to below 5V by using an internal divider resistor, processes it through an emulation circuit and generates a ZC signal for commutation detection. Since different motors, operating voltages, or loads will affect the ZC signal, the external ZC filter capacitor needs to be adjusted to achieve the best operation. The capacitance value between "COM" and "FLT" ranges from about 10pF to 10nF.

PT2513 adopts 180° commutation and sinusoidal PWM control to help reduce audible current noise. Generally during operation, PT2513 uses U phase to open a (Hi-Z) window to detect BEMF. At this time, the operation noise is minimal. However, when the system noise is too large or the motor's BEMF signal is too weak, it will affect the accuracy of the ZC signal and may lead to control failure. There are two options to enhance BEMF detection capabilities. The first way is to set "SEL" to low level (GND) and use six Hi-Z windows to detect BEMF signals. Another method is to use SEL2 (20-pin package required) to set a larger opening angle. The disadvantage of these two setting methods is that the phase current distortion will be higher. When the PWM is less than 20% or in the acceleration/deceleration interval, because the BEMF is small or changes more drastically, the PWM control method with six Hi-Z windows will also be forced to be adopted at this time. For different motor applications, the 20-pin package SEL3 and SEL4 can set several maximum speed limits to avoid abnormalities. Please refer to the pin description for the setting method.



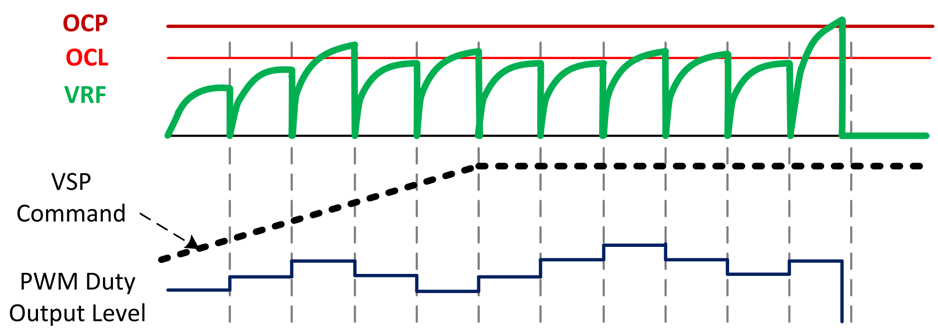
When SEL=low or PWM<20% and acceleration/deceleration process,
six Hi-Z windows method is used to detect BEMF



When SEL≠low or PWM>20% is in normal operation mode,
one Hi-Z window of U phase is used to detect BEMF

Over Current Limit (OCL) and Over Current Protection (OCP)

PT2513 detects the total current flowing through the motor coil and collected via an external resistor RF, and realizes the functions of over-current limitation (OCL) and over-current protection (OCP). The current flowing through the RF resistor is not the average current value of the DC bus, and the detection level is also triggered by the peak current. Due to the characteristics of different motors, when the average of bus current is the same, the peak current may be different, so the trigger conditions of OCL or OCP will be different. When choosing the value of the RF resistance, we recommend an actual testing with target motor and load.



The process of PWM duty cycle output when OCL/OCP occurs

PT2513 has two built-in comparators, OCL is 0.3V, OCP is 0.5V. When the VRF voltage exceeds the OCL, the PWM duty will be reduced by 1/512 in the next commutation cycle. If the OCP is still exceeded, the PWM duty will continue to be reduced. On the contrary, if the OCL is not exceeded, the actual output will accelerate to the PWM duty of the command target. When the VRF voltage exceeds OCP, the program judges it to be abnormal, and the system immediately stops output and enters the lock protection mode.

There are two situations where the current limit protection does not work. The first is to prevent the current limit from affecting the startup when the PWM duty cycle has not reached 14%. The second is the deceleration stage. When the motor load inertia is heavier and the deceleration time is short, although the PWM duty cycle will gradually decrease, the inertia may cause the BEMF voltage to rise, and the current will exceed the predetermined limit value.

Lock Protection

PT2513 has three conditions to make the control algorithm enter the lock protection mode. First, when the motor is in the starting phase, the controller cannot determine any correct commutation signal. Second, when the motor is successfully started and is in running mode, but the ZC signal suddenly changes too much. Third, when the motor current is too large, the OCP_H potential is triggered. At this time, the motor stops immediately and closes the output driver stage. After a few seconds, the control algorithm will try to restart the motor. If the motor starts successfully, it will continue to run normally. However, if the motor still fails to start, the control algorithm will return to the lock on protection mode and try to restart the motor again after a few seconds.

Over Temperature Protection

PT2513 has a built-in temperature detection circuit. When the internal temperature exceeds 150°C, PT2513 will turn off the output driver stage. When the internal temperature drops below 120°C, PT2513 will restart again and operate normally.

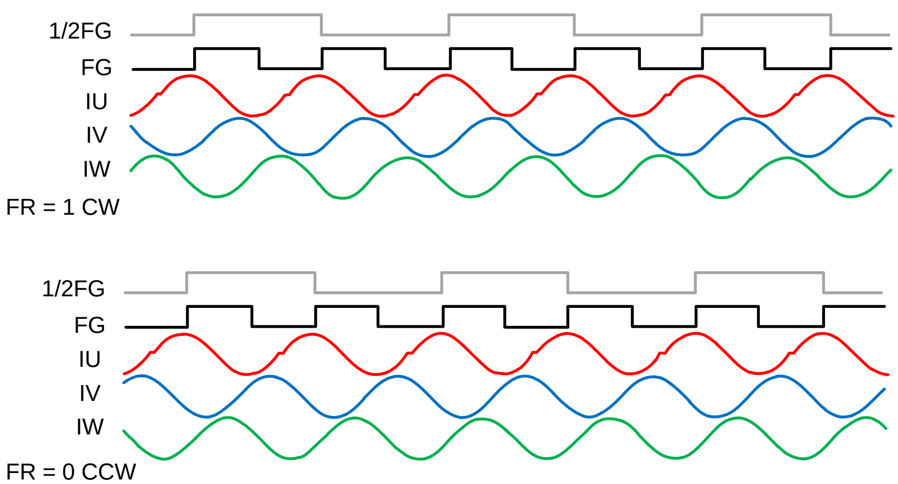
FG Output and Setting

PT2513 provides FG output to monitor motor speed. When the rotor runs for one (electrical) cycle, the FG pin will output a high and a low. It is necessary to know the number of rotor poles when calculating the speed. For example, if the rotor has 8 poles (four pairs of NS), one cycle of the motor will produce 4 FG outputs. Generally, the motor speed is based on RPM (revolutions per minute). The conversion formula of speed (RPM) and FG frequency (Hz) is as follows:

$$RPM = FG \times 120 / POLE,$$

Where FG is the frequency in Hz; the number of stages of the POLE motor rotor (N, S are each a magnetic pole).

PT2513 will start to output FG when it detects BEMF signal when PWM starts to output. When PWM stops output, FG will stop output regardless of whether the motor is rotating or not. The FG trigger position is about 90 degrees behind the U-phase commutation point, and the starting point may be a rising edge or a falling edge. The FG output pin has an open drain structure, and the highest power supply can be pulled up to VDD. In addition, PT2513 also provides 1/2FG frequency output, and SEL must be set to M (1/2 VREG) level.



1/2 FG, FG, IU, IV, IW relationship diagram

Forward and Reverse Rotation

The PT2513 can be set to forward or reverse mode through the FWR pin. If the FWR mode is changed during operation, the controller will brake to stop the motor, and then start rotation in the opposite direction. There is a pull-up resistor internally the FWR pin. When the forward and reverse switching is not required, it can be left unconnected. Because PT2513 is using sensorless control method, the forward and reverse settings can also be changed by switching the motor wiring.

Selection of Capacitance between COM and FLT pins

PT2513 detects the motor position by comparing the back electromotive force generated by the motor rotation and the virtual midpoint voltage to generate a ZC signal. However, noise caused by motor startup or rotation may interfere with the accuracy of the zero-crossing signal, which may cause failure at startup or affect rotation stability. The capacitor between the COM and FLT pins helps to reduce noise interference. The recommended capacitance range is 0.1nF to 10nF. In addition, when a filter circuit is used, the commutation signal ZC will cause a delay. Therefore, the higher the speed of the motor, the smaller the capacitance value, so that too much delay will not affect the efficiency. Because FLT_C = 1nF, it is suitable for applications where the maximum motor FG is about 100Hz. For other applications with different maximum speeds, this value can be used as a preliminary setting, and then fine-tuned to achieve a more stable and efficient effect. Generally, higher speed motors have higher frequency, and smaller FLT capacitors can be selected, and vice versa. The initial selection of FLT capacitor can be the same as that of OSC capacitor, and then fine-tune it according to the desired effect.

Selection of Capacitance OSC pins

OSC is the relative benchmark for all variable adjustment steps or timing of PT2513, including the start step, acceleration and deceleration time. When OSC_C= 1nF, OSC~1KHz, it is also suitable for applications where FG is about 100Hz when the motor rotates at the highest speed. For other applications with different maximum speeds, OSC_C=1nF, FG=100Hz can be used as the initial setting value, and then fine-tuned to achieve a smoother start effect. Usually higher speed or faster start-up applications choose a smaller OSC capacitor, and vice versa.

ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Conditions	Max.	Unit
VDD supply voltage	VDDmax	PT2513 No break down	20	V
Output pin current[(1)]	Iout,max	PT2513 UO, VO, WO pins	1.0	A
Input pin withstand voltage	Vin,max	VSP, FR, SELx, MIN, MAX	6	V
Power dissipation 1	Pd,max1	Independent IC	0.3	W
Power dissipation 2	Pd,max2	Mounted on evaluation board[(2)]	1.2	W
Operating temperature	Topr	Junction temp. < 150°C	–40 to +105	°C
Storage temperature	Tstg	–	–40 to +150	°C

Notes: 1. 500ms test time and mounted on the designated board with heat-sink area.
2. Mounted on the designated board with heat-sink area.

ELECTRIC CHARACTERISTIC

(VDD=12V, T =25°C unless otherwise specified)

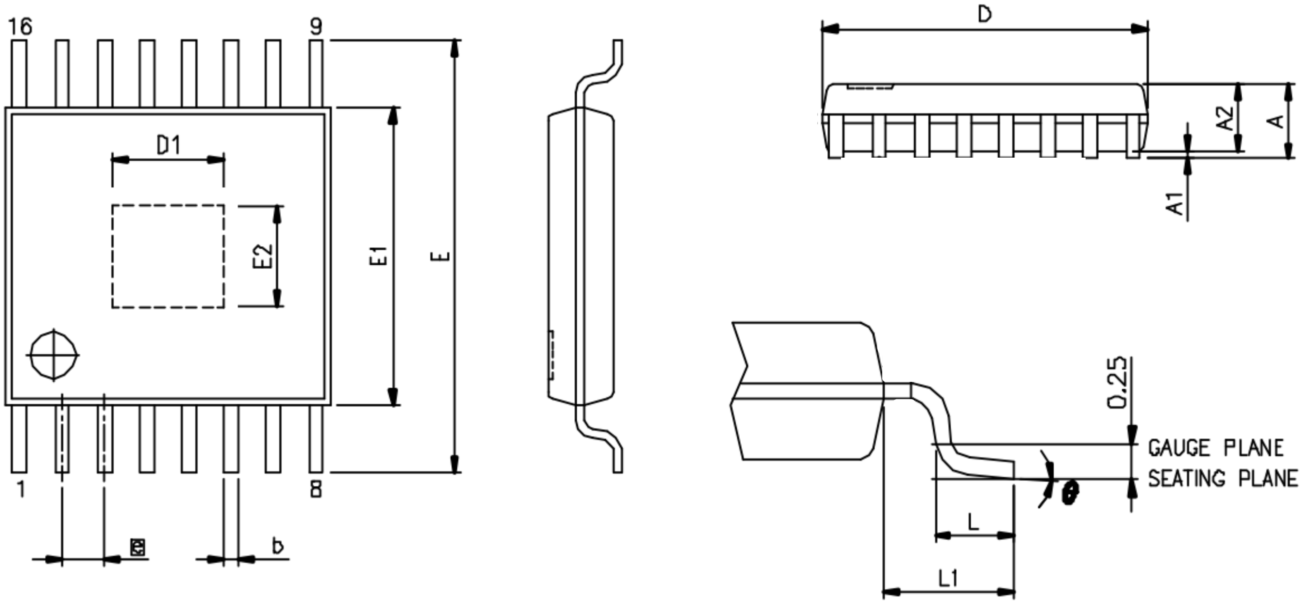
Parameter	Symbol	Conditions	Min	Typ	Max	Unit
VDD supply voltage	VDD	PT2513	6.0	–	16	V
Power supply current 1	IDD	PWM pin = VREG, without load	–	5.0	7.0	mA
Power MOS Rdson	Rdson	Io = 500mA (H+L)	–	1.0	–	Ω
MOS switching frequency	Fmos	U, V, W output	30	40	50	KHz
OSC charge/discharge current	Iosc	OSC pin	–	5.6	–	μA

VREG pin voltage	Vreg	No load	4.5	5	5.5	V
DC for VSP control range(1)	DCvsp	VSP input	0.4	–	3.2	V
PWM frequency for VSP control	Fpwm	VSP input	1	–	25	KHz
PWM high input voltage for VSP control	Vpwmh	VSP input , PWM voltage rising	3.3	–	5	V
PWM low input voltage for VSP control	Vpwml	VSP input PWM voltage falling	0	–	0.3	V
FG output low voltage	Vfgl	IFG=1mA	–	0.55	–	V
FG output leak current	Ifgl	VFG=20V	–	–	10	μA
Logic input pull high current	Isource	FR, SEL,pins	–	25	–	μA
SELx input high level	Vselh	SELx pins	3.8V	–	VREG	V
SELx input middle level	Vselm	SELx pins	2.0	1/2 VREG	3.0	V
SELx input low level	Vsell	SELx pins	0	–	0.5	V
Current limiter voltage (OCL)	Vocl	RF pin	0.25	0.3	0.35	V
Over current voltage (OCP)	Vocp	RF pin	–	0.5	–	V
Lock protection off time	Tlock	OSC cap = 100pF	–	3.0	–	S
Thermal shutdown trigger	Tshdn	Design target	–	150	–	°C
Thermal shutdown release	Trel	Design target	–	120	–	°C

Note: When PWM input, the minimum startup PWM duty = 2.3%, when VSP (DC) input, the minimum voltage to startup is about 0.5V. If the PWM/VSP is too small, it may fail to startup.

PACKAGE INFORMATION

16 PINS, HTSSOP (Shrink Small Outline Package with Heat Sink)

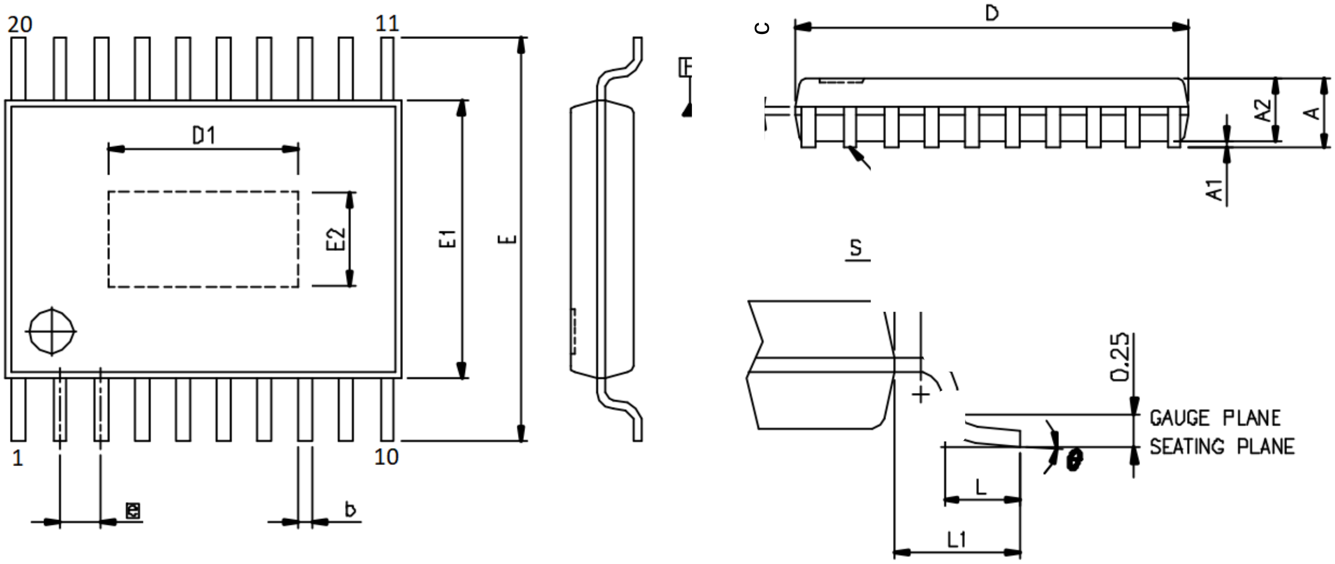


Symbol	Dimensions(mm)		
	Min.	Typ.	Max.
A	-	-	1.20
A1	0.00	-	0.15
A2	0.80	1.00	1.05
b	0.19	-	0.30
D	4.90	5.00	5.10
D1	2.40	-	3.00
E	6.4BSC		
E1	4.30	4.40	4.50
E2	2.40	-	3.00
e	0.65 BSC		
L	0.45	0.60	0.75
L1	1.00REF		
θ	0º	-	8º

Notes:

1. Reference to JEDEC MO-153 AB/ABT (Thermally Enhanced Variations only)
2. Unit: mm

20 PINS, HTSSOP

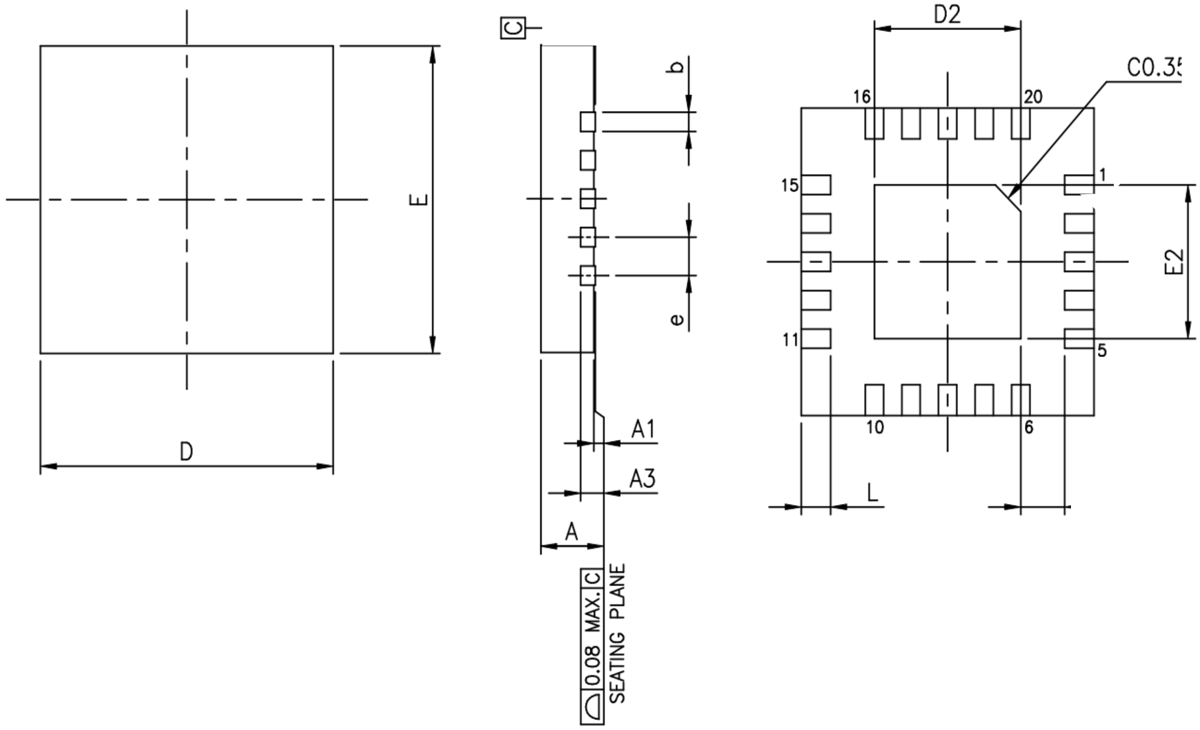


Symbol	Dimensions(mm)		
	Min.	Typ.	Max.
A	-	-	1.20
A1	0.00	-	0.15
A2	0.80	1.00	1.05
b	0.19	-	0.30
c	0.09	-	0.20
D	6.4	6.5	6.6
D1	3.79	3.99	4.35
E	6.4BSC		
E1	4.30	4.40	4.50
E2	2.60	2.8	3.15
e	0.65 BSC		
L	0.45	0.60	0.75
L1	1.00REF		
θ	0º	-	8º

Notes:

1. Reference to JEDEC MO-153 AB/ABT (Thermally Enhanced Variations only)
2. Unit: mm

20 PINS, QFN



Symbol	Dimensions(mm)		
	Min.	Typ.	Max.
A	0.7	0.75	0.8
A1	0.00	0.02	0.05
A3	0.203 REF.		
b	0.20	0.25	0.30
D	4.00 BSC		
D2	1.90	2.00	2.05
E	4.00 BSC		
E2	1.90	2.00	2.05
e	0.50 BSC		
L	0.30	0.40	0.50

Notes:

1. Reference to JEDEC MO-220 REV.K (WGGD-1)
2. Unit: mm

IMPORTANT NOTICE

Princeton Technology Corporation (PTC) reserves the right to make corrections, modifications, enhancements, improvements, and other changes to its products and to discontinue any product without notice at any time.
PTC cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a PTC product. No circuit patent licenses are implied.

Princeton Technology Corp.
2F, 233-1, Baociao Road,
Sindian Dist., New Taipei City 23145, Taiwan
Tel: 886-2-66296288
Fax: 886-2-29174598
http://www.princeton.com.tw