■ General Description

This Technical Information Paper explains how to choose external components for DC/DC converters. The external components should be carefully selected because the components greatly effect on the DC/DC converters' characteristics in chart 1. For the part number of each external component, please refer to the typical application circuits of Torex's data catalogs or data sheet.

■ Selection of external components

The selection of external components for connection to TOREX products greatly influences the characteristics of the DC/DC converters. Please take the Chart 1 below as a reference, and fully determine with the actual devices. For details of the external components such as part number and so on, please refer to the typical application circuits shown in Torex data sheet.

Chart 1 : Selection of external components by characteristics

		COIL		CL *	SD *	EXTERNAL TR.	EXTERNAL TR. (BIPOLAR)	
		L	DCR			(POWER MOSFET)	R_B	C_B
For higher current		Small	Small	Large	Small V_F	(Low ON resistance)	Small	Large
For higher efficiency	Light load	Large	Small	-	Small I_R	-	Large	Small
	Heavy load	Large	Small	-	Small V_F	(Low ON resistance)	Small	Large
For low ripple output voltage		Large	-	Large	-	-	-	-
For better transient response		Small	-	Large	-	-	-	-

Note : No R_B or C_B is needed when power MOSFET is used as external transistor.
*C_L : Load Capacitor, SD : Schottky Diode

■ Coil

For selecting inductance value, please refer to the Chart 2 below, which lists the value according to oscillation frequency and output current (load). The higher the oscillation frequency, the lower the inductance value and the smaller the coil that can be chosen. It is better to use a coil with a lower direct current resistance (DCR) wherever possible. As the L value becomes smaller, the peak current (Ipeak) of the coil increases, and the maximum output current becomes a maximum with a certain L value. When the L value is increased, the loss of the switching transistor by peak current becomes smaller and efficiency reaches a maximum with a certain L value. Further, the more the L value is increased, the loss caused by the direct current resistance (DCR) of the coil becomes large resulting in reduction of efficiency. For selection of the coil, the rated allowable current value is one of the important parameters. If a current exceeds the rated allowable current value, a coil will emit heat and it causes magnetic saturation of the coil resulting in a significant decrease in efficiency. It will cause a serious damage to the IC if the peak current exceeds the allowable current value.
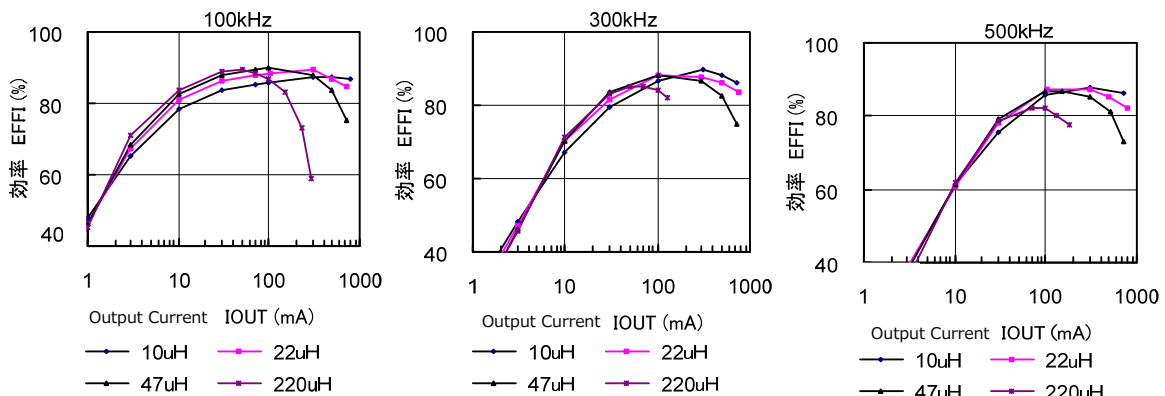
Chart 2 : Selection of the inductance value

LOAD	50kHz	100kHz	180kHz	300kHz	500kHz
Light Load	330µH	220µH	100µH	47µH	22µH
Medium Load	220µH	100µH	47µH	22µH	10µH
Heavy Load	100µH	47µH	22µH	10µH	6.8µH

[Figure 1] Comparison of XC6367A and XC6368A series' efficiencies when differing oscillation frequencies but using the same coil
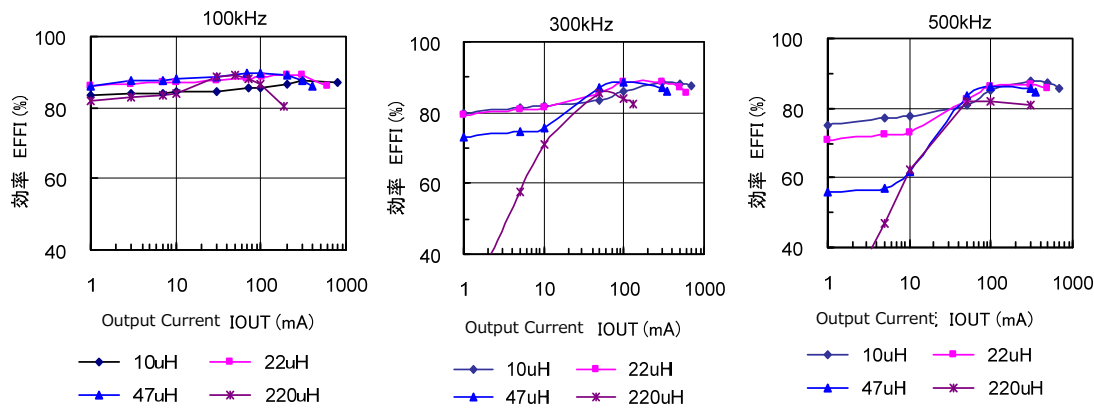
・XC6367A Series, VOUT=5V, Vin=3.3V

Tr.=XP161A1355PR, SD=MA2Q737, Coil=CR54, Cin=220µF, CL=47µF

・XC6368A Series, VOUT=5V, Vin=3.3V

Tr.=XP161A1355PR, SD=MA2Q737, Coil=CR54, Cin=220μF, CL=47μF

When in is continuous mode, the peak current (I_{L_PEAK}) of the coil can be calculated using the equation below. The allowable current value of the coil should be more than the peak current value. The equation below can be adapted to the case with no loss. In practice, the peak current value is larger than the result of the equation.

$$ILpeak^2 = 2(Vout-Vin) \times Iout \div (L \times f_{OSC})$$
$$Ex.) \ Vin=3V, \ Vout=5V, \ Iout=10mA, \ f_{OSC}=100kHz, \ L=100\mu H$$
$$ILpeak = SQRT(2 \times (5-3) \times 0.01/(100000 \times 0.0001)) \doteqdot 63mA$$

■ Diode

a. A diode with small forward voltage (V_F) is recommended as it prevents losses caused by voltage drop of the forward voltage and increases efficiency. In the step-up circuit, operating start voltage also decreases. The forward voltage should be smaller than 0.6V at the peak current value of the coil.

b. The capacitance between the terminals of the diode should be small because if it is large, switching speed is slowed and spike noise, which rises out of diode's turn-on and off time, becomes large. When the switching speed is slowed, the switching loss increases.

c. Please select a diode, which has small reverse leak current (I_R). With the higher reverse leak current, not only efficiency decreases at light load but also spike noise increases. The reverse leak current tends to be high at high temperatures. Reverse leak current also tends to be high with high current (low V_F) diodes.

d.   For step-up DC/DC converters, the rated current of the diode should be two or three times higher than the peak current of the coil at the input voltage minimum value to be used. For step-down DC/DC converters, the rated current should be two or three times higher than the peak current of the coil at the input voltage maximum value to be used. With PFM control, it should be noted that the peak current value will increase so caution needs to be taken.

e. The rated voltage of the diode should be one and a half times higher than the output voltage for step-up DC/DC converters and one and a half times higher than the input voltage for step-down DC/DC converters. In practice, the voltage between the terminals should not be exceeded the rated voltage value.

■ Load Capacitance (CL)

a. When using a ceramic load capacitor for Torex ICs compatible with low ESR capacitors, please be aware of the temperature characteristics. Capacitor's other than those with B characteristics may not operate normally because electric capacity decreases according to ambient temperature or DC bias characteristics. Please fully check the operation, when tantalum capacitors, OS-CONs, and alminium electrolytic capacitors are used with TOREX ICs compatible with low ESR capacitors.

b. When using a tantalum capacitor, please use a capacitor with at least a 10mF capacitance value. For application's, which require output current of more than 100mA, a tantalum capacitor with over 100mF of load capacitance value should be connected. The ESR (equivalent serial resistance) value for the load capacitor should be about 0.1W to 0.5W. If a low ESR capacitor such as an OS-CON is used as a load capacitor, abnormal operation may occur because of inadequate phase compensation. Therefore, please do not use ceramic capacitors. Even if tantalum, OS-CON, or alminium electrolytic capacitors are used with the ICs compatible with such capacitors, the operation should be fully checked.

■ Load Capacitance (CL)

c. When using alminium electrolytic capacitors, the load capacitance value should be two or three times higher than the value recommended in the typical application circuit in order to avoid any reduction of capacitance at low temperature and increases in ESR. In such cases, please connect a tantalum capacitor of 10mF or more, or a ceramic capacitor or 0.1mF to 1.0mF in series in order to reduce ESR. The allowable ripple current is the important parameter for the alminium electrolytic capacitor. Excessive ripple voltage generates heat and shortens the life of the IC. (Less than 50mV output ripple voltage should be selected.)

■ Input Capacitor （CIN）

a. The input capacitor performs as the IC's power supply ripple rejection capacitor for the step-down DC/DC converters. Please connect the capacitor as close to the IC as possible.

b. The input capacitor should be connected to the step-up DC/DC converters IC because the capacitor reduces the influence of input power supply impedance to the IC. Unlike the load capacitor, lower ESR value can be chosen regardless of the type of capacitors.

■ External Transistor

When the input voltage is less than 1.2V, there may not be sufficient gate voltage to turn on a Power MOSFET. In this case, please use a bipolar transistor. For higher output currents, a Power MOSFET with lower ON resistance should be used. The bipolar transistor generally has a smaller current amplification rate (hFE). Therefore, when the bipolar transistor is used for high current, the base current becomes high and efficiency decreases when compared to a MOSFET.

■ Power MOSFET

a. Please choose a power MOSFET with an input capacitance (Ciss) and output capacitance (Coss) less than 1000pF.

b. A MOSFET with fast switching speed should be selected. Efficiency goes up when the switching speed increases. [fast switching speed : short turn-on delay time (td (on)), rise time (tr), turn-off delay time (td (off))]

c. A MOSFET with a gate to source cut-off voltage (Vgs (off)) much lower than the input voltage should be selected. A bipolar transistor is suitable where the supply voltage is lower than 1.2V. When starting up the step-up DC/DC converter ICs, a voltage more than the gate to source cut-off voltage (Vgs (off)) needs to be applied to the power supply pin.

d. ON resistance (Rds (on)) between drain and source of the Power MOSFET should be low. However, MOSFETs with extremely low ON resistance commonly have large input capacitance (Ciss) and output capacitance (Coss). There is a tradeoff among ON resistance, input capacitance and output capacitance.

e. For the step-up DC/DC converters, please choose a MOSFET with a rated current two or three times more than the peak current. For the step-down DC/DC converters, a rated current around two times of the output current multiply by step-down ratio should be selected. Please check the current waveform and the heat of the MOSFET by an actual device before the selection. It is also necessary to pay attention to the peak current value because the peak current becomes high especially in PFM control.

f. The MOSFET's rated voltage for step-up DC/DC converter ICs should be one and a half times larger than the output voltage. The rated voltage for step-down DC/DC converter ICs should be one and a half times larger than the input voltage. Please check with the actual parts before use and avoid a situation where that the voltage between the pins exceeds the rated voltage.

g. If it is supposed that all losses of the circuit while efficiency falls are consumed by a transistor, the power dissipation of the MOSFET should be larger than the losses. When the output voltage and the output current are high, the MOSFET should have sufficient margin (additional coverage) to resist to the electric power loss. Please check the heat falls within the operating temperature range, and if necessary, please consider the heat dissipation.

■**Bipolar Transistor**

a. The current gain rate hFE should be selected from the range of 100 to 500. Please be aware that a bipolar transistor where the current gain rate is extremely high commonly has a small base current and a high OFF leak current.

b. Please use a bipolar MOSFET with fast switching speed as much as possible. Efficiency goes up when switching speed increases.   Also please use a MOSFET with a collector output capacitance (Cob) of around 10pF. [fast switching speed : short turn-on time (ton), fall time (tf), storage time (tstg)]

■**Base Resistance (R$_B$) and Speed-Up Capacitance (C$_B$) Value of Bipolar Transistor**

Base Resistance (R$_B$)

Base resistance (RB) should be selected within a range of 250Ω to 2kΩ because a resistance less than 250Ω has an effect on the IC's operation.
With a small RB value of around 200Ω ~ 500Ω, the output current becomes higher but efficiency reduces at the light loads.
With a high RB value of around 700Ω ~ 2kΩ, the output current becomes smaller but efficiency increases at the light loads.

The RB value is calculated using the following equations, which are based on the collector current value ISW (IC) when the transistor is ON.
Fluctuation may occur to the rate of current amplification hFE. Please calculate using more than three times the actual value for ISE (IC).

$$ISW(IC)=h_{FE} \times IB = Vout \div (RB + R_{EXTH})$$
$$RB \leqq (Vout-0.7) \times h_{FE} \div ISE(IC) - R_{EXTH}$$

Ex.） Iin=100mA, Vout=5.0V, h$_{FE}$=200, 250Ω≦RB≦1.4kΩ

Speed-Up Capacitor (C$_B$)

The Speed-up capacitor (C$_B$) is added to improve efficiency. The C$_B$ value is fixed by the R$_B$ value and oscillation frequency (f$_{OSC}$) of the switching regulator. Please select a C$_B$ value by referring to the equation below for improving switching speed and efficiency.

$$CB \geqq 1 \div (2\pi \times RB \times fosc \times 0.7)$$
Ex.） fosc=100kHz、CB=2200pF～3300pF
RB=1kΩ,

If the C$_B$ value is increased greatly, switching speed becomes faster and supply current becomes higher. Even if the C$_B$ value is increased just a little, the changes in the switching speed will have an effect. Please use the above equation for the calculation.