

## DC/ AC Inverter Unit for Liquid Crystal Display (LCD) Panel

### 1. Introduction

Liquid crystal display (LCD) panels are used in various applications ranging from smaller portable electronic equipment to larger fixed location units. Applications such as the display device for laptop PCs, word processors, arcade game machines, pinball machines, video cameras, automobile navigation systems, and industrial machines.

The LCD panel itself cannot emit light. Therefore, a backlight system that supplies the light from behind is normally required. The backlight system consists of a light emitting device that produces light, a conductor panel that distributes the light to the entire LCD surface uniformly, and a power supply that drives the light emitting device.

Currently, the most commonly used light emitting device is a fluorescent tube called a cold cathode tube or CCFL. The CCFL is called a cold cathode tube because even though the principle of illumination is the same as that of the hot cathode tubes used by indoor lamps, this lamp does not require preheating of the filament. Also, the electrodes at the end of the bulb stay at a low temperature while emitting light. A special power supply, inverter, which generates approximately 1000 to 1500V AC is required to drive a CCFL. This inverter is a small power supply used to make this CCFL illuminate, and is one of the important functional parts of a complete LCD display.

As LCD panels are used in various markets and applications, requirements for the backlight system have become diversified as shown in table 1. In particular, the European computer display market is evolving from CRT displays to the LCD displays, this is partly due to strict EMI emission regulations.

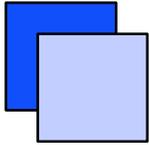
DC/AC Inverter characteristic applied to various

Market	DC/AC Inverter characteristic			
	Downsizing	Efficiency	Life	Wide Dimming
Audio & Visual	View Finder	ooo	ooo	o
	Video Monitor	oo	ooo	oo
	LCD TV	oo	ooo	oo
Automotive	LCD Monitor	oo	oo	ooo
	Navigation	oo	oo	ooo
Computer	Note PC	oo	ooo	ooo
	PCS	ooo	ooo	oo
Communication	Pager	ooo	oo	oo
	Game	oo	ooo	oo
Others	Monitor	oo	oo	ooo

Table 1

The balance of this application note will discuss the basic operation, features, and design precautions of the most commonly used inverters. We will also discuss inverter requirements and selection methods for those planning to use LCD panels.

In order to select the proper inverter unit, it is necessary to understand the features of the CCFL that is the load of the inverter. For those users who use LCD panels for laptop PCs and first-time users of backlighting systems, the fundamental features and basic operating principles of the CCFL and the inverter resonant push-pull circuit are explained.



### 2.0 Characteristics of the cold cathode tube

The brightness and the electrical characteristics of the CCFL change depending on the ambient temperature. Specific characteristics such as the length and diameter of the CCFL as well as the type and pressure of the gas, will also affect these electrical characteristics. Therefore, it is necessary to check the characteristics of the specific CCFL that you plan to use.

#### **Discharge in the cold cathode tube**

In a CCFL, the discharge starts when electrons and positive ions, which are accelerated by the high electric field, collide with the surface of the cathode such that secondary electrons are emitted. After the initial discharge starts a lower voltage is required to maintain the discharge. The CCFL emits ultraviolet light caused by the ejection of the secondary electrons. This ultraviolet light strikes the fluorescent material painted on the tube surface and emits visible light. Depending on the size of the LCD panel the typical CCFL diameter is 2 to 3mm and lengths vary from about 50 to 280mm.

#### **Discharge startup time and the tube voltage**

The discharge starts when a high voltage of about 1000Vrms is applied between both electrodes of the CCFL. This voltage is called the discharge starting voltage. (It is also sometimes referred to as the startup voltage or initial voltage.)

When current flows through the CCFL, the impedance of the tube decreases and the voltage between the electrodes of the CCFL drops rapidly. When current flows to a certain level, decline of the voltage stops and the CCFL shows an almost constant voltage characteristic as shown in Figure 1. The voltage at this time is called the CCFL voltage and it is approximately 300 to 700Vrms, depending on the type of the CCFL. Though this characteristic resembles that of the zener diode, the CCFL has a negative constant voltage characteristic where the voltage drops when current increases, whereas the voltage in a zener diode rises when current increases, giving it a positive constant voltage characteristic.

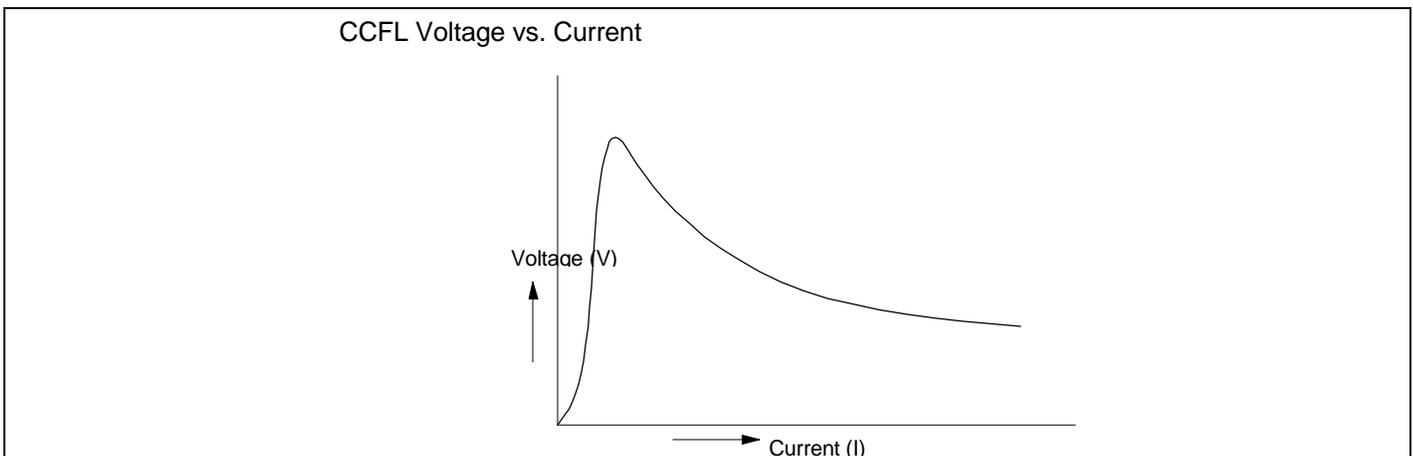
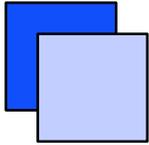


Figure 1

In general, the starting voltage and the CCFL voltage tend to be higher under the following conditions:

- When the ambient temperature is low.
- When the diameter of the cold cathode tube is small.
- When the length of the CCFL is long.



## DC/ AC Inverter Unit for Liquid Crystal Display (LCD) Panel

In order to ensure that the CCFL starts, a starting voltage of 1000 to 1500Vrms, which is higher than the operating voltage of the CCFL, is required as the inverter generates the open voltage (a voltage that the inverter generates before the discharge starts).

### CCFL current and brightness

In order to maintain the discharge after starting, it is necessary to keep current flowing. Even though the brightness increases by increasing current to the CCFL, too much current may damage the electrodes and lead to a shorter lifetime. While 2 to 7ma is commonly used for each CCFL, it is important to control the current at an appropriate level. Reference should be made to the brightness verses rated current listed in the specification sheet of the CCFL. Figure 2 is an example of CCFL brightness verses starting voltage and temperature. When the ambient temperature is lower as shown in Figure 2, the brightness decreases as opposed to the rising starting voltage.

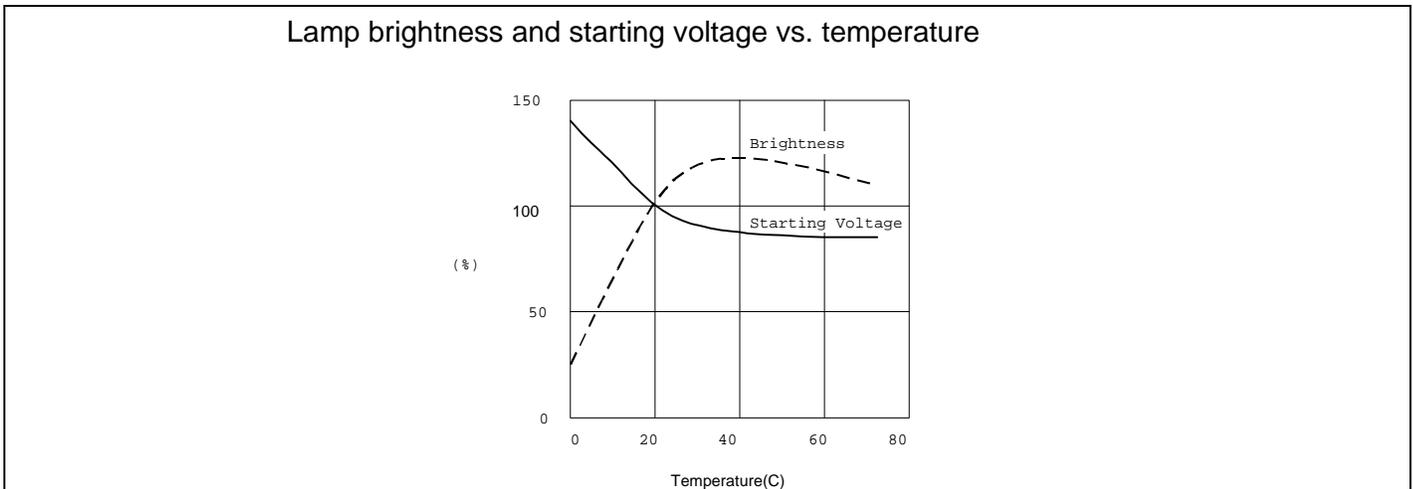
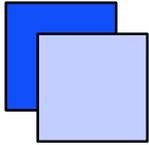


Figure 2

### Frequency

Generally, CCFL's are lit by alternating current (AC). This is because when direct current (DC) is used, the mercury ions in the cold cathode tube are shifted, the intensity of the tube becomes unbalanced (cataphoresis phenomenon), and the life of the CCFL will be shorter. The AC frequency is typically 30 to 70 kHz. The higher the frequency, the greater the light output. Due to current leakage through the wiring capacitance between the inverter and the CCFL, light output to power efficiency may decrease. This is because not all of the output current from the inverter flows to the CCFL. In addition, it is necessary to consider the interaction with the LCD refresh frequency to avoid flickers and noise streaks that can occur from interference from the operating frequency of the LCD panel.

It is necessary to consult the CCFL specification regarding these and other characteristics. Other light characteristics to consider are the color temperature and color spectrum of the individual lamp.

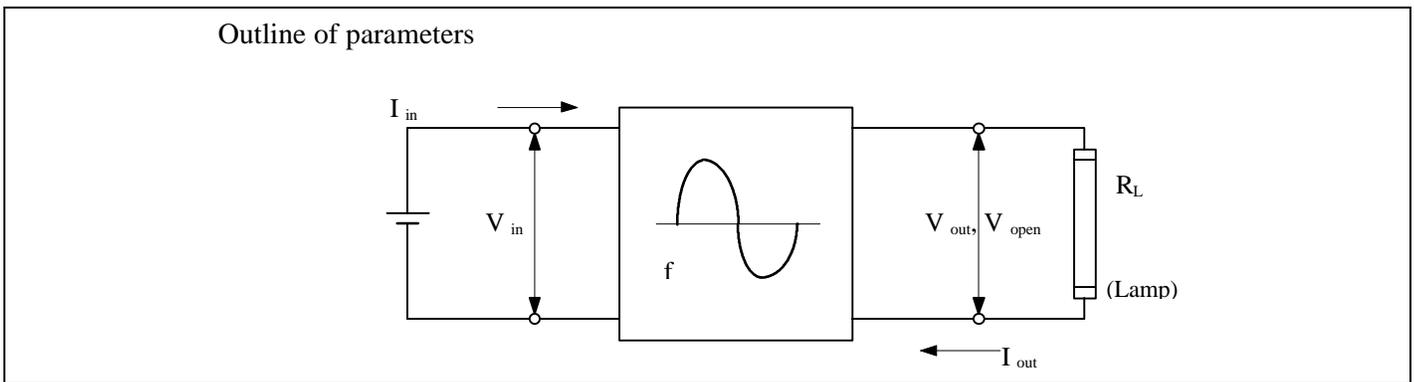


**DC/ AC Inverter Unit for Liquid Crystal Display (LCD) Panel**

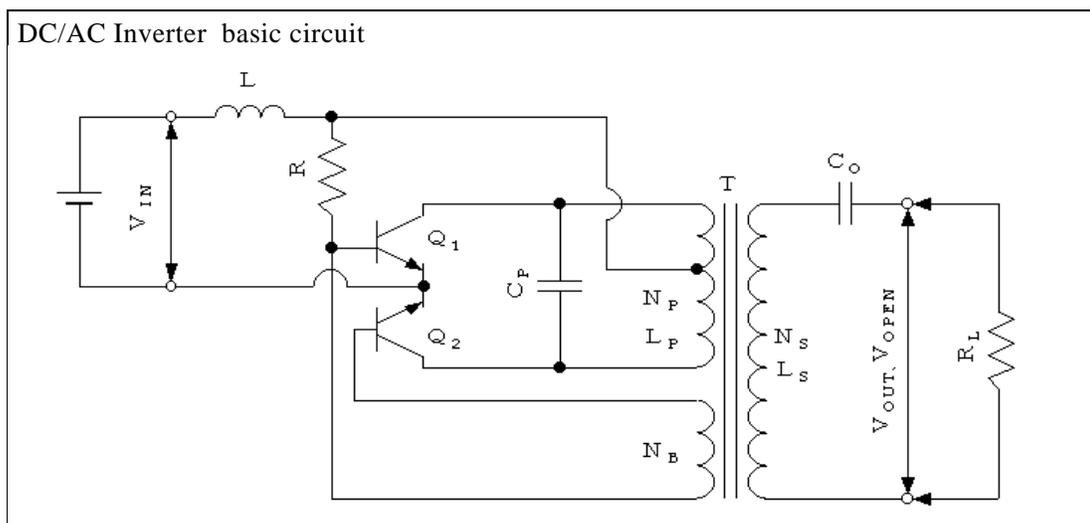
**2.1 Fundamental operation**

In order to select the appropriate inverter it is necessary to understand the basic theory of operation. When the inverter is considered as a black box, there are seven parameters that can be given from outside as shown in Figure 3:

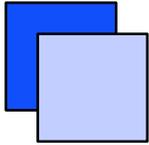
Input voltage $V_{IN}$	Input voltage to the inverter.
Input current $I_{IN}$	Input current to the inverter.
Output voltage $V_{OUT}$	CCFL voltage between the electrodes after the discharge has started.
Open voltage $V_{OPEN}$	Voltage necessary to start the discharge in the CCFL.
Equivalent load resistance $R_L$	Equivalent resistance obtained by dividing the CCFL voltage by the CCFL current.
Output current $I_{OUT}$	CCFL Current
Oscillator frequency $f$	Frequency used when the CCFL is driven by alternating current.



**Figure 3**



**Figure 4**



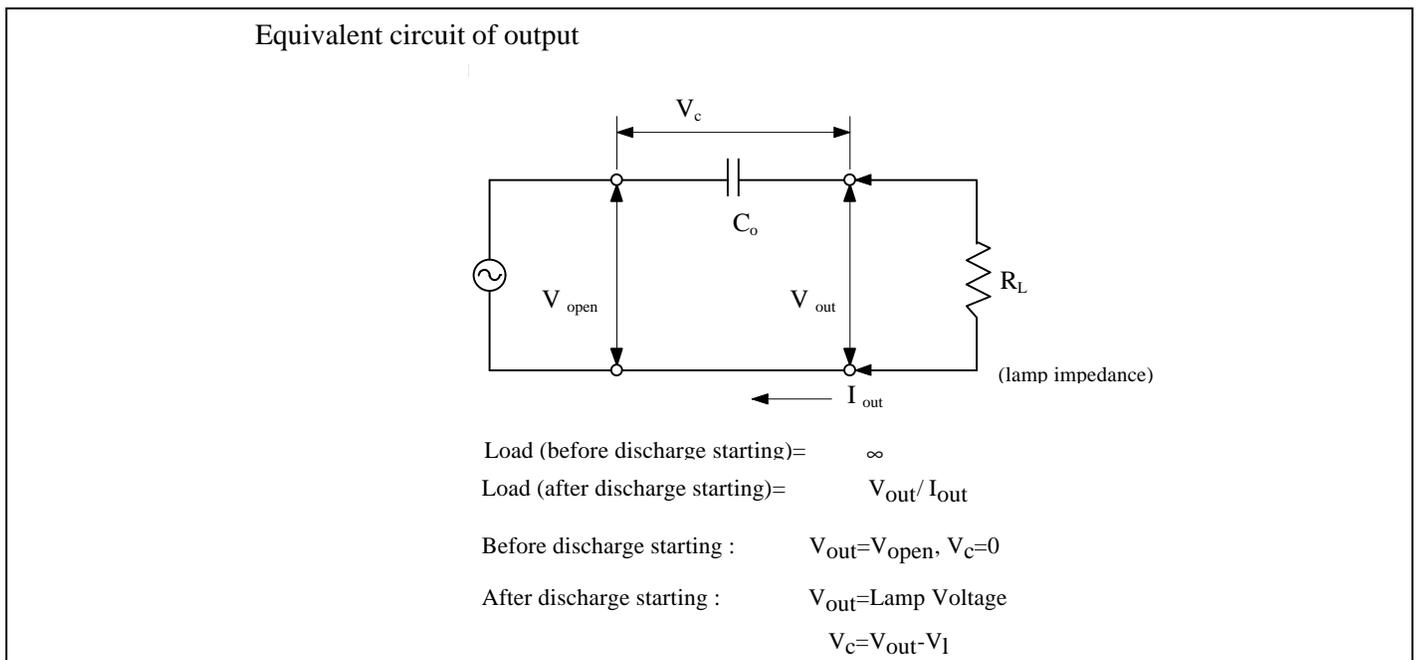
**DC/ AC Inverter Unit for Liquid Crystal Display (LCD) Panel**

Figure 4 shows the basic inverter circuit. (Push-pull voltage resonant circuit) This circuit is suitable for CCFL's. This circuit can generate a symmetric sine wave with a relatively simple design. The open circuit voltage necessary for starting the CCFL is shown in the following formula when the primary and secondary winding ratio of the ideal transformer is N and the ON voltage of the switching transistor Q1 or Q2 is  $V_{CESAT}$ .

$$\text{Open voltage } (V_{OPEN}) = 1.11 \times N \times (V_{IN} - V_{CESAT})$$

Since there is no feedback from the output, the output voltage increases proportionally to the input voltage. The relationship between the output voltage and the CCFL voltage and CCFL current are explained using the equivalent circuit of the secondary of the transformer as shown in Figure 5.

Capacitor  $C_o$  is inserted in series with the CCFL in this circuit. This capacitor  $C_o$  allows the output voltage from the transformer to be applied directly to both electrodes of the CCFL before the start of the discharge (when the impedance of the CCFL is infinity and there is no apparent load).



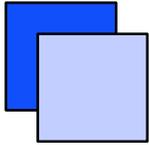
**Figure 5**

After the discharge starts, the capacitor  $C_o$  works as a current control device and the output current  $I_{OUT}$  is determined by the composite impedance of the capacitor  $C_o$  and the equivalent load resistance  $R_L$  of the CCFL.

$$\text{Output current } I_{OUT} = V_{OUT} / Z = V_{OUT} / ( \sqrt{R_L^2 - X_C^2} )$$

(Reactance  $X_c = 1/\omega C$ )

In the inverter circuit, we make the reactance component  $X_c$  of the capacitor  $C_o$  larger than the equivalent load circuit  $R_L$ . This is because by making the  $C_o$  component of the composite impedance larger, the output current  $I_{OUT}$  is determined by  $C_o$  and the constant current characteristic, which is suitable for driving the CCFL, can be artificially achieved. This  $C_o$  is called the "ballast capacitor."



## DC/ AC Inverter Unit for Liquid Crystal Display (LCD) Panel

The frequency is determined by the parallel resonant circuit that consists of the push-pull combined inductance  $L_P$  in the primary side of the transformer, the resonant capacitor  $C_P$ , and the total capacitance of  $C_O$  that was translated to the primary side from the ballast capacitor.

When the reactance component of the CCFL is ignored, the fundamental frequency is represented by the following formula:

$$\frac{1}{(2\pi \sqrt{L_P (C_P + C_O)})}$$

In order to maintain the resonance generated by the transformer and the capacitors, a feedback from the drive signal base winding of the transformer is applied to the switching transistor. The base drive current is supplied through the base resistor  $R$  from the input voltage by connecting the base winding  $N_B$ . The oscillation is maintained by adjusting the resonant frequency as shown in Figure 6 and by alternately turning ON Q1 and Q2.

By making the choke coil  $L$  two to three times larger compared with the primary winding  $L_P$ , the input side will act as a constant current source.

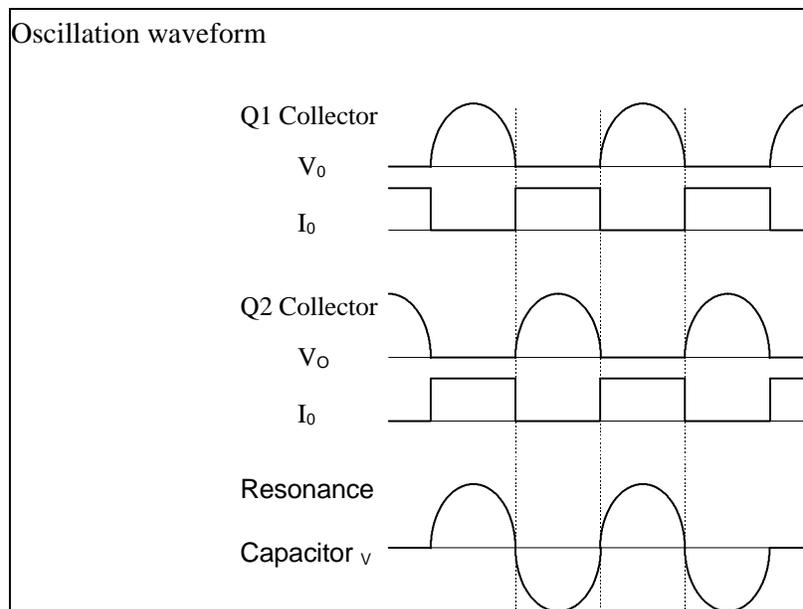
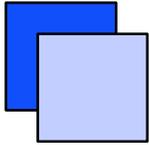


Figure 6



### 2.2 Precautions of implementation

#### 1) Effect of the distributed capacitance

When high frequency backlighting is performed, the measurement values of evaluating the CCFL unit only and the evaluation values in the system configuration will be different. The effect is especially significant when grounded conductors exist in the vicinity of the wiring that connects the high voltage output terminal of the inverter and the CCFL. This is because of the distributed capacitance around the high voltage.

Figure 7 shows a conceptual model. When there is distributed capacitance the output voltage from the transformer is divided by  $C_o$  and  $C_G$  after the CCFL starts. Brightness may be lower than that of the CCFL by itself because the current drops by  $I_L = I_{out} - I_G$  while the lamp is lit. Therefore, it is necessary to make the high voltage lead wire as short as possible and to make the distributed capacitance  $C_G$  as small as possible. When a conductor is added along the CCFL, however, it has the effect of lowering the starting voltage. This method is actually utilized in some designs. Since it is difficult to describe the above usage in the form of specifications, testing using an actual system is recommended.

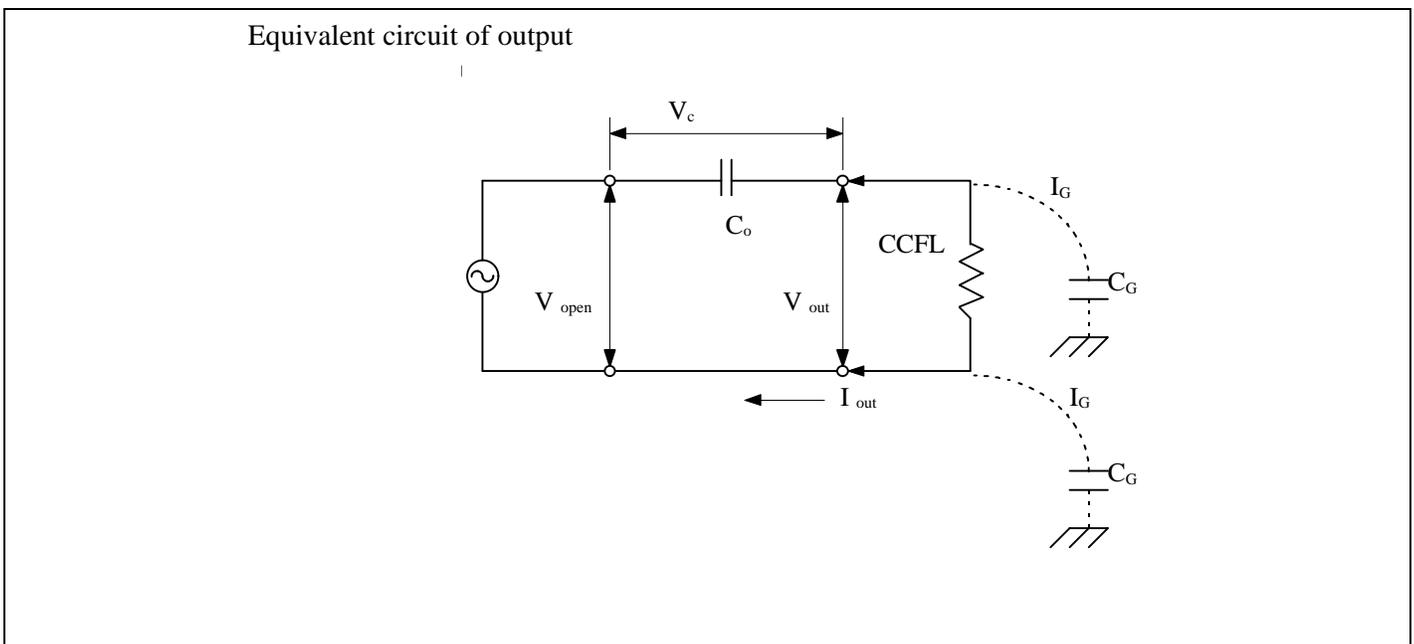
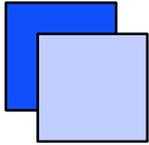


Figure 7

#### 2) Use environment

Unpredictable problems may occur depending on the application. For example, should the LCD system be used in a food sales environment, moisture or solid contaminants may contaminate and short circuit the output terminals of the inverter. Shorting the output can cause damage to the inverter. As the range of the applications of the LCD system becomes wider, more accidents of this kind are possible. Care should be taken to check the conditions of the application of the high voltage portion of any LCD backlighting system.

**DC/ AC Inverter Unit for Liquid Crystal Display (LCD) Panel**

---

**3) Safety standards**

Since the inverter generates a high voltage, special care is required to prevent electric shock and the possibility of fire. The inverter is designed with the assumption that it is built into a product and that there are no covers as the ones used by ordinary power supplies. Therefore, caution should be exercised so that the inverter cannot be touched directly. By adding a high voltage warning label and using an insulator sheet you can prevent accidental electric shock during equipment repair. Even if an electric shock occurs, the circuit characteristics allow the electric current to flow only at a level that has no harm to the human body, this is not considered to be a safety problem.

As a counter measure against heat and fire caused by a short circuit of the output or by component failure, a protective device such as a fuse is used to cut the circuit. Flame retardant materials are used for the circuit boards and resin materials in order to prevent the spread of fire. This is also required of the product in which the inverter is built-in.

Since the PL (product liability) law came into force in July 1995, there has been a growing interest in making safe designs. As official safety standards, each country has its own standards in addition to the international standard IEC950. Two important points to consider are:

**1) Ensuring the safety of the human body,****2) Ensuring the safety of the product and the surrounding objects.**

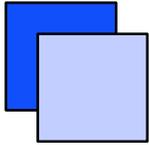
Prevention of burns and electric shock are important for item 1. Spatial distance, distance from the surface, thickness of the insulation, insulation resistance, degradation of the insulation materials, and the type of the insulation are defined in regard to the electric shock that is related to the inverters.

There are four types of insulation; functional insulation, basic insulation, additional insulation, and enforced insulation. Which type of insulation should be satisfactory depends on whether the following conditions apply or not:

- What is the product in which the inverter is used?
- Is it the primary circuit or the secondary circuit?
- Is it a current control circuit?

The inverter is usually used in office automation equipment such as laptop PCs and FAX machines, and it belongs to the group class 1. The inverter is defined as a secondary circuit because it is not directly connected to the external main power supply. Thus, the structure should satisfy the spatial and surface insulation of the functional insulation if it is a specified current control circuit. Even if there is not enough room for the required distance, the IEC950 standard [5.4.4] items b) and c) must be satisfied. (Refer to the applicable standard such as IEC and UL for the details of each item.)

Item 2 requires the use of materials certified by UL standard (for example 94V-O) or equivalent for the organic materials used in the transformer bobbin and the circuit boards, etc. It should be noted here that the safety standards are the minimum standards to be followed, and there is no guarantee that there will not be any safety problem even if these standards are met. In addition to the safety of the inverter by itself, it is also very important to check it in the actual application.



### **3.0 Inverter for laptop PC's**

The inverters used in a laptop PC applications have some specific desirable features. Some of the most common are discussed in this section.

#### **A wide range of input voltages**

Though the input voltage range varies depending on the specific battery used in each application, the inverter needs to support battery voltages of approximately 5 to 15 V. When an AC adapter is used, however, even higher voltages are present. In some cases, the input voltages range more than 4 to 1.

#### **A wide range of brightness control**

Since we assume portable use, the required brightness needs to be adjusted depending on the ambient environment. Recently, the use of laptop PCs at home and in airplanes demands a stable illumination not only at a high brightness but also at a low brightness.

#### **Low power consumption**

The efficiency of the inverter has a significant effect on the lifetime of the battery. It is necessary to use a circuit configuration and components that consume as little power as possible. Although indirect, decreasing the intensity by adjusting the brightness lowers the power consumption.

#### **Small-size, narrow-shape**

As the size of the screen becomes larger, the space for installing the inverter is getting tight. Not only thinner but narrower inverters are demanded these days. Fewer components in the circuit and miniaturization not only contribute to reducing the size of the unit but also to the reduction of the power consumption.

### **3.1 Wide range of input and the light control circuit**

By adding a DC-DC converter circuit to the push-pull resonant circuit, dimming control over a wide range input voltage becomes feasible. Figure 8 shows an example of a brightness control circuit that uses a control IC for a DC-DC converter. In this method, the output current (CCFL current) from the inverter is detected by resistor R and used as feedback to the DC/DC converter. Since the CCFL current is an AC current, the detected AC voltage is converted to a DC value by an integration circuit then applied to the error amplifier of the control IC.

Output voltage at the CCFL can be varied by controlling the input voltage to the push-pull amplifier. Furthermore by changing the output voltage of the DC-DC converter, the output current can be set to an arbitrary value for brightness control. Since the feedback of the detected output current is compared with the reference voltage, the brightness is controlled by changing the reference voltage. This scheme is sometimes referred to "brightness control by current."

In order to achieve a wide range of brightness control, the discharge needs to be stable even when the CCFL current is reduced. Low current through the CCFL can result in flickering and the discharge may become unstable at low temperatures.

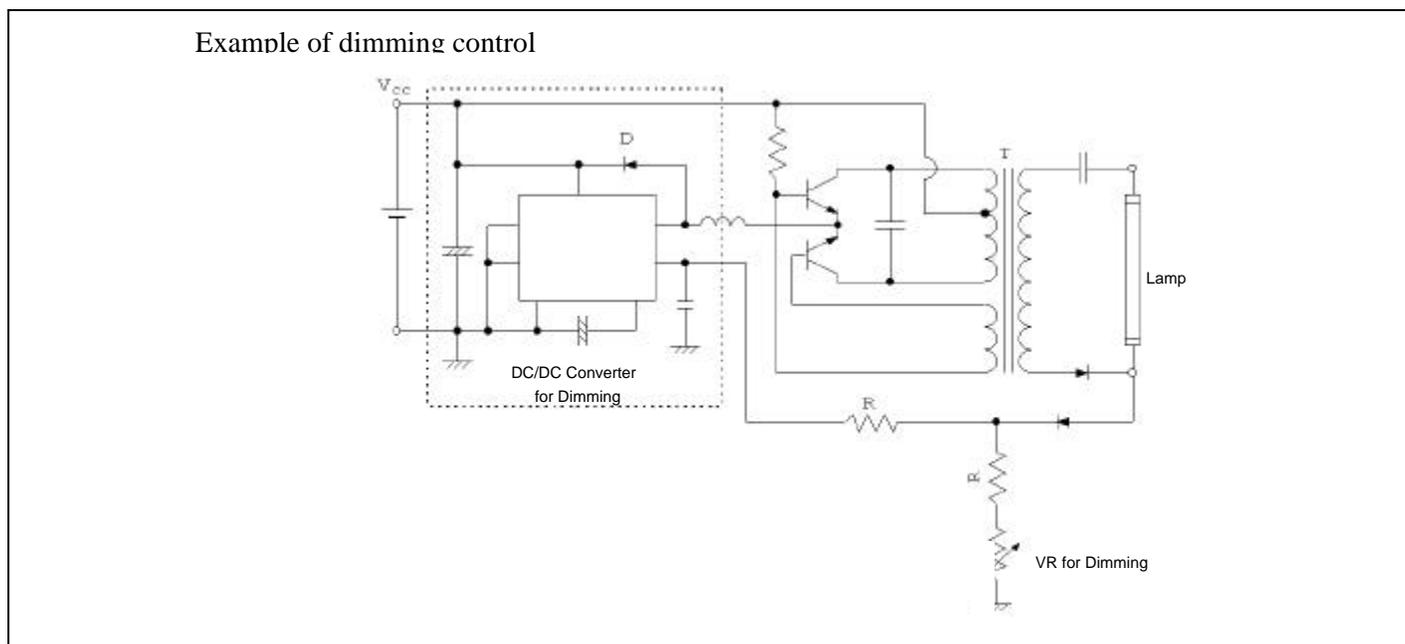


Figure 8

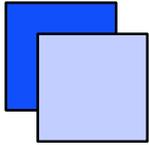
The CCFL characteristics also have a significant effect on dimming range and it is necessary to select a CCFL that can maintain a stable discharge under a low current condition. When the brightness control is reduced, the output voltage of the inverter drops while the CCFL voltage increases. Thus the inverter needs to generate a voltage that can maintain the CCFL voltage between both ends. In other words, the question is whether the output impedance and the output voltage of the inverter are appropriate for the impedance and the voltage of the CCFL.

Another brightness control method is duty control. This method intermittently turns ON and OFF the input power to the inverter to control the brightness by a duty ratio. In this method a wide dimming range of 10% to 100% can be achieved. We can achieve this wide dimming range with this duty control method because the open circuit voltage and the voltage applied to the CCFL does not drop when the duty cycle is reduced. However, a kind of stabilizer circuit is required because the output voltage changes directly by the voltage drift of the input source such as a battery. In addition, the frequency of the duty cycle control circuit is generally within the audible frequency range, and the transformer or the coil might hum. Extra care must be taken with the transformer design.

### 3.2 Reducing power consumption

In order to reduce the power consumption, use of high performance switching devices, coils, and transformers are required. Not only the efficiency of the power supply, but also the oscillator frequency and the waveform of the CCFL current effect the efficiency of the light output with respect to the total input power. For example, while the waveform of the primary side oscillator of the inverter is a sine wave, distortion can occur from the leakage of the transformer and from the distributed capacitance when the CCFL is connected.

The relationship between the waveform and the brightness seems to show improvement in intensity as the CCFL current waveform gets closer to a square wave. Therefore, it is necessary to examine the CCFL current and the frequency while checking the luminance at the surface of the LCD panel.



## DC/ AC Inverter Unit for Liquid Crystal Display (LCD) Panel

The inverter transformer is one of the important components and EE type transformers with divided bobbins have been proven to be an effective design. Molded and closed magnetic path style transformers that do not use a ballast capacitor, have also been used successfully. Newly developed piezoelectric transformers made of ceramic materials not only eliminate the ballast capacitor, but also achieve a high brightness efficiency as shown in figure 9.

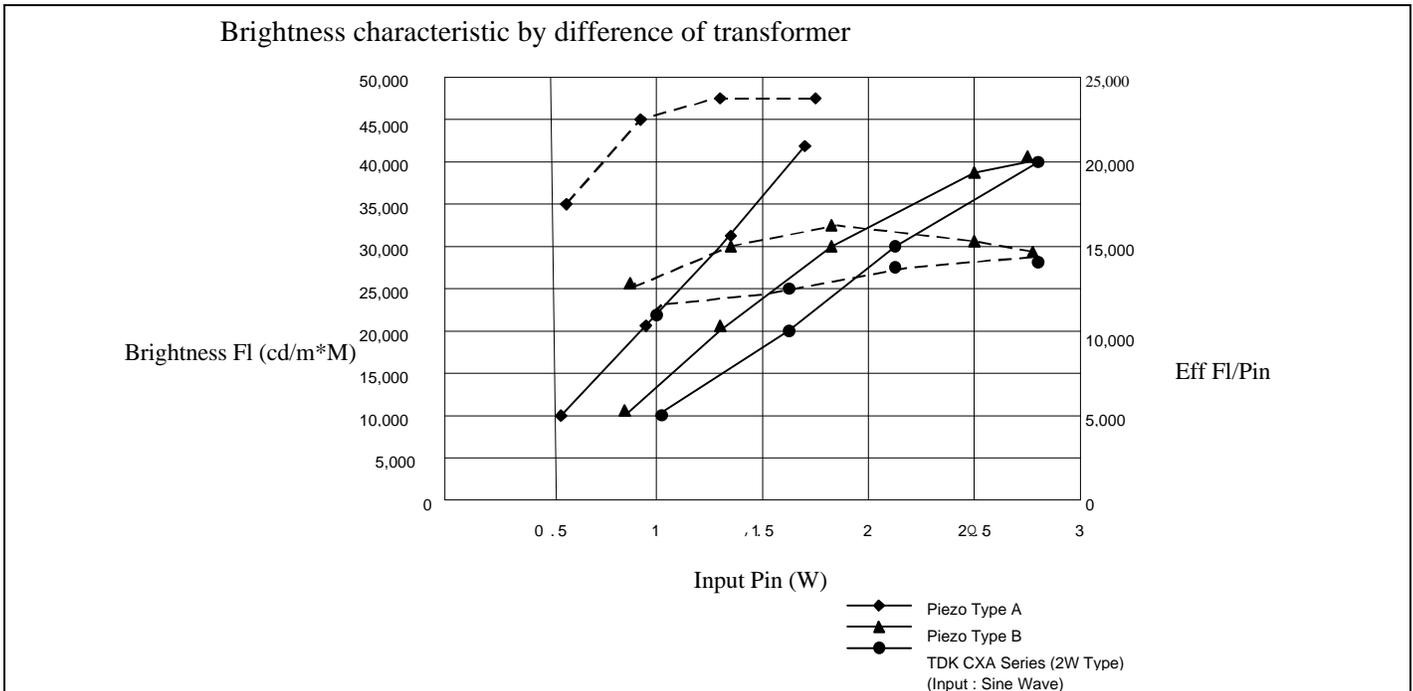


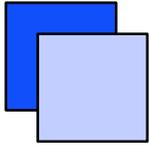
Figure 9

Since piezoelectric transformers also have advantages in small size and low height, they are becoming increasingly popular for use in inverters for laptop PCs. However, the driver circuit becomes complicated in order to boost the voltage step up ratio and to maintain the output power to support larger panels. The cost of piezoelectric transformers tends to be higher due to the materials and structure.

### 3.3 Miniaturization

Making inverters smaller and thinner is a common request. Components such as the coil, transformer, and connectors are the key to miniaturization of the inverter. Once the required power is determined the physical shape is dictated. Usually, a high voltage over 1000Vrms is required and the structure has to take into consideration the insulation distance, this makes it more difficult to design the system including smaller and lower profile connectors.

In practice, it is very important to consider the mechanical layout of the system. The requirements of the custom designed systems differ by each manufacturer. The shape of the panel, location of connectors, location of dimming controls, and the shape of the circuit board all will effect the inverter design.



## **4.0 Inverters from TDK**

The main TDK standard products are briefly explained here. TDK's inverters fall into two basic categories:

- Non-dimming using a push-pull resonant circuit.
- Dimming control that has the added DC-DC converter.

Features of both types are discussed.

### **4.1 Standard products of the non-dimming type (PCB Mountable)**

The non-dimming type is suitable for applications that do not require a variable brightness control. Typical applications include industrial and general information displays as well as for initial evaluation of an LCD panel and the reliability test of the LCD panel. The inverter is simple and inexpensive, therefore it is the best suited for applications that simply illuminate the CCFL.

TDK recently added the "P" type inverter that includes a built-in circuit protection device in addition to the conventional non-dimming circuit. The addition of this circuit protection further improves the safety of the inverter. Generally, this type of inverter has an input voltage range of  $\pm 5\%$ . Because the output voltage and output current change in proportion to the input voltage, small adjustment of the output current and the brightness can be easily achieved by inserting a three terminal voltage regulator or a diode in the inverter's input.

In some instances, when the input voltage is lowered, the open circuit voltage of the inverter becomes lower than the starting voltage of the CCFL. In this case, an inverter that can generate a higher open circuit voltage is used. One unit can drive one or two of CCFL's and the output current setting can be set differently by four different kinds of connection methods. With the exception of the **CXA-P10x-P** Series these inverters use a terminal pin construction and are designed to be mounted directly to a PC board.

#### **CXA-L10x-L Series**

This model can be used for CCFL's with a starting voltage of up to 900V. Two models with input voltages of 5V or 12V are available. The standard application is with two CCFL's and an operating voltage of 450V and current of 5mA. This series can handle a maximum of 4.5W.

#### **CXA-M10x-L Series**

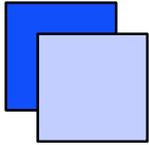
This model can be used for CCFL's with a starting voltage of up to 1200V. There are three models depending on the input voltage; 5V, 12V, or 24V. The standard use is for two CCFL's with a voltage of 600V and current of 5mA. This series handles a maximum of 6W.

#### **CXA-M14L-P**

This model is a high-power type developed for very large LCD panels. This model can be used for CCFL's with a starting voltage of up to 1500V. The input voltage is 12V. The usage is for two CCFL's with a voltage of 560V and a current of 7mA. Maximum power is 8W. Up to 14-inch LCD backlight systems can be driven with this inverter.

#### **CXA-P10x-P Series**

This model can be used for CCFL's with a starting voltage of up to 1500V. There are three models each with different input voltages; 5V, 12V, or 24V. The standard application is for two CCFL's with a voltage of 600V and current of 5mA. Maximum power of 6W.



## **4.2 Standard products of the non-dimming type (Connector I/O)**

This series is similar in electrical design as the non-dimming type discussed above. The advantage of this series of inverters is the addition of input and output connectors replacing the PC pins.

### **CXA-L05xx-NJL Series**

This model can be used for CCFL's with a starting voltage of up to 1500V. There are three models depending on the input voltage; 5V, 12V, or 24V. The standard application is for two CCFL's with operating voltages of 600V and current of 5ma. Maximum power is 4 watts.

### **CXA-P1012-NJL**

This model provides 7 watts of power and was specially developed for large panels. This model can be used for CCFL's with a starting voltage of up to 1500V. An input of 12 volts is currently available. The typical application is for two CCFL's with a voltage of 600V and current of 7mA. Up to a 14 inch LCD backlight system can be driven.

## **4.3 Standard products of the dimming control type**

The products described below are inverter units with the addition of a dimming function utilizing a current feedback method. The input voltage is wider making these products suitable for use in battery powered applications such as laptop PCs and other portable equipment. In addition, modules for large LCD backlight systems have protection circuits and alarm signal outputs so that they are suitable for industrial equipment and liquid crystal monitors which require higher reliability. All of the dimming function type models have connectors for both input and output.

### **CXA-K0505-VJL**

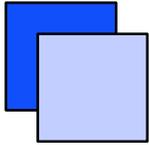
This inverter is used for driving one 2W-type CCFL and is capable of driving a color LCD panel of up to 8 inches. Three types are available depending on the type of the output connector. The input voltage range is 5 to 12V, output current is 2 to 5ma, and the dimming can be controlled by a 0 to 3V DC source.

### **CXA-L0612 Series**

This inverter is used for driving one CCFL with a maximum power of 4W and is capable of driving a color LCD panel of up to 13 inches. In addition to the three different types of output connector, two types of the output polarity are also available making the CXA-L0612 series compatible with many different LCD panels. This makes a total of six types that are commercially available. The input range is from 10 to 15V, the output current is 2 to 6ma, and they can be used for CCFL's with a voltage up to 600V or even higher. Therefore, this series can drive most of the popular LCD panels that use one lamp. The dimming control method is the same as that of the **CXA-K0512 series**.

### **CXA-0190 (CXA-M1112-VJ)**

This model was developed for industrial display equipment and LCD panels of up to 14 inches with two CCFL's. It can support a wide input voltage of 8 to 20V. Where high reliability is a requirement, features such as a thermal fuse and an alarm function to indicate when the CCFL's are approaching the end of life are desired. Both of these features are included with this model. This model can support two CCFL's with a voltage of 600V and a current of 5.5ma. This unit provides a maximum of 7W. In addition, a cost reduced version that has a narrower input voltage of 12V±20% with the same dimensions, **CXA-0217 (CXA-P1212-VJL)**, will be commercially available shortly.



## DC/ AC Inverter Unit for Liquid Crystal Display (LCD) Panel

### CXA-K0612 series

This is a new product currently under development. The shape is a narrow, 12 mm width, inverter in which TDK's ferrite technologies are utilized. The transformer is an 11mm wide slim transformer that can drive a CCFL with a maximum open voltage of 1300V and power levels of up to 3W. This transformer has a special structure that uses a U shape core. Though it's only 11mm in width, the cross section of the core is large, to keep the efficiency high as well as making the output current similar to the trapezoidal wave as shown in figure 10. Because of these features, it has about 10% higher intensity for the same CCFL current compared with the conventional products.

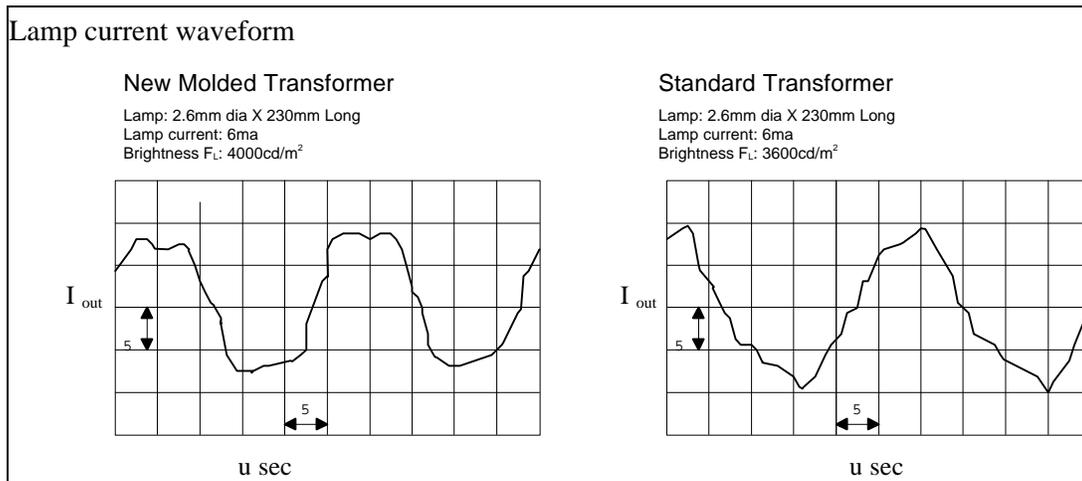


Figure 10

### 4.3 Components used in the inverter

TDK's manufactured inductors and capacitors, used in the design and manufacture of these inverters, are briefly explained.

#### Inductors

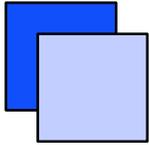
Due to the good DC superimpose characteristics and low DC resistance, the TDK SLF series of surface mount, SMD, style coils are suitable not only for the input of the inverter resonant circuit but also for use as the coil of the ordinary step down DC-DC converter.

#### Capacitors

When using a closed magnetic path transformer, a smaller high voltage circuit with higher reliability can be constructed by using a SMD high voltage capacitor such as a the TDK radial shape CC45 type or C4520 type.

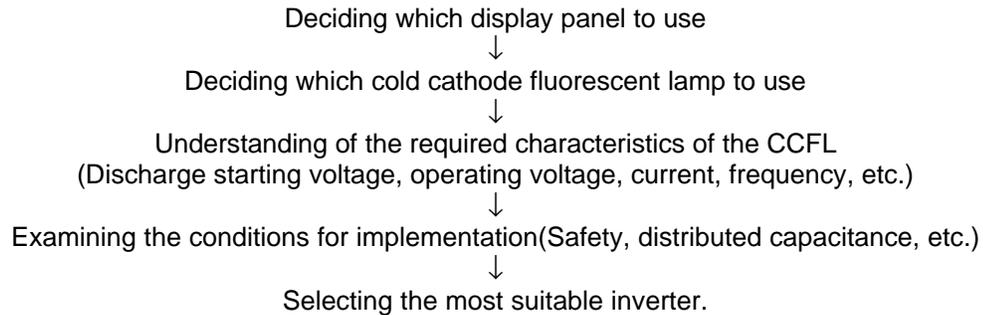
In addition to setting the brightness control frequency and phase compensation of the control IC, multilayer capacitors with capacitance's higher than 1 $\mu$ F are used for filtering the input of the switching circuit.

Use of these TDK components allows further miniaturization and the ability to achieve a higher reliability CCFL inverter.



### 5.0 Summary

A broad outline of the previous explanation regarding the use and selection of the inverters follows:



Due to better image quality, larger size, and lower price, toward the year 2000 LCD panels will become more widely used. Color displays are common now, and CCFL's that can emit a white light will be the mainstream of the LCD backlight. Thus, high efficient inverters will be indispensable as their power supply.

The basics of the CCFL and the inverter are explained in this issue. When new technologies and new components are developed, a clear definition of the application as well as the component selection for selecting and designing the best inverter will be increasingly important in order to aim for a smaller size and higher efficiency.

TDK is designing the best inverters for typical LCD panels. Please feel contact us with your questions regarding our line of standard or custom inverters, or the components we use.