NOVATEK
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Data Sheet

For ***NT71391***

CABC_Application Note for B&N

Preliminary V0.1

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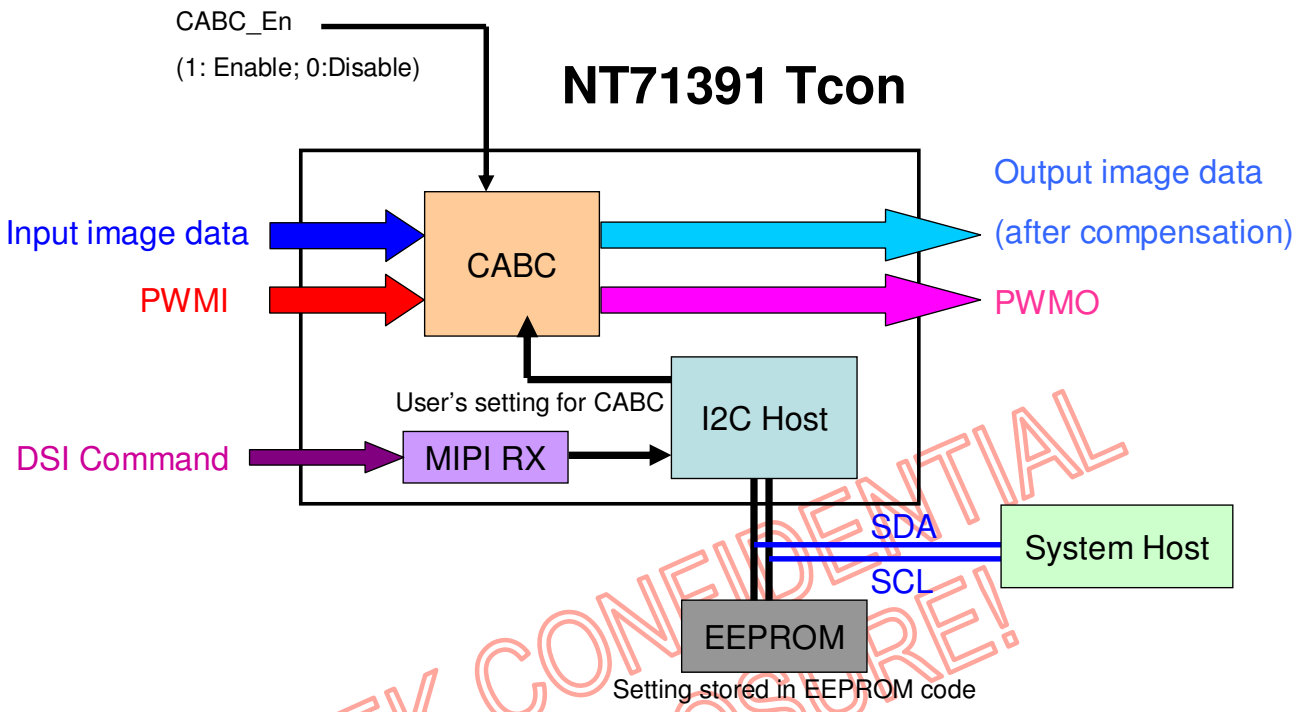
1. Revision History

Specification Revision History			
Version	**Content**	**Editor**	**Release Date**
0.1	1. Preliminary Version	Charlene Shen	2012/08/21

2. Tcon Block Diagram



1. Use hardware pin “CABC_En” to control CABC ON/OFF
   When CABC_En = 0, CABC is OFF and PWMO = PWMI.
   When CABC_En = 1, CABC is ON and the PWMO will output according to user’s setting and algorithm result.

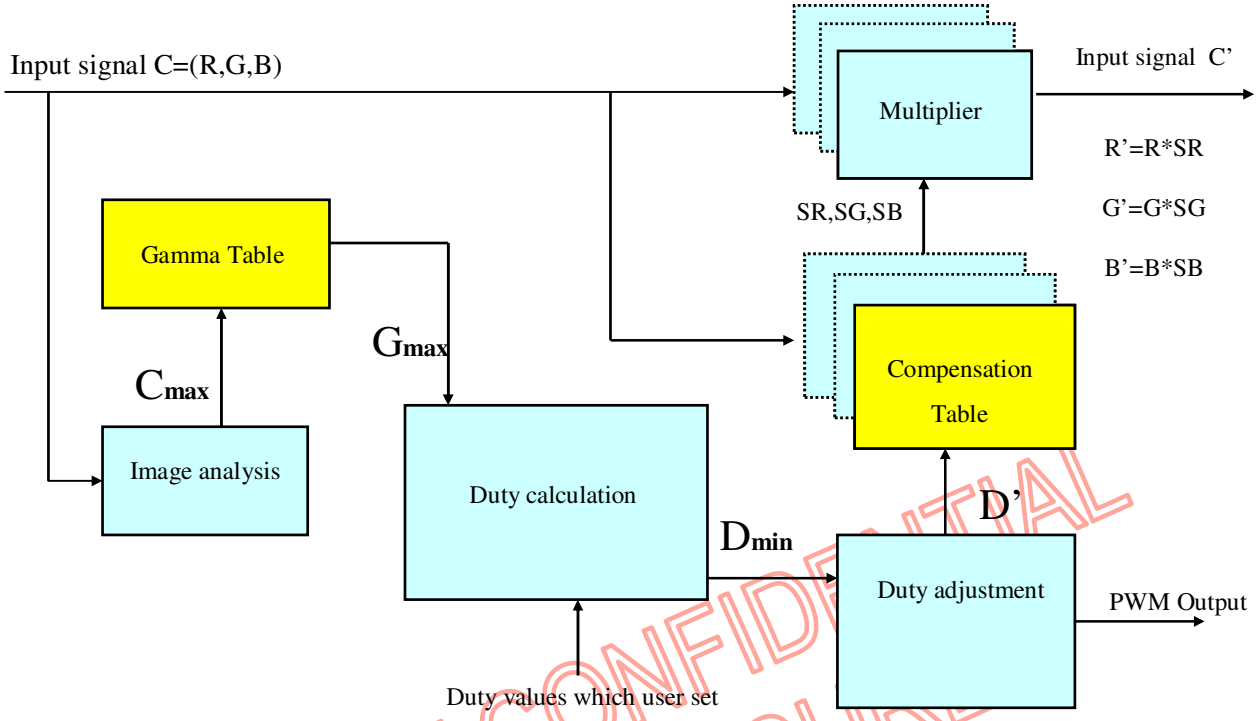
2. TCON I2C Host will download setting value stored in EEPROM for CABC in power-on period. The PWMO and image data will adjust based on these settings.

3. System Host can also control CABC ON/OFF and settings through I2C bus.
   The device address = 0xC0, and the CABC ON/OFF control register is 0x0E[3]. (1: Enable; 0: Disable)

   Please be aware that System Host can access I2C bus in any time ONLY EXCEPT the power-on download period to avoid bus arbitration.

4. If using MIPI Interface, you can also control the CABC by DSI Command.
   The register address is the same as that controlled by I2C (0x0E [3]).

3. CABC Block Diagram



Gamma Table: 0x600 ~ 0x6FF
Compensation Table: 0x700 ~ 0x7FF

(3-1). Image analysis

All image input data will be analyzed in the Block of Image Analysis.
The purpose of this block is to find out the Cmax value of input image data.

The maximum luminance (which means the largest gray level within the image data) and the average luminance (which means the average gray level of the image data) are found in this block. And then Cmax = x / 16 * the maximum luminance + (16-x) / 16 * the average luminance, where x depend on the setting of “Average_ratio”.

In addition, the “Allow_distort” is contained in the Block of Image Analysis.
And the input image data which is larger than (255-2*Allow_distort) will be mapped to (255-2*Allow_distort).

(3-2). Gamma Table

The Gamma Table is the 1st LUT of CABC Block (eg. Page6 in 24C16 EEPROM). The Gamma Table provides the reference of PWMO duty mapping in order to get the target duty. (eg. Cmax V.S. Gmax, where Cmax is the result from Image Analysis, Gmax is our target duty).

(3-3). Duty Calculation

As we get the target duty “Gmax”, we still need the calculation for final PWMO output duty. The calculation will refer to user’s setting for CABC Block.

These settings include “PWM_ref”, “PWM_set”, “PWM_min”, which lead to the result of “ PWM_min ≦ PWMO output duty ≦ PWM_set ”.

(3-4). Duty Adjustment

The purpose of Duty Adjustment is to control the PWMO duty from the current duty to target duty (which is calculated out by Block of Duty Calculation). Users can control the adjustment speed by “Adjust_step” and “Adjust_frame”.

(3-5, 3-6). Compensation Table & Multiplier

The Compensation Table is the 2nd LUT of CABC Block (eg. Page7 in 24C16 EEPROM). The Compensation Table provides the coefficient (SR, SG, and SB) of output data compensation.

The image data after the compensation will be processed in “Multiplier”, and the output data equals to“the coefficient (SR, SG, and SB) * original input data (R, G, and B)”to keep Gamma 2.2 curve.

4. CABC Register

General Setting

Address	Bit	Register Name	R/W	Description	Default
0xE0	[7]	DBCoff_bypass	R/W	**When disable DBC (DBCEN = 0), Bypass PWMI (PWMO=PWMI)** (The 2nd priority)-	0
0xEB	[6]	Bypass_pwmi	R/W	**When enable/disable DBC, Bypass PWMI (PWMO=PWMI)** (The 1st priority)	0

- Need to bypass PWMI? If users want to let PWMO=PWMI, then can set these registers, “Bypass_pwmi” is effective no matter CABC is on or off. And “DBCoff_bypass” is effective when CABC is off.

Address	Bit	Register Name	R/W	Description	Default
0xE5	[7:4]	Abrupt_threshold	R/W	When the difference of the current frame and previous frame maximum data is bigger than "Abrupt_threshold *16", PWMO will make the adjustment from duty 100% to target duty. Function turns off when Abrupt_threshold=4'hf.	4'hE
0xEA	[7:4]	Average_ratio	R/W	Set frame average ratio 0 : maximum Luminance 1 : 15/16 maximum Luminance + 1/16 average Luminance 2 : 14/16 maximum Luminance + 2/16 average Luminance 3 : 13/16 maximum Luminance + 3/16 average Luminance … 15 : 1/16 maximum Luminance + 15/16 average Luminance e.g. Average_ratio = 3, the frame average ratio will be 13/16 maximum Luminance + 3/16 average Luminance.	4'h0

- Average_ratio :
  - This register will affect the final "Target duty".
  - If set to 0: maximum Luminance, the PWMO duty will always refer to the maximum value to keep picture quality.
  - If set to other value, users can gain power consumption but sacrifice picture quality by different ratio.

PWMO Setting – Frequency

Address	Bit	Register Name	R/W	Description	Default
0xE0	[0]	en_internal_freq	R/W	Enable PWMO frequency generate by internal frequency 1: enable 0: disable (PWMO generates from PWMI)	1
0xE1	[5:4]	prd_sel	R/W	Select the base of internal generate frequency 00: vsync 01: hsync 10: 50Hz	10
0xE1	[3:0]	prd_divider[11:8]	R/W	Multiple the internal base frequency PWMO frequency = prd_sel * prd_divider e.g. When prd_sel = "10" and prd_divider = 200, PWMO Freq. = 50*200 = 10kHz	12'h008
0xE2	[7:0]	prd_divider[7:0]			

- According to the backlight characteristic.
  - If PWMO frequency is set too fast, when input pattern from gray level 0th to gray level 255th, users may see pattern flicker.
  - If PWMO frequency is set too slow, when input pattern gray level 128th, users may see pattern flicker.

Test pattern:

	
gray level 0th	gray level 255th
	
gray level 128th	

PWMO Setting – Duty

Address	Bit	Register Name	R/W	Description	Default
0xE7	[7:0]	pwm_min	R/W	Set minimum duty (lower-bound duty) of PWMO	8'h8F
0xE8	[7]	pwm_ref (PWM_max)	R/W	Decide maximum duty of PWMO 0: by pwm_set 1: by PWMI duty e.g. When pwm_ref = 0, Max duty of PWMO will be decided by pwm_set, not PWMI.	0
0xE9	[7:0]	pwm_Set	R/W	Set Maximum duty of PWMO (Effective only when pwm_ref =0)	8'hFF
0x93	[7:0]	off_dbc_set	R/W	PWMO Maximum (when CABC is OFF)	8'hFF

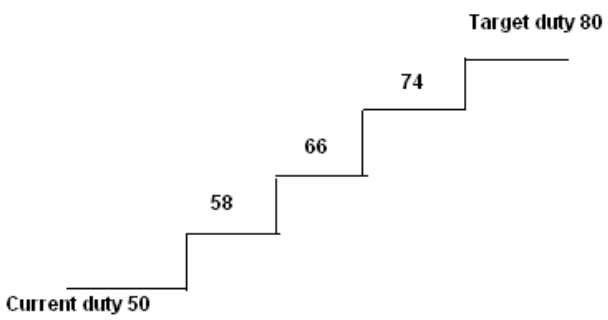
- First we should determine the minimum duty of PWMO, the suggested value is 8'h8F (minimum duty=56%).
- "pwm_ref" decides the maximum duty of PWMO, refer to "pwm_set or PWMI duty. Usually we'll set by "pwm_set", and "pwm_set"=8'FF (maximum duty=100%).
- When CABC is off, PWMO maximum duty is set by "off_dbc_set".

PWMO Setting – Adjust Speed

Address	Bit	Register Name	R/W	Description	Default
0xE6	[7:4]	Adjust_frame_rate	R/W	The number of frames keeping for each time adjustment	4'h3
	[3:0]	Adjust_step	R/W	The number of steps for each time adjustment	4'h1

- Let input pattern switch from gray level 128th to gray level 255th. We adjust "Adjust_frame_rate" & "Adjust_step" to approach to the target duty like stairs. If "Adjust_step" is set too large and "Adjust_frame_rate" is set too small, when pattern switch users may see pattern flicker.

  - For example:
    Switch input pattern from gray level 50th to gray level 80th, as 0xE6=8'h18, duty changes as 50→58→66→74→80, and each duty keeps 2 frames.



As 0xE6=8'h18, each step=8, and keeps 2 frames.

PWMO Setting – Protect

Address	Bit	Register Name	R/W	Description	Default
0xE1	[7]	en_noFreq_protect	R/W	Only when en_internal_freq=0 and PWMI duty=0% or 100% 0: PWMO frequency equals to the last PWMI frequency 1: PWMO frequency equals to internal generate frequency	0
	[6]	en_lowFreq_protect	R/W	Only when en_internal_freq=0 and PWMI frequency is smaller than internal frequency 0: PWMO frequency still use PWMI frequency 1: PWMO frequency equals to internal generate frequency	0

When PWMO frequency refers to external PWMI frequency, and when PWMI frequency is abnormal, how should PWMO react? (Defined by customer)

- en_noFreq_protect：
  - As “en_internal_freq”=0 (refer to external PWMI frequency) and “en_noFreq_protect”=0, turn off PWMI, PWMO frequency would keep the last normal PWMI frequency.
  - If “en_noFreq_protect”=1, turn off PWMI, PWMO frequency would change with internal frequency.
- en_lowFreq_protect：
  - As “en_internal_freq”=0 (refer to external PWMI frequency) and “en_lowFreq_protect”=0, if PWMI frequency< internal frequency, PWMO frequency still refer to PWMI frequency.
  - If “en_lowFreq_protect”=1, PWMI frequency< internal frequency, PWMO frequency would change with internal frequency.

Address	Bit	Register Name	R/W	Description	Default
0xE3	[7]	en_duty0_offDBC	R/W	When PWM_max duty = 0% , if enable En_duty0_offDBC, DBC will turn off (Effective only when pwm_ref = 1)	0
	[6]	en_lowduty_offDBC	R/W	When PWM_max duty is lower than pwm_min , if enable En_lowduty_offDBC, DBC will turn off (Effective only when pwm_ref = 1)	0

When PWMO maximum duty refer to PWMI, and when PWMI duty is abnormal, need to disable CABC or not? (Defined by customer)

- en_duty0_offDBC：
  - When “pwm_ref” =1(maximum PWMO duty refer to PWMI duty), and “en_duty0_offDBC”=1, when PWMI duty=0%, disable CABC.
- en_lowduty_offDBC：
  - When “pwm_ref” =1(maximum PWMO duty refer to PWMI duty), and “en_lowduty_offDBC”=1, when PWMI duty<pwm_min, disable CABC.

Address	Bit	Register Name	R/W	Description	Default
0xEC	[5]	off_cabc_en_internal_freq	R/W	Enable PWMO frequency generate by internal frequency (when CABC is OFF) 1: enable (internal frequency) 0: disable (PWMO generates from PWMI)	1

Data Process

Address	Bit	Register Name	R/W	Description	Default
0xE4	[7]	cabc_dither_enable	R/W	1: Enable CABC dither (for smooth) 0: Disable	1
	[6]	modify_rgb	R/W	Modify RGB value according to Algorithm result If modify_rgb = 0, RGB may not keep gamma 2.2	1

- cabc_dither_enable：
  Set “cabc_dither_enable”=1 will let the input image smooth.

- modify_rgb：
  Set “modify_rgb”=1, input RGB data will change with algorithm and the output RGB data will keep gamma 2.2 curve.

Guideline of CABC Adjustment

	Description	Register	Address
1.	PWMO status when CABC is off		
	When disable CABC, need to bypass PWMI or not?	DBC_off_bypass	0xE0[7]
2.	Determine the PWMO general setting		
	PWMO minimum duty?	pwm_min	0xE7[7:0]
	PWMO maximum duty?	pwm_ref	0xE8[7]
		pwm_set	0xE9[7:0]
	PWMO frequency refers to internal or external?	en_internal_freq	0xE0[0]
	When PWMO frequency refers to internal, what is the frequency?	prd_sel	0xE1[5:4]
		prd_divider	0xE1[3:0]
			0xE2[7:0]
3.	Adjust speed & Power consumption		
	If users want to adjust the “adjust speed”?	Adjust_frame_rate	0xE6[7:4]
		Adjust_step	0xE6[3:0]
	If want to gain more power consumption but may loss picture quality?	Average_ratio	0xEA[7:4]
4.	Protection of PWMO		
	As PWMO maximum duty refers to PWMI, when PWMI duty is abnormal, need to disable CABC or not?	en_duty0_offDBC	0xE3[7]
		en_lowduty_offDBC	0xE3[6]
	As PWMO frequency refers to PWMI, when PWMI frequency is abnormal, how should PWMO react?	en_noFreq_protect	0xE1[7]
		en_lowFreq_protect	0xE1[6]

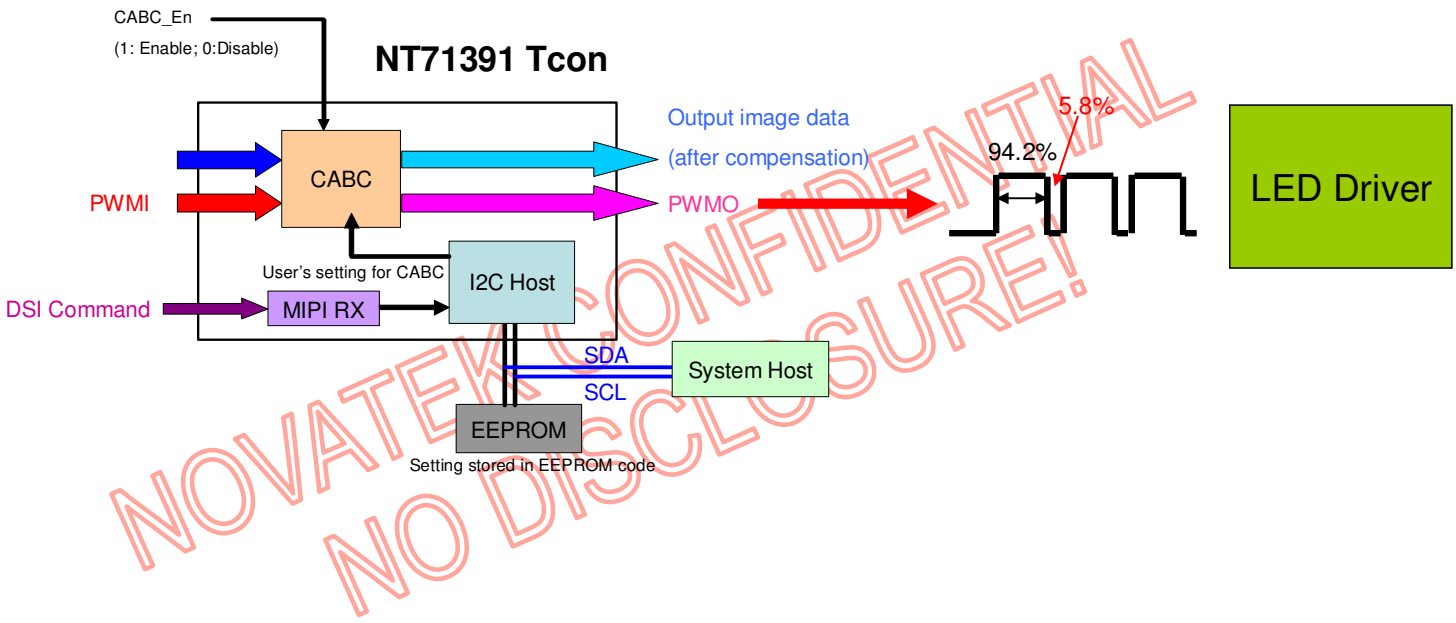
5. Example for PWMO duty calculation

a. White Pattern

Register "PWM_set" and CABC LUT_1 6xFF value can determine the PWMO duty of white pattern.

PWM_set (0xE9) = 8'hF2, and CABC LUT_1 6xFF value = 8'hFD.

So, PWMO duty = [242(F2)/255] * [253(FD)/255] = 94.2% (in white pattern)
In other words, power saving = 5.8%



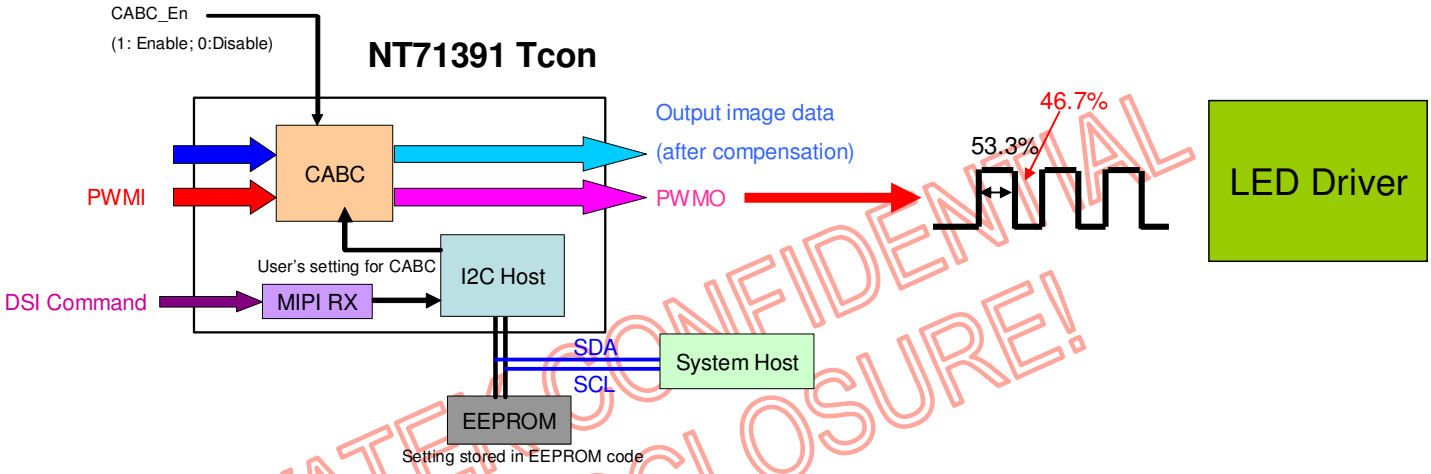
b. black pattern.

Register “PWM_min” can determine the minimum PWMO duty.

The PWMO duty will equal to “PWM_min” setting even if the algorithm result is smaller than “PWM_min”.

PWM_min (0xE7) = 8’h88.

So, PWMO duty = [136(88)/255] = 53.3% (in black pattern)
In other words, power saving = 46.7%



6. CABC algorithm

- **Formula : L = T x B = T' x B'**
  L: Luminance felt by human eyes.
  T: The current (including average and max.) of the "Y" value from input. (0~255)
  B: Back light brightness (0%~100%)
  T': The modified target "Y" (maximum 255).
  B': The modified Back Light Brightness.

- **Principle**

  Reduce the power consumption: keep the output PWM value lower than the PWM maximum.

  In order to let the luminance felt by human eyes (gamma value) be the same when CABC is ON and OFF, CABC algorithm keeps the gamma.