EEFL-Backlight Technology
(End-Cap Type External Electrode Fluorescent Lamp)

KDT m&s Co., Ltd., Korea
Basic Characteristics of CCFL & EEFL

I–V Characteristics

19” Lamp (2.6 mm / 393 mm)
Basic Characteristics

- Multi-CCFLs

  - Co : Ballast Capacitor for the Uniformity

- Multi-EEFLs

  - Good Uniformity
Key Issues:

1\textsuperscript{st}. Switching Inverter generating \textbf{AC-Square Pulses}

2\textsuperscript{nd}. Driving Methods of \textbf{Self-Discharge Synchronizing}

3\textsuperscript{rd}. New External Electrode Formation Scheme
   : \textbf{Metal-Glass Melt-Bonding Technology} provides
   High Capacitance
**Lamp Operation**

**CCFL (LC-Resonance Inverter)**

- V-I Phase Synchronized (Zero Crossing)

![Diagram of CCFL](image)

**EEFL (Switching Inverter)**

- Self-Discharge Synchronized for high Efficiency

(i) Rising Voltage

![Diagram of EEFL Rising Voltage](image)

(ii) Sustaining Voltage

![Diagram of EEFL Sustaining Voltage](image)

(iii) Falling Voltage

![Diagram of EEFL Falling Voltage](image)
Switching Inverter

- Full-Bridge Circuit
- Half-Bridge Circuit
- Push-Pull Circuit
- ASStable Multi-Vibrator
EEFL Driven by a Switching Inverter

- 19” Lamp

- EEFL (Switching Inverter)

![Graph showing brightness vs. power for EEFL and CCFL inverter configurations. The graph includes three axes: Voltage (2kV/Div.), Current (100mA/Div.), and Optical Signal. The inverter Duty cycle is 50%.]

EEFL (Switching Inverter)

CCFL (LC-Resonance Inverter)

EEFL (LC-Resonance Inverter)
EEFL Driven by a Switching Inverter

- **Duty = 24%**
  - i) Voltage (2kV/Div.)
  - ii) Current (100mA/Div.)
  - iii) Optical Signal
  - 25 µs (40 kHz)
  - Vp
  - 6 µs
  - 12.5 µs

- **Duty = 40%**
  - i) Voltage (2kV/Div.)
  - ii) Current (100mA/Div.)
  - iii) Optical Signal
  - 25 µs (40 kHz)
  - Vp
  - 10 µs

- **Ch1 2.00kV  Ch2 100mA  Ch3 200mV**
- **Main Discharge**
- **Self Discharge**

**Confidential**
EEFL Driven by a Switching Inverter

a) Rising Voltage

Main-discharge Current

b) Sustaining Voltage

Wall charge $V_w$

Self-discharge Synchronizing Point

Current (Synchronize)

Delayed

Over Current

c) Falling Voltage

Self-discharge Current

Current (Delayed)
Self-Discharge Synchronized Wave Formulas

a) Rounded Wave

b) Over-Shot

c) Sloped

d) Sawtooth
EEFL Electrode Structure

- Optimum Electrode Length

![Graph showing the relationship between electrode length and brightness and power. The graph includes lines for different electrode lengths: 1cm, 1.5cm, 2cm, 2.5cm, 3cm, and 3.5cm. The x-axis represents power in watts, the y-axis represents brightness in cd/m². The graph shows an increase in brightness with an increase in power. At each electrode length, there is an optimum brightness point. The lamp length is 375mm.]

Lamp length : 375mm
EEFL Electrode Structure

Electrode Formation Methods
1) Metal Cap (Copper Cap)
2) Metal Foil Taping
3) Metal Plating
4) Metal–Glass Melt-Bonding
EEFL Electrode Structure

- Ag melt-bonding
- Al melt-bonding
- Al-taping
- Cu-taping

**Brightness [cd/m²]**

**Efficiency [lm/W]**

**Power [W]**

**EEFL (Ag melt-bonding)**

**conventional CCFL**

Bonding

Taping
Metal–Glass Melt–Bonding Technology

- **Metal–taping**
  (Low Capacitance)

- **Metal–glass melt–bonding**
  (High Capacitance)
Various EEFL-Lamps

- Color EEFL Lamps
Various EEFL-Lamps
Various EEFL-Lamps

- Lengths: 450 mm, 393 mm, 355 mm, 314 mm, 291 mm, 1000 mm
EEFL–Edge Lighting  Backlight

1) Elongated Bottom Electrode

2) Bended Electrode

Dead Zone (~0.8cm)
EEFL–Backlight (Edge–Lighting)

17” Panel

19” Panel

Reflector

Full-Bridge Switching Inverter

Multi-Vibrator Switching Inverter

(12 * 3 * 1) (cm)

(15 * 3 * 1) (cm)
## EEFL–Direct Lighting Backlight

<table>
<thead>
<tr>
<th>Type 1: Electrodeless Lamps</th>
<th>Type 2: Elongated EEFLs</th>
<th>Type 3: Bended EEFLs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrodeless Lamp</strong></td>
<td><strong>Elongated</strong></td>
<td></td>
</tr>
<tr>
<td>Lamp Hole</td>
<td>Lamp Hole</td>
<td>Lamp Hole</td>
</tr>
<tr>
<td>Lamp Connector</td>
<td>Lamp Connector</td>
<td>Lamp Connector</td>
</tr>
<tr>
<td>(Conductive Lubber Inside Hole)</td>
<td>(Copper Inside Hole)</td>
<td>(Copper Inside hole)</td>
</tr>
</tbody>
</table>

- Simple Connection
- Low Efficiency ~50 lm/W
- Narrow Dead Zone
- High Efficiency ~60 lm/W
- Narrow Dead Zone
- High Efficiency ~60 lm/W
EEFL–Backlight (Direct–Lighting)

20.1" Panel

Diffusion Plate Opened

(12 * 3 * 1) (cm)

(9.5 * 4.8 * 1) (cm)
EEFL–Backlight (Direct–Lighting)

Full bridge Switching Inverter

- 12 EEFLs
  - i) Voltage (2kV/Div.)
  - ii) Current (100mA/Div.)
  - iii) Optical Signal

(12 * 3 * 1) (cm)

Multi-Vibrator Switching Inverter

- 12 EEFLs
  - i) Voltage (2kV/Div.)
  - ii) Current (40mA/Div.)
  - iii) Optical Signal

(15 * 3 * 1) (cm)
EEFL-Backlight (Direct-Lighting)

Cu-Taping Electrode

17 Inch panel

Efficiency [lm/W]

Frequency [kHz]

Brightness [cd/m²]

20 Inch panel

Efficiency [lm/W]

Frequency [kHz]

Brightness [cd/m²]
EEFL-Backlight (Direct Lighting)

20.1 Inch (Input: 12V) : Metal-Bonding Electrode

Graphs showing input voltage and current, efficiency, brightness, and power [W/M²] vs. power [W].
EEFL-Backlight (Direct-Lighting)

20.1 Inch (Input: 24 V): Metal-Bonding Electrode
17 Inch (Input : 12V) : Metal-Bonding Electrode

Input Current [A]

Input Voltage [V]

Brightness [cd/m^2]

Power [W]

Efficiency [lm/W]

12V

14000

12000

10000

8000

6000

4000

20 30 40 50 60

58 60 62 64 66 68 70 72 74

Efficiency

Brightness
## EEFL–Backlight specification

- Metal Bonding External Electrode

<table>
<thead>
<tr>
<th></th>
<th>Conventional Edge-Lighting</th>
<th>Direct Lighting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>panel</strong></td>
<td>17 inch 38.4<em>28</em>2(cm)</td>
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</tr>
<tr>
<td><strong>Tubes</strong></td>
<td>4- lamps</td>
<td>12 - lamps</td>
</tr>
<tr>
<td><strong>Inverter size</strong></td>
<td>LC-Resonance 16<em>4.5</em>1 (cm)</td>
<td>Full Bridge 12<em>2.8</em>1(cm)</td>
</tr>
<tr>
<td><strong>Input</strong></td>
<td>12V/ 1.7A</td>
<td>12V/ 3.61A</td>
</tr>
<tr>
<td><strong>Input Power</strong></td>
<td>20 W</td>
<td>43 W</td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td>50 KHz</td>
<td>56 KHz</td>
</tr>
<tr>
<td><strong>Brightness</strong></td>
<td>3,500 cd/m²</td>
<td>11,000 cd/m²</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>50 lm/W</td>
<td>70 lm/W</td>
</tr>
</tbody>
</table>
A large Area Backlight about 40 inch in diagonal

Phase Synchronized Gate Signal Generator

A Section
B Section
C Section
Multi-CCFLs Driven by a Switching Inverter

- Self Discharge Synchronizing provides a high Efficiency

Co

a) Rising Voltage : Charging Capacitor

\[ V_C \quad Q = C_o V_c \]

\[ V_{r-v_c} \]

b) Rising & Sustaining : Main discharge ( \( V_r - V_c \geq V_f \) )

\[ Q = C_o V_p \]

Main-discharge Current

\[ V_p \]

c) Falling Voltage : Charging Lamp

\[ V_p \rightarrow 0 \]

\[ Q/C_f = V_f \]

d) Falling Voltage ( \( V_f \geq V_f \) ) : Self-discharge

\[ V_p \rightarrow 0 \]

Self-discharge current

- Co : Synchronizing Capacitor for the Uniformity
Multi-CCFLs Driven by a Switching Inverter

- Self-discharge in Multi-CCFLs with an optimum Ballast Capacitor

(a) $C_o = 47 \text{ pF}$  (Without Self-discharge)

(b) $C_o = 18 \text{ pF}$  (With Self-discharge)
CCFL Backlight (Direct-Lighting)

1) Full bridge Switching Inverter

- 12 – CCFLs : 17 inch Panel

- i) Voltage (2kV/Div.)
- ii) Current (100mA/Div.)
- iii) Optical Signal

2) Multi-Vibrator Switching Inverter

- 12 – CCFLs : 17 inch Panel

- i) Voltage (2kV/Div.)
- ii) Current (40mA/Div.)
- iii) Optical Signal
Conclusions

1. High Brightness & High Efficiency EEFLs;
   - External Electrode Formulated by Metal-Glass Melt-Bonding
   - A Self-Discharge Synchronizing Operation
   - By a Switching Inverter

2. Edge-Lighting EEFLs-Backlight Panels;
   - A good Uniformity obtained with single Transformer
     on a single Stage Inverter.

3. Direct-Light EEFLs-Backlight Panels of 17 & 20.1 inch in Diagonal
   - High Luminance of 7,000 ~ 10,000 cd/m²
   - High Efficiency of 70 ~ 80 lm/w
     (With single Transformer on a single Stage Inverter.)
EEFL-Backlight & Switching Inverter promise a new generation of LCD Backlight & Operation

- Low Power consumption
- Long Life Time
- High Brightness Backlight Up to ~ 10,000 cd/m²
- High Efficiency Up to ~ 70 lm/W
- Application to a Large Size Backlight Up to 1m×1m inch LCD
- Low Cost
- Simple Assembly

< Ref from Presentation at SID’02 Boston by KDT >