DESIGN OF LOW COST LOW POWER INTEGRATED (LED) DRIVER
- **Introduction**  
  (Heba Abd Al-Moniem)

- **Boost Converter & DCM Mode**  
  (Aya Gebreel)

- **Power Stage of System**  
  (Mahmoud Nassary)

- **Control of System**  
  (Noha Ibrahim)

- **IC Design**  
  (Aya Bakr & Mahmoud Nassary)

- **Layout**  
  (Aya Gebreel & Heba Abd Al-Moniem)
Design of Low cost Low power Integrated (LED) drive

Project steps:-

Project goal is to replace a lamp with low cost low power integrated LED drive.

- Choose the lamp that will be replaced.
- Design the system of LED Drive and make it in integrated circuit
- Made the design of the IC and the layout of it.
Disadvantages of Halogen lamp

1. As with incandescent bulbs, percent of the energy used by halogen bulbs is given off as heat instead of light. So using too hot of a bulb creates a fire risk.
2. Low lifetime 3000 hour (4 months).
3. High power consuming 50w.
Advantages of led lamp

- **Energy Efficiency**
  LEDs are highly efficient. an LED circuit will approach 80% efficiency.

- **Long Life**
  Some LEDs are projected to produce a long service life of about 100,000 hours (10 years).

- **Range of Colors**
  LEDs are available in a range of colors (see above), including white light.

- **No UV Emissions/Little Infrared**
  LEDs produce no UV radiation and little heat, making them ideal for illuminating objects, such as works of art, that are sensitive to UV light.
Cont.

• Durable
  LEDs are highly rugged. They feature no filament that can be damaged due to shock and vibrations. They are subject to heat, however, and being overdriven by the power supply.

• Small Size/Design Flexibility
  A single LED is very small and produces little light overall

• SAFETY

• Improved safety may be one of the most important benefits of LED lighting. LED lights generate virtually no heat

• Lights instantly

• Can be easily dimmed
Two options are typically available for replacements

• Replace only the halogen lamp with an integrated LED lamp. In this case, the LED product—combining LED package(s), optics, thermal management, and driver—must both conform to the MR16 form factor and operate in conjunction with the transformer built in to the track head or remotely powering the low-voltage track.

• Compatibility should be carefully evaluated, and following the recommended practices provided in this fact sheet is strongly encouraged. Dimming presents an added concern; if it can be avoided, finding compatible products may be more straightforward.
Fig 1. Values less than 0.1% are considered negligible
As seen in Figure 1, from 2010 to 2012 the installed base of incandescent A-type lamps decreased from 65 percent to 55 percent, while CFLs increased from 34 percent in 2010 to 43 percent in 2012.

While nearly 20 million LED A-type lamps are installed in the U.S. this is less than one percent of the total A-type lamp installed base.
### 2010 vs. 2012

- **2010**: Halogen 99%, LED 1%
- **2012**: Halogen 90%, LED 10%

### MR16 Lamps

<table>
<thead>
<tr>
<th>Year</th>
<th>LED Installed Base Units (millions)</th>
<th>Total Energy Consumption (Source: tBtu (Site – TWh))</th>
<th>LED Energy Savings (Source: tBtu (Site – TWh))</th>
<th>Potential LED Energy Savings (Source: tBtu (Site – TWh))</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>4.8</td>
<td>70 (6.7)</td>
<td>3.7 (0.4)</td>
<td>65 (6.2)</td>
</tr>
</tbody>
</table>
### Cost Comparison between LEDs, CFLs and Incandescent light bulbs

<table>
<thead>
<tr>
<th></th>
<th>LED</th>
<th>CFL</th>
<th>Incandescent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light bulb projected lifespan</td>
<td>50,000 hour</td>
<td>10,000 hour</td>
<td>1,200 hour</td>
</tr>
<tr>
<td></td>
<td>5 years, 9 months</td>
<td>1 year, month</td>
<td>Month, 10 days</td>
</tr>
<tr>
<td>Watts per bulb (equiv. 60 watts)</td>
<td>10</td>
<td>14</td>
<td>60</td>
</tr>
<tr>
<td>Cost per bulb</td>
<td>$35.95</td>
<td>$3.95</td>
<td>$1.25</td>
</tr>
<tr>
<td>KWh of electricity used over 50,000 hours</td>
<td>300 500</td>
<td>700</td>
<td>3000</td>
</tr>
<tr>
<td>Cost of electricity (@ 0.10 per KWh)</td>
<td>$50</td>
<td>$70</td>
<td>$300</td>
</tr>
<tr>
<td>Bulbs needed for 50k hours of use</td>
<td>1</td>
<td>5</td>
<td>42</td>
</tr>
<tr>
<td>Equivalent 50k hours bulb expense</td>
<td>$35.95</td>
<td>$19.75</td>
<td>$52.50</td>
</tr>
<tr>
<td>Total cost for 50k hours</td>
<td>$85.75</td>
<td>$89.75</td>
<td>$352.50</td>
</tr>
</tbody>
</table>
Applications of LED

- LED backlighting in large LCD panels; LCD-TV and notebooks
- General lighting and illumination
- Automotive lighting
- Flashlights
- Freezer Case LED Lighting
- Status lights on electronic devices of all kinds
- Decorative lighting strings (both indoor and outdoor)
- Traffic lights
- Outdoor lighting fixtures for parking lots, streets, and parks
- Retail display lighting
- Home lighting applications such as recessed down-lights and under-cabinet lights
XLamp XP-G LED lamp

- The Lampe choose:-

From Cree company

Fig 2. XLamp XP-G LED lamp
Specification

- Available in white, outdoor white and 80-CRI, 85-CRI and -CRIwhite
- ANSI-compatible chromaticity bins
- Maximum drive current: 1500 mA
- Low thermal resistance: 4 °C/W
- Wide viewing angle: 125°
- Unlimited floor life at ≤ 30 °C/85% RH
- Electrically neutral thermal path
- RoHS- and Reach-compliant
- UL-recognized component(E349212)
- Efficiency 102lum/watte
- 367 lumens
Fig 3. Block Diagram of System
**Boost converter**

- As the LED lamps are not operate from AC input power supply directly. Therefore, an AC/DC converter is needed to drive the LED lamp.
- We choose the boost converter. A boost converter (step-up converter) is a **AC-to-DC** power converter with an output voltage greater than its input voltage.
Fig 4. Boost converter

Fig 5. Operation modes of boost
Advantages of Boost Converter

• The converter can easily be designed to operate at efficiencies greater than %.

• Both the MOSFET and LED string are connected to a common ground. This simplifies sensing of the LED current, unlike the buck converter where we have to choose either a high side MOSFET driver or a high side current sensor.
DCM mode

- In this project the boost converter is operate in DCM (Discontinuous conduction mode) because a converter behaves as resistor emulator where the line current naturally follows the line voltage and provides a high power factor that near to one.

Fig6. DCM Mode
DCM Advantages

• Near unity power factor and using constant switching frequency
• Simple PWM control and only one control loop is needed
• Cheap and easy to implement.
System Design

Fig 7. Block Diagram of System
System design

Fig 8. System with feedback
Closed loop output in nominal value

<table>
<thead>
<tr>
<th>signal</th>
<th>Max</th>
<th>Min</th>
<th>Mean</th>
<th>Ripple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inductor current (A)</td>
<td>1.86</td>
<td>0</td>
<td>0.33</td>
<td>1.86</td>
</tr>
<tr>
<td>Iout (A)</td>
<td>0.22</td>
<td>0.19</td>
<td>0.21</td>
<td>0.02</td>
</tr>
<tr>
<td>Vout (V)</td>
<td>12.11</td>
<td>10.65</td>
<td>11.54</td>
<td>1.45</td>
</tr>
</tbody>
</table>
When make variation -20% in vin (vin=6.78 VPTP)

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<tr>
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<td>0.35</td>
</tr>
<tr>
<td>Iout (A)</td>
<td>0.22</td>
<td>0.192</td>
<td>0.20</td>
</tr>
<tr>
<td>Vout (V)</td>
<td>12.43</td>
<td>10.583</td>
<td>11.539</td>
</tr>
</tbody>
</table>
When make variation +20% in vin (vin= 10.182 VPTP)

<table>
<thead>
<tr>
<th>signal</th>
<th>Max</th>
<th>Min</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inductor current (A)</td>
<td>0.22</td>
<td>0</td>
<td>0.295</td>
</tr>
<tr>
<td>Iout (A)</td>
<td>0.228</td>
<td>0.1893</td>
<td>0.209</td>
</tr>
<tr>
<td>Vout (V)</td>
<td>12.54</td>
<td>10.40</td>
<td>11.539</td>
</tr>
</tbody>
</table>
## System output comparison

<table>
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<td>Vout (V)</td>
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<td>1.45</td>
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</tbody>
</table>

### Nominal value

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</tbody>
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### Variation -20% in Vin

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</tr>
<tr>
<td>Iout (A)</td>
<td>0.228</td>
<td>0.1893</td>
<td>0.209</td>
</tr>
<tr>
<td>Vout (V)</td>
<td>26</td>
<td>10.40</td>
<td>11.539</td>
</tr>
</tbody>
</table>

### Variation +20% in Vin
Why controller?

Our System consists of two stage

- Power stage circuit
- Control circuit

The Control circuit avoid

- The change in output voltage
- Characteristics of led

The out of control circuit is the input to power stage
Control circuit consist of

- Pi control
- Comparator

Control types

- P (proportional control)
- PI (proportional with integral control)
- PID (proportional-integral-derivative control)
Comparison between types of controller

- **P** control
  - The most easy in implementation
  - very simple one
  - But it can’t arrive to error equal zero
- **PI** control
  - Can arrive to zero error
  - Have overshoot
  - Take some time to arrive zero error
  - Easy and simple
- **PID** control
  - Can arrive to zero error in high speed
  - No over shoot
  - But it very hard in implementation and very complex
Choosing of PI

We can’t use P control
- Because it can’t arrive to zero error.

We choose PI control because of:
- It can arrive to zero error
- It is simple
- It is easy in implementation

We develop in PI control to get small overshoot
\[
\frac{U(s)}{E(s)} = K_P + \frac{K_I}{s}
\]

\[
\frac{U(s)}{E(s)} = -\frac{1}{sC_1 + R_2} + \frac{1}{R_1}
\]

**Fig 10. The PI Control Circuit**
PI Implementation

- Tuning PI Controllers

General approach to tuning:

1. Initially have no integral gain (TI large)
2. Increase KP until get satisfactory response
3. Start to add in integral (decreasing TI) until the steady state error is removed in satisfactory time (need to reduce KP)
Bode diagram in MATLAB
Block diagram of system

Fig 11. Block Diagram of System
Input signal to PI control
Output signal from PI control

Fig 12. Control Signal
 Comparator

- The signal which out from pi control is the input to comparator
- This signal compare with saw tooth signal to get duty cycle as feed back to power stage circuit
- Duty cycle change by change in output voltage of power stage circuit
- We use gate drive to operate MOSFET in boost converter
Pulse width modulation circuit

Fig 13. pulse width modulation circuit
Output voltage from comparator

Fig 14. Output Voltage of comparator
IC Design

- Design of:
  - Operational Amplifier
  - Current Mirror
  - Differential Amplifier
  - Oscillator
  - Gate Drive
  - Power FET
System design

Fig 8. System with feedback
Design of Operation Amplifier

• An operational amplifier, or op-amp, is a differential amplifier with very high differential-mode gain, very high input impedances, and a low output impedance (Ideal OpAmp).

Fig 15. Symbol of Operational Amplifier
Fig 16. Operational Amplifier
Design of Current Mirror

A current mirror is a circuit designed to copy a current through one active device by controlling the current in another active device of a circuit, by changing in the ratio of the width and length of the MOSFET, according to the equation:

$$ID = \frac{\mu Cox W}{2L} (Vgs - Vth)^2$$
Fig 17. Current Mirror
A differential amplifier is a type of electronic amplifier that amplifies the difference between two voltages.

\[ V_{\text{out}} = A_d (V_{\text{in}+} - V_{\text{in} -}) \]

For ideal differential amplifier.

Where \( V_{\text{in}+} \) and \( V_{\text{in} -} \) are the input voltages and \( A_d \) is the differential gain.
Differential amplifier

Fig 18. Differential Amplifier
Test of Gain

Gain vs. Frequency graph
Slew Rate of Differential Amplifier

- **Slew rate** is defined as the maximum rate of change of output voltage per unit of time and is expressed as volt per microsecond.

  \[ SR = \frac{dv}{dt} \quad (V \mu s) \]
❖ Slew Rate Test

![Graph showing Input Voltage & Output Voltage over Time](image)
Design of Operational Amplifier

Fig 16. Operational Amplifier
Test of Gain and Phase
Ramp circuit

**Fig 19.** Ramp circuit
Ramp oscillator

Fig 20. Ramp Oscillator
❖ Ramp output

MAX = 2.36 V

MIN = 373.953 mV
Gate Driver
Power FET Design

NCH_LDMLSLV3_LG
W = 20u
L = 1.4u
M = 50000

Ron = 4 mΩ
TOP Level System
Top Level Simulation Result

Inductor current
Top Level Simulation Result

Inductor current
Output current

MAX = 227.698 mA
MIN = 194.308 mA
I_{out} = 210.941 mA
Top Level Simulation Result

Output Voltage

MAX = 12.37 V  V_{out} = 11.544 V  MIN = 10.631 V
Top Level Simulation Result

Rectifier Output
Top Level Simulation Result

PI output
Top Level Simulation Result

V drain Source
Top Level Simulation Result

PWM (Gate drive output)
❖ IC Layout
IC Layout

- Converts a circuit description into a geometric description to be fabricated
- **Integrated circuits**: many transistors on one chip.
  - *Very Large Scale Integration* (VLSI): very many
- **Metal Oxide Semiconductor (MOS) transistor**
  - cheap, low-power transistors
  - Complementary: mixture of n- and p-type leads to less power

**Basic Layout Component**:
1. CMOS Transistors
2. Capacitors
3. Resistors
n-channel Transistor

Fig 21. n-channel Transistor

- Four-Terminal device:
  1. gate
  2. source
  3. drain
  4. body
n-channel Transistor Layout

Fig 22. n-channel Transistor Layout

Fig 23. n-channel Transistor
p-channel MOS Transistor

Fig 24. p-channel MOS Transistor
Fabrication Layers

Fig 25. Fabrication Layers
MOS Transistor Behavior

Fig. MOS Transistor Behavior
CMOS Transistor

Fig 27. CMOS Transistor
CMOS Transistors

- Multi Fingers

\[ w = 8 \text{ um} \]
\[ l = 0.5 \text{ um} \]
\[ n_f = 1 \]

\[ w = 2 \text{ um} \]
\[ l = 0.5 \text{ um} \]
\[ n_f = 4 \]
Resistors

• Poly Resistor Structure
Resistors

- Resistance ($\Omega$) = No. of squares * Sheet Res. ($\Omega/\square$)
- Parameters Affecting the Res. Value
  - Width
  - Length
  - Sheet resistance ($\Omega/\square$)
  - No. of fingers (Contacts)

![Fig 28. Resistor]
Matching

• Process variations during fabrication may limit accuracy and desired performance of analog circuits
• Matching between components in layout is an important issue in many designs; like current mirrors and diff. pairs

Matching Techniques:
• Common Centroid
• Inter-Digitization

Example: we match two components A(A1-A4) and B(B1-B4) and A, B are any component
Common Centroid

• Common centroid Technique: Placing components such that both components have same centroid.
• Both A and B have common center

• This Technique is used in Current Mirror
Inter-Digitization

- Inter-digitization Technique: Placing alternate components

This Technique is used in Differential Amplifier
the three basic DRC checks

Fig 29. DRC check
- Layout of IC

- Layout of:
  - NMOS & PMOS
  - Capacitor (DN-well, SP-well)
  - Resistor
  - Low Pass Filter
  - Inverter
  - Current Mirror
  - Differential Amplifier
  - Operational Amplifier
PMOS

Fig 20. p channel MOSFET

Fig 21. Layout of P channel MOSFET
Fig 22. N channel MOSFET

Fig 23. Layout of N channel MOSFET

NCH When M=2
Resistor

Fig 24. Resistor

Fig 25. Layout of Resistor
Fig. DNWELL Capacitor
Fig 27. SPWELL Capacitor
RC Circuit

Fig 28. RC Circuit

Fig 29. RC Layout
Inverter

Fig 30. Inverter Circuit

Fig 31. Inverter Layout
Ic in circuit system
Block diagram of system

Fig 37. Block Diagram of System
Block of system
System design

Fig 38. System with feedback
Current mirror
Differential Amplifier

Fig 33. Differential Amplifier
Fig 35. Operational Amplifier
Fig 36. The layout of Operational Amplifier
• Block of Ramp signals
Circuit of RS
R S latch figure 3.7
N comparator
• Layout of n comparator
P comparator
• Lay out p comparator
Charge and Discharge
The Layout of charge and Discharge
• Layout Control circuit
Practical circuit

Fig 39. Power Stage
Inductor Current

Fig 40. Inductor Current
Fig 41. Inductor Current (Zoomed)
Output Voltage

Fig 42. Output Voltage
Output Rectifier

Fig 43. Output Rectifier
Drain Source Output

Fig 44. Drain Source Output
PI Output & Output Voltage & Duty Cycle

Fig 45. PI Output Output Voltage Duty Cycle
Fig 46. PI Output & Output Voltage & Duty Cycle
PI Output & Output Voltage & Duty Cycle

Fig 47. PI Output Output Voltage Duty Cycle
Control Stage

Fig 48. Control Stage
PWM Output

Fig 49. PWM Output
PWM Output & Saw tooth Generator Output

Fig 50. PWM Output & Saw tooth Generator Output
Practical Test

Fig 51. Practical Test
END

Thank You