SUMMARY This paper proposes a backlight module which drives multiple cold-cathode fluorescent lamps (CCFLs) with a current mirror technique to equalize the driving current for each lamp. We first adopt a half-bridge parallel-resonant inverter as the main circuit and use a single-input, multiple-output transformer to drive the multi-CCFLs. Next, we introduce current-mirror circuits to create a new current-sharing circuit, in which its current reference node and the parallel-connected multi-load nodes are used to accurately equalize all CCFLs’ driving current. This will balance each lamp’s brightness and, consequently, improve the picture display quality of the related liquid crystal display (LCD). This paper details the design concept for each component value with the assistance of an actual design example. The results of the example are examined with its actual measurements, which consequently verify the correctness of the proposed control strategy.

key words: backlight, current mirror, CCFL, liquid crystal display, half-bridge, parallel-resonant inverter, bipolar junction transistor, PFC

1. Introduction

Being a key component in the lighting source, the backlight module usually determines the reliability and the stability of the lamp(s), which in turn will directly influence the LCD’s display uniformity and quality [1], [2]. Due to the rapid technical development for larger-size LCD panels, the single-lamp backlight module adopted in the past has not been able to provide enough backlighting. Multi-lamp backlight modules hence are in demand.

To build a multi-lamp driver, the lamps can be connected in series to reduce the number of components. However, the start-up voltage then will have to be raised relatively higher, resulting in a detrimental effect in the lamps’ life span [3]. Such lamp connection method thus is not popular.

As the number of backlight-module lamps increases, how to balance each CCFL’s driving current to maintain the display uniformity, namely to maintain the current differences among lamps within a reasonable ±5% (or ±0.3 mA) range, has become the R&D focal point in the panel display industry [4], [5]. Some researchers adopt impedance matching theory to build a balance controller to equalize each CCFL’s driving current. This proposed system’s main circuit comprises the DC input source, V_DC, the voltage-dividing capacitors, C1 and C2, the switches S1 and S2, the resonant inductor L_r, the resonant capacitor C_r, a single-input, four-output step-up transformer T1, the stabilizing capacitors C_B1 through C_B4 and the half-bridge resonant inverter composed by CCFL1 through CCFL4. In the current-sharing circuit, each CCFL is separately connected to a current-mirror circuit made by a BJT to achieve the equal sharing for the multi-lamp driving current.

As an example for better explanation in this paper, a circuit shown in Fig. 1(a) is used to drive a four-CCFLs’ half-bridge parallel-resonant inverter, where the current-sharing circuit composed by current-mirror circuits is applied to equalize each lamp’s driving current. This proposed system’s main circuit comprises the DC input source, V_DC, the voltage-dividing capacitors, C1 and C2, the switches S1 and S2, the resonant inductor L_r, the resonant capacitor C_r, a single-input, four-output step-up transformer T1, the stabilizing capacitors C_B1 through C_B4 and the half-bridge resonant inverter composed by CCFL1 through CCFL4. In the current-sharing circuit, each CCFL is separately connected to a current-mirror circuit made by a BJT to achieve the equal sharing for the multi-lamp driving current.

Some other researchers adopt common-mode chokes between the CCFLs to balance the current flowing through each CCFL [5]. The structure of the common-mode choke is similar to the structure of a transformer with two same windings resulting that each CCFL provides same amount of luminance. However, the weight and volume of magnetic components will increase proportionally with the number of lamps. When applied in larger-size LCDs where the number of the lamps will be greater, said current-equalizer becomes rather bulky, which is unfavorable to the desired thinness of the larger-size LCDs.

To meet the desired trend of thinness and to improve the above-mentioned shortcomings, this paper proposes a current-sharing circuit based on current-mirror circuits for the multi-CCFLs to effectively equalize the driving current to the lamps. The proposed CCFLs’ driving circuit is simpler than other multi-lamp current-sharing circuits already published and can be laid in an IC with ease to reduce the system dimension and to increase the overall efficiency.

2. The Analysis of the Main Circuit

As an example for better explanation in this paper, a circuit shown in Fig. 1(a) is used to drive a four-CCFLs’ half-bridge parallel-resonant inverter, where the current-sharing circuit composed by current-mirror circuits is applied to equalize each lamp’s driving current. This proposed system’s main circuit comprises the DC input source, V_DC, the voltage-dividing capacitors, C1 and C2, the switches S1 and S2, the resonant inductor L_r, the resonant capacitor C_r, a single-input, four-output step-up transformer T1, the stabilizing capacitors C_B1 through C_B4 and the half-bridge resonant inverter composed by CCFL1 through CCFL4. In the current-sharing circuit, each CCFL is separately connected to a current-mirror circuit made by a BJT to achieve the equal sharing for the multi-lamp driving current.

The steady-state equivalent circuit of Fig. 1(a) is shown in Fig. 1(b), where the primary-side input source, v_s, resonant inductor, L_r, resonant capacitor, C_r, and the magnetizing inductance of T1, L_m, after being reflected to the transformer’s secondary side and combined with C_B1 through C_B4 and CCFL1 through CCFL4 will constitute a resonant tank [8]. Since the lamp in the transformer’s secondary side can be treated like an impedance under steady state, we thus use R1 through R4 to replace the four CCFLs. The circuit in Fig. 1(b) can be further simplified into a regular parallel-connected resonant circuit as shown in Fig. 1(c), in which
the inverter’s resonant frequency \( f_r \) is written as

\[
 f_r = \frac{1}{2\pi \sqrt{LC}} 
\]

where

\[
 L = N^2 \left( \frac{L_m L_r}{L_m + L_r} \right) 
\]

\[
 C = \frac{C_B}{N^2} + MC_p 
\]

\[
 C_B = C_{B1} = C_{B2} = C_{B3} = C_{B4} 
\]

\[
 R_t = R_{t1} = R_{t2} = R_{t3} = R_{t4} 
\]

\[
 C_p = \frac{C_B}{\omega^2 C_B R_t^2 + 1} 
\]

\[
 R_p = \frac{R_t + \frac{1}{\omega^2 C_p R_t^2}}{M} 
\]

where \( M \) is the system’s number of CCFLs actually laid.

For a valid backlight module design, we first need to be able to start the CCFLs normally. Since a backlight circuit usually has a low-voltage input yet the CCFLs need a high voltage to start up, we hence need to insert a step-up transformer, \( T_1 \), between the main circuit and the load, and the minimum turn ratio is determined by the CCFLs’ start-up voltage, \( V_{\text{start}} \), and the lowest DC input voltage, \( V_{\text{DC,min}} \), as expressed in [9]

\[
 N = \frac{N_s}{N_p} \geq \frac{\sqrt{2} V_{\text{start},\text{rms}}}{4 V_{\text{DC,min}}} \left( \frac{\pi}{2} \right) 
\]

where \( N_p \) and \( N_s \) denote the numbers of turns in the primary and the secondary sides. The purpose for the series connection of \( C_{B1} \) to \( C_{B4} \) and CCFL1 to CCFL4, respectively, in the secondary side is to make sure that the load holds positive impedance characteristics [8]. Although under high frequency operations, inductors also can be used for lamp stabilization, rendering an even better result; capacitors are, however, preferred for their size advantage [10]. In implementation, we usually adopt a capacitive impedance greater than the CCFL’s impedance to effectively reduce the nonlinearity of the CCFLs’ dynamic negative resistance [3], [12].

On the other hand, we don’t want to excessively increase the capacitance—should the stabilization capacitance be set too high, it will increase the circuit loss.

With Fig. 1(b) and Thévenin’s Theorem, we can calculate the transfer function between the input voltage \( v_i(t) \) and the lamp’s voltage \( v(t) \); with the sinusoidal approximation, we can obtain the following equation:

\[
 \begin{align*}
 v_l(j\omega) &= \frac{NL_m}{L_r + L_m + \omega^2 L_m C_r} \\
 &= \left( \frac{J_{CB} R_t}{N^2 - \omega^2 L_C r} \right) \\
 &= \frac{J_{CB} R_t \left( N^2 - \omega^2 L_C r \right)}{N^2 - \omega^2 L (MN^2 C_B - C_r) + J_{CB} R_t \left( N^2 - \omega^2 L_C r \right)} \\
 \end{align*} 
\]

The amplitude can be expressed as

\[
 \begin{align*}
 \frac{v_l(j\omega)}{v_i(j\omega)} &= \frac{NL_m}{L_r + L_m + \omega^2 L_m C_r} \\
 &= \frac{J_{CB} R_t \left( N^2 - \omega^2 L_C r \right)}{\omega C_B R_t \left( N^2 - \omega^2 L_C r \right)} \\
 &= \frac{\sqrt{\left( N^2 - \omega^2 L (MN^2 C_B - C_r) \right)^2 + \left( \omega C_B R_t \left( N^2 - \omega^2 L_C r \right) \right)^2}}{\sqrt{N^2 - \omega^2 L (MN^2 C_B - C_r) + J_{CB} R_t \left( N^2 - \omega^2 L_C r \right)}} \\
 \end{align*} 
\]

In (10) we observe that, under steady state, the lamp voltage and the input voltage, the operation frequency, the lamp characteristics, the number of lamps \( M \), the transformer’s characteristics (the magnetizing inductance, \( L_m \), and the turn ratio, \( N \)) and the resonant tank components, including the resonant inductor, \( L_r \), and the resonant capacitor, \( C_r \), are all closely related.

3. The Small Signal Analysis for the Current-Mirror Circuit

As the number of backlight-module lamps increases, how to equalize each lamp’s driving current and to limit the current differences among the lamps within a reasonable range, i.e. \( \pm 5\% \) or \( \pm 0.3 \text{ mA}_{\text{rms}} \), has become an R&D focal point.

US Patent No. US6534934 adopts impedance matching theory to arrive a balance controller to equalize each CCFL’s current [4], as shown in Fig. 2. Said patent’s balance controller circuit mainly uses energy-storage components to reach the impedance matching goal. However, generally, it is not easy to control the components’ impedance precisely;
under lengthy continuous usage, the impedance components can detrimentally affect the current sharing result.

Next, US Patent No. US6781325B2, illustrated in Fig. 3, adopts common-mode chokes to balance the current flowing through each CCFL [5]. The structure of the common-mode choke is similar to the structure of a transformer having two same windings. Since any adjacent two CCFLs are respectively connected to the corresponding common-mode chokes, all the currents flowing through the windings are identical. However, the weight and volume of magnetic components will increase in proportion to the number of lamps. When applied to larger-size LCDs where the number of lamps will be greater, said current-equalizer becomes rather bulky, a disadvantage to the larger-size LCDs’ trend for thinness.

To improve the above-mentioned current-sharing problems, this paper proposes a multi-lamp current-sharing circuit based on current-mirror circuits to equalize the multi-CCFLs’ driving current.

In analog circuit design, the current-mirror circuit is applied to the bias-current or load components in micro-electronic circuits and, with its current reference node precisely adjusting the current of other transistors’ load nodes connected in parallel, is also used to reduce the impact on the current sharing caused by the fluctuations of the power source. The current-sharing circuit composed by the current mirror structure adopted in this paper is shown in Fig. 4(a).

Since the CCFLs are driven by sinusoidal current, we can thus analyze and verify the driving-current relations among the multiple CCFLs with a small signal equivalent model. The reference current $i_{L1}$ in the equivalent model of Fig. 4(b) is expressed as follows:

$$i_{L1} = \alpha i_{ex} + \alpha i_{e1} + i_{bx}$$  \hspace{1cm} (11)

where

$$i_{ex} = i_{b1} + i_{b2} + i_{b3} + \cdots + i_{bM}$$  \hspace{1cm} (12)

$$i_{e1} = (1 + \beta) i_{h1}$$  \hspace{1cm} (13)

$$i_{bx} = i_{ex} - \alpha i_{ex}$$  \hspace{1cm} (14)

Hence, substituting (12) to (14) into (11), we obtain

$$i_{L1} = \left[ M(i_{b1} + i_{bM}) \right] + \alpha(1 + \beta) i_{h1}$$  \hspace{1cm} (15)

Next, apply Kirchhoff’s Current Law to resolve the relations for each loop’s nodal current:

$$i_{LM} = i_{eM} - i_{hM}$$  \hspace{1cm} (16)

where

$$i_{eM} = (1 + \beta) i_{bM} - i_{bM}$$  \hspace{1cm} (17)

Substituting (17) into (16), we attain

$$i_{LM} = \beta i_{bM}$$  \hspace{1cm} (18)
Since this paper adopts the current mirror structure to equalize four CCFLs’ driving current, we hence can use (18) to analyze the relations of \(i_{t2}, i_{t3}\) and \(i_{t4}\) in the current-mirror circuit as follows:

\[
i_{t2} = \beta i_b \tag{19}
\]

\[
i_{t3} = \beta i_b \tag{20}
\]

\[
i_{t4} = \beta i_b \tag{21}
\]

Assuming \(i_b = i_b1 = i_b2 = i_b3 = i_b4\) and substituting (15) into (19) through (21), we reach

\[
i_{t1} = [M + \alpha(1 + \beta)] i_b \tag{22}
\]

\[
i_{t2} = i_{t3} = i_{t4} = \beta i_b \tag{23}
\]

Hence, we can resolve the driving-current relations among the four CCFLs from (22) and (23).

\[
\frac{i_{t2}}{i_{t1}} = \frac{i_{t3}}{i_{t1}} = \frac{i_{t4}}{i_{t1}} = \frac{1}{1 + \frac{M + \alpha}{\beta}} \tag{24}
\]

4. The Design Considerations and the Actual Measurement Results

The CCFL itself is a non-linear load, the characteristics of which are affected by some factors such as the lamp’s length, diameter or actual structure; these factors hence will influence the design of the driving circuit. In general, the closer the lamp-driving current’s waveform is to a sinusoid, i.e. with a crest factor approaching 1.414, the better; a sinusoidal current waveform not only can reduce EMI but also can increase the lamp efficiency [8]. Although other types of waveforms might provide greater brightness to the lamp, they can, however, shorten the lamp’s life span [11].

In this paper, the CCFL adopted is a Model No. FL-26388, which comes with a rated power of 5.5 W, a general operation voltage and current of 920 \(V_{\text{rms}}\) and 6 \(mA_{\text{rms}}\), respectively, and a start-up voltage of 1200 \(V_{\text{rms}}\). The general CCFL’s operation frequency is around 20–80 kHz; in this study, we set the operation frequency \(f\) at 60 kHz and the input voltage \(V_{\text{DC}}\) at 240 V (adopt the PFC’s output voltage). The most vital parameters in the adopted circuit structure are the turn ratio, \(N\), the magnetizing inductance, \(L_m\), the resonant inductor, \(L_r\), the resonant capacitor, \(C_r\), and the stabilization capacitance, \(C_B\). The design considerations are as follows:

1) Determine the transformer’s turn ratio

The turn ratio should be designed to provide just enough start-up voltage for the CCFLs to avoid the undesired insulation problem and to keep the circuit volume down. Substituting the above-mentioned \(V_{\text{start}}\) and \(V_{\text{DC,min}}\) into (8), we obtain

\[
N = \frac{N_i}{N_p} = \frac{\sqrt{2}V_{\text{start, rms}}}{\frac{4 \times V_{\text{DC,min}}}{\pi}} = \frac{\sqrt{2} \times 1200}{\frac{\pi \times 240}{2}} = 11 \tag{25}
\]

2) Determine the resonant inductor \(L_R\) and the \(C_R\)

According to (25) and adopting 15 for \(N\), which comes with \(L_m\) equal to 3 mH, \(C_p=10 \mu F\), lamp resistance \(R_t = v_t/i_t\) 153.3 k\(\Omega\), \(f\) at 60 kHz and the number of lamps, \(M\), equal to 4, we arrive the following

\[
\frac{v_t(j\omega)}{v_d(j\omega)} = \frac{920 \sqrt{2}}{4 \times \frac{240}{\pi}} = 9 \tag{26}
\]

From the conditions we set and (1), we arrive

\[
f = \frac{1}{2\pi \sqrt{\frac{L_mL_r}{L_m + L_r} \frac{C_t}{N^2 + 4C_p}}} = 60 \text{ kHz} \tag{27}
\]

Substituting the known parameter values and solving the joint equations, (26) and (27), we obtain: \(L_r=1.3 \text{ mH}\) (use 1.4 mH); \(C_r=0.54 \text{ nF}\) (actually use 0.5 nF).

3) Analyzing the characteristics of the current-sharing circuit

In this paper, the four CCFLs’ driving current adopts the current-mirror circuits built with BJTs to reach current sharing. Type 2SC1815G BIT is used, where \(\alpha=0.95, \beta=200\) [13]. Substituting \(M=4\) and the preset reference driving current of CCFL1, i.e. \(i_{t1}\), in Fig. 1(a), we obtain the current sharing under three different driving current.

Case 1. \(i_{t1} = 6 \text{ mA}_{\text{rms}}\). Substituting \(i_{t1} = 6 \text{ mA}_{\text{rms}}\) into (24), we arrive: \(i_{t2} = i_{t3} = i_{t4} \equiv 5.85 \text{ mA}_{\text{rms}}\). Hence, the difference of the driving current of CCFL2 to CCFL4 (i.e. \(i_{t2}\) to \(i_{t4}\)) and that of CCFL1 (i.e. \(i_{t1}\)) is 0.12 \(\text{mA}_{\text{rms}}\). With

\[
e = \frac{|i_{t2}|}{i_{t1}} \times 100\% \tag{28}
\]

and substituting \(i_{t1}\) at 6 \(\text{mA}_{\text{rms}}\) and \(i_{t2}\) at 0.15 \(\text{mA}_{\text{rms}}\) into (28), we obtain an percentage error of 2\%, i.e. \(e=2\%\).

Case 2. \(i_{t1} = 4 \text{ mA}_{\text{rms}}\). Substituting \(i_{t1} = 4 \text{ mA}_{\text{rms}}\) into (24), we arrive: \(i_{t2} = i_{t3} = i_{t4} \equiv 3.91 \text{ mA}_{\text{rms}}\). Hence, the difference of the driving current of CCFL2 through CCFL4 (i.e. \(i_{t2}\) through \(i_{t4}\)) and that of CCFL1 (i.e. \(i_{t1}\)) is 0.09 \(\text{mA}_{\text{rms}}\). Substituting \(i_{t1}\) at 4 \(\text{mA}_{\text{rms}}\) and \(i_{t2}\) at 0.09 \(\text{mA}_{\text{rms}}\) into (28), we obtain a percentage error of \(2\%\).

Case 3. \(i_{t1} = 2 \text{ mA}_{\text{rms}}\). Substituting \(i_{t1} = 2 \text{ mA}_{\text{rms}}\) into (24), we arrive: \(i_{t2} = i_{t3} = i_{t4} \equiv 1.95 \text{ mA}_{\text{rms}}\). Hence, the difference of the driving current of CCFL2 to CCFL4 (i.e. \(i_{t2}\) to \(i_{t4}\)) and that of CCFL1 (i.e. \(i_{t1}\)) is 0.05 \(\text{mA}_{\text{rms}}\). Substituting \(i_{t1}\) at 2 \(\text{mA}_{\text{rms}}\) and \(i_{t2}\) at 0.05 \(\text{mA}_{\text{rms}}\) into (28), we obtain a percentage error, \(e\), of \(2\%\).

Thus, the proposed current-sharing circuit displayed in Fig. 1(a) can, in theory, exert an effect in equalizing the multi-CCFLs’ driving current with differences among all the driving current all falling within \(\pm 5\% (\pm 0.3 \text{ mA}_{\text{rms}})\). Next, we will attain experimental results to verify the feasibility and the correctness of the mentioned theory.
The actually-measured waveforms of the CCFLs’ driving current prior to the insertion of the current-sharing circuit are shown in Figs. 5(a)–5(c), where ch1 through ch4 denote the measured driving current waveforms of CCFL1 through CCFL4 respectively. Figure 5(a) shows the driving current with CCFL1 operating at 6.025 mA rms; the current difference between CCFL2 and CCFL1, \(i_{ld1}\), is 0.158 mA rms. Substituting \(i_1 = 6.025\) mA rms and \(i_{ld1} = 0.158\) mA rms into (28), we obtain a percentage error of 2.6%. Next, the current difference between CCFL3 and CCFL1, \(i_{ld2}\), is 0.427 mA rms; substituting this into (28), we obtain a percentage error of 7.1%. Again, the current difference between CCFL4 and CCFL1, \(i_{ld3}\), is 0.135 mA rms; substituting this into (28), we obtain a percentage error of 2.2%.

Figure 5(b) shows the driving current with CCFL1 operating at 4.026 mA rms; the current difference between CCFL2 and CCFL1, \(i_{ld2}\), is 0.065 mA rms. Substituting them into (28), we obtain a percentage error, \(\varepsilon\), of 1.6%. Next, the current difference between CCFL3 and CCFL1, \(i_{ld3}\), is 0.916 mA rms; substituting this into (28), we obtain a percentage error of 22.8%. Again, the current difference between CCFL4 and CCFL1, \(i_{ld4}\), is 0.325 mA rms; substituting this into (28), we obtain a percentage error of 8.1%. Figure 5(c) shows the driving current with CCFL1 operating...
The preset driving current
Without the current-mirror’s driving current
With the current-mirror’s driving current

Fig. 7 The comparison of the current sharing effect for the four CCFLs’ preset driving current (a) 6 mA_{rms}, (b) 4 mA_{rms}, (c) 2 mA_{rms}.

at 2.087 mA_{rms}; the current difference between CCFL2 and CCFL1, \(i_{td}\), is 0.288 mA_{rms}. Substituting them into (28), we arrive at a percentage error of 13.8%. Next, the current difference between CCFL3 and CCFL1, \(i_{td}\), is 1.855 mA_{rms}; substituting this into (28), we obtain a percentage error of 88.9%. Again, the current difference between CCFL4 and CCFL1, \(i_{td}\), is 0.346 mA_{rms}; substituting this into (28), we obtain a percentage error of 16.6%.

The measured waveforms shown in Figs. 5(a)–5(c) indicate that the driving-current differences of the four CCFLs are far above a reasonable range of ± 5% (±0.3 mA_{rms}). Therefore, without the proposed multi-lamp current-sharing circuit, the uneven driving current in the multi-lamp backlight system will cause apparent display-uniformity problem to the related LCD.

The actual measured driving-current waveforms for CCFL1 operating at 6.050 mA_{rms}, 4.008 mA_{rms} and 2.060 mA_{rms}, with the current-sharing circuit included, are shown in Figs. 6(a)–6(c). Under any test conditions, the measured driving-current waveforms for CCFL2 through CCFL4 are all maintained within ± 5% (±0.3 mA_{rms}) among their differences.

Figures 7(a)–7(c) are the current-sharing characteristic comparisons of the four CCFLs’ driving current measured in Figs. 5(a) to 5(c) and Figs. 6(a) to 6(c). The effect of the current-sharing circuit is apparent from said comparisons. Form (28), we can verify that the added current-sharing circuit indeed can reduce the driving-current difference-range among each CCFL to far less than ± 5% (±0.3 mA_{rms}). Hence, the multi-lamp current-sharing circuit constructed by the current-mirror circuits proposed in this paper can indeed exert its effect in equalizing the multi-CCFLs’ driving current. This will balance each lamp’s brightness and, consequently, improve the display uniformity and, hence, quality of the associated liquid crystal display.

5. Conclusion

This study first adopts a half-bridge parallel-resonant inverter to drive a multi-CCFLs’ backlight module and, next, utilizes a single-input, four-output step-up transformer, merged with a current-sharing circuit, to equalize each lamp’s driving current.

The current-sharing circuit proposed in this paper is simple in structure, low in cost and easy to merge with the control circuit to be laid together into an IC to reduce the circuit’s size and the system’s physical dimension. Next, using current-mirror circuits, said current-sharing circuit can significantly enhance the multi-lamps’ current sharing. Furthermore, the CCFLs can select, without modifying the original feedback compensation circuit, any suitable gas-discharge-lamp dimming method, including the duty-cycle control, the frequency control and the burst dimming control, to fulfill the dimming function and to uplift the overall system efficiency.

This paper also provides an actual design example which renders said driving current differences, among the four lamps used, all remaining within ± 0.42% (±0.025 mA_{rms}) and thus verifies the correctness of the proposed control method.

Acknowledgments

This study is sponsored by the National Science Council (NSC) of the Executive Yuan, the Republic of China (Taiwan), under Research Proposal # NSC 93-2213-E-129-014; NSC’s financial support to this project is hereby acknowledged.

References


Chang-Hua Lin was born in Taipei, Taiwan, R.O.C., in 1964. He received his B.S., M.S. and Ph.D. degrees all in electronic engineering from National Taiwan University of Science and Technology, Taipei, Taiwan, R.O.C., in 1989, 1991, and 2000 respectively. Since 1991, he has been teaching in the Department of Electronic Engineering and then the Department of Computer and Communication Engineering, St. John’s University, Taipei, Taiwan, R.O.C. He is currently an Associate Professor as well as the Chairman of the Department of Computer and Communication Engineering. Dr. Lin has been engaged in research projects in the areas of power electronics and electronic circuit design.

John Yanhao Chen graduated from National Taipei Institute of Technology and received his M.S. and Ph.D. degrees all in electrical engineering from the University of Nebraska, Lincoln, Nebraska and the University of Pittsburgh, Pittsburgh, Pennsylvania, USA in 1978 and 1982 respectively. He was with Westinghouse R&D Center in Pittsburgh as a Senior Engineer during part of the 1980’s. He has been teaching and involved in a number of special research projects in the Department of Electrical Engineering, St. John’s University, Taipei County, Taiwan since 1993. Dr. Chen has participated and led many R&D projects since 1979.

Fuhliang Wen graduated from St. John’s & St. Mary’s Institute of Technology, Taipei County, Taiwan, majoring in Mechanical Engineering, in 1985. He received his M.S. degree in Manufacturing Technology (Automation) from Minnesota State University at Mankato, Minnesota, USA and his Ph.D. degree from National Tsing Hua University, Hsinchu, Taiwan in Engineering and System Science in 1992 and 2004 respectively. Part of his recent research interests includes the field of design, analysis and control of piezoceramic-driven ultrasonic actuators. Dr. Wen has been with the Department of Mechanical Engineering and the Graduate School of Automation and Mechatronics, St. John’s University since 1993.