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SMALL SIZE OLED DISPLAY AND TFT LCD APPLICATIONS IN LOW POWER, PORTABLE MEDICAL DEVICES - POWER CONSUMPTION AND USABILITY

Modern medical devices are very complex, they must show many different kind of information, from ordinary digital values to sophisticated graphical data. Medical devices have to do it in an understandable way to avoid dangerous mistakes. There are several different ways to present the information. The most appropriate is to use display, in this case the best choice would be the color graphical display. Such kind of display allows many different data to be presented clearly and makes possibilities to create an very intuitive user friendly interface, avoiding misinformation. In portable devices this kind of data presentation is great advantage but we need to take under consideration low power consumption. Additionally, in medical portable devices very important aspects are power source operation time prediction possibility and power consumption stability. To achieve this we need to use displays which have well defined power characteristics, because in portable applications, color displays are often most power consuming parts.

1. INTRODUCTION

The most developed technology over the last few years is OLED (Organic Light Emitting Diode). OLED displays achieve outstanding contrast ratio which approach for example 10000:1. This level is hard to rich by the displays made in the other technology. Very good color representation and high contrast ratio makes this type of displays suitable for using in applications which have to present high quality data like photos or moving images from sources like camera module. All that makes them very attractive option. On the other hand TFT LCD (Thin Film Transistors Liquid Crystals Display) are still very popular.

Which technology is better for use nowadays in low power medical devices?

2. METHOD

To compare OLED and TFT displays, two parts has been selected, one of each technology. Both displays had the same diagonal size, resolution, viewing area, pixel size and comparable control interface. Displays parameter are presented in Table 1.

Table 1. OLED and TFT display parameters

Parameter			OLED DISPLAY	TFT LCD
			C0283QGLH	DEM 240320D TMH-PW-N
Diagonal size			2,83 inch	2,83 inch
Resolution			240 x 320 dots	240 x 320 dots
Brightness			200 cd/m^2	250 cd/m^2
Contrast ratio			10000/1	250/1
Operation lifetime			20000 hrs	50000 hrs
Viewing angle	Right	φ = 90°	85 Degree	45 Degree
	Left	φ = 270°	85 Degree	45 Degree
	Top	φ = 0°	85 Degree	35 Degree
	Bottom	φ = 180°	85 Degree	15 Degree
	Horizontal		170 Degree	90 Degree
	Vertical		170 Degree	50 Degree
Pixel size			0.18 x 0.18 mm	0.18 x 0.18 mm
Power consumption			0,35 W **(30% pixels ON)**	0.79 W **(Maximum backlight power)**

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To make the comparison with correspondent TFT display one may use only the measurements done with full white pattern. The other color patterns measurements in Table 2 are shown to highlight specific OLED display properties which is ability to reduce display power when only basic colors pattern is being display.

Table 2. OLED display measurements

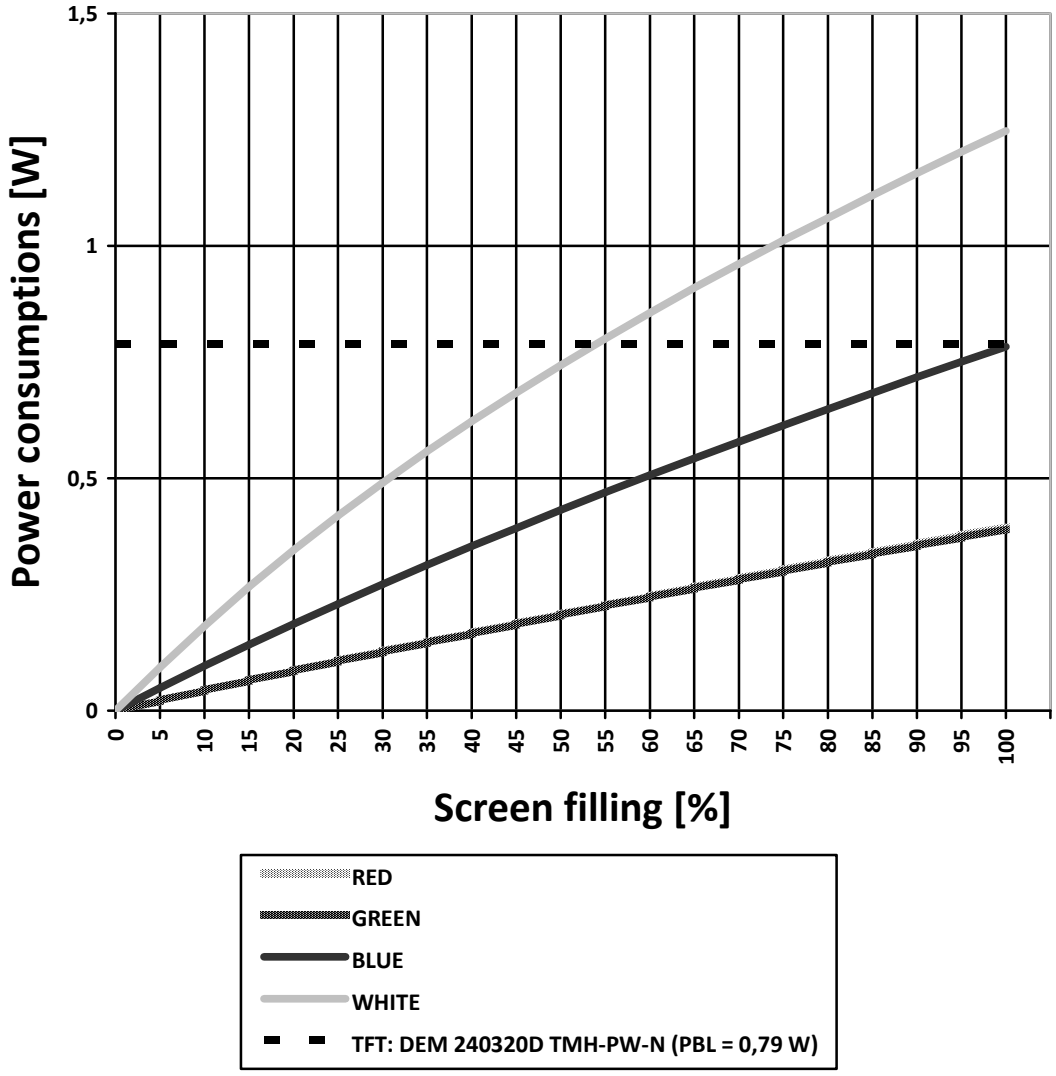
Brightness 100%												
Screen filling	Power consumptions											
	Red			Green			Blue			White		
Display area [%]	I(+4.6V) [mA]	I(-4.4V) [mA]	P_{tot} [W]	I(+4.6V) [mA]	I(-4.4V) [mA]	P_{tot} [W]	I(+4.6V) [mA]	I(-4.4V) [mA]	P_{tot} [W]	I(+4.6V) [mA]	I(-4.4V) [mA]	P_{tot} [W]
0	0	0	0	0	0	0	0	0	0	0	0	0
5	2,4	2,4	0,022	2,4	2,4	0,022	5,4	5,4	0,049	10,3	10,3	0,093
10	4,8	4,8	0,043	4,8	4,8	0,043	10,7	10,7	0,096	20,2	20,2	0,182
15	7,2	7,2	0,065	7,2	7,2	0,065	15,8	15,8	0,142	29,6	29,6	0,266
20	9,6	9,6	0,086	9,5	9,5	0,085	20,7	20,7	0,186	38,4	38,4	0,346
25	11,9	11,9	0,107	11,8	11,8	0,106	25,5	25,5	0,229	46,6	46,6	0,419
30	14,2	14,2	0,128	14,0	14,0	0,126	30,2	30,2	0,272	54,5	54,5	0,491
35	16,4	16,4	0,148	16,2	16,2	0,146	34,8	34,8	0,313	62,0	62,0	0,558
40	18,6	18,6	0,167	18,4	18,4	0,166	39,3	39,3	0,354	69,2	69,2	0,623
45	20,8	20,8	0,187	20,6	20,6	0,185	43,6	43,6	0,392	76,0	76,0	0,684
50	23,0	23,0	0,207	22,8	22,8	0,205	48,0	48,0	0,432	82,6	82,6	0,743
55	25,2	25,2	0,227	25,0	25,0	0,225	52,2	52,2	0,470	88,9	88,9	0,800
60	27,3	27,3	0,246	27,1	27,1	0,244	56,3	56,3	0,507	95,1	95,1	0,856
65	29,5	29,5	0,265	29,2	29,2	0,263	60,3	60,3	0,543	101,1	101,1	0,910
70	31,6	31,6	0,284	31,3	31,3	0,282	64,3	64,3	0,579	106,8	106,8	0,961
75	33,7	33,7	0,303	33,3	33,3	0,300	68,2	68,2	0,614	112,4	112,4	1,012
80	35,8	35,8	0,322	35,4	35,4	0,319	72,1	72,1	0,649	117,8	117,8	1,060
85	37,8	37,8	0,340	37,4	37,4	0,337	75,9	75,9	0,683	123,2	123,2	1,109
90	39,9	39,9	0,359	39,4	39,4	0,355	79,7	79,7	0,717	128,5	128,5	1,156
95	41,9	41,9	0,377	41,4	41,4	0,373	83,4	83,4	0,751	133,6	133,6	1,202
100	43,9	43,9	0,395	43,4	43,4	0,391	87,0	87,0	0,783	138,6	138,6	1,247

For proper operation OLED display needs four supply voltages: logic part, input-output, OLED matrix positive and OLED matrix negative. P_{tot} in the Table 2 is a sum of OLED matrix positive and negative voltages power consumption. OLED matrix positive voltage is 4.6 V, negative voltage is -4.4 V.

For proper operation TFT display needs three voltages: logic part, input-output and backlight. TFT backlight contains four white LED with forward current I_f = 60 mA and typical forward voltage U_f = 3.3 V. Overall backlight power consumptions is $P_{BT} = 4(U_f \cdot I_f)$ which is near to 0.79 W. This value is independent from displaying content.

Logic and I/O operating voltage are the same in TFT and OLED display ($U_L = U_{I/O}$ = 2.8 V) with comparable power consumptions of about 12 mW which is not considered here.

Graph 1 presents power consumption in function of percentage screen filling for OLED and TFT display. To create this graph three monochrome patterns red, green, blue and full white pattern have been used.



Graph 1. Power consumptions in function of screen filling

As is shown on Graph 1, OLED display power consumption is very dependent on screen filling. Greater screen filling results in higher power consumptions. As is shown 55 % active white pixels on OLED display consuming more power as full white filling TFT display. If one need to reduce OLED display power consumption, he can use OLED ability to work with reduced power consumption. Such ability is the result of OLED display structure which simplified model is shown on Fig.1. Each subpixel is an independent light source, thus each can work independently. In this case one need to consider displaying information in basic colors only: red, green, blue or variations of red and green.

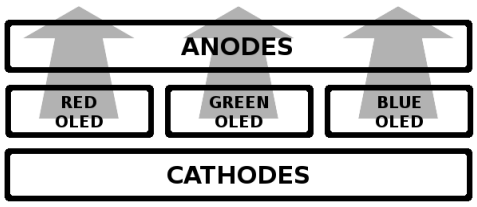


Fig. 1. Simplified OLED display structure

This way there is a possibility to greatly reduce display power consumptions, because full red or full green filing display consuming only 50 % of TFT display backlight power.

TFT display backlight consumes the same power regardless of display content other than the OLED display. Backlight power is dependent only on the display brightness as is shown on Graph 2. On Fig.2 a simplified model of TFT LCD structure is shown.

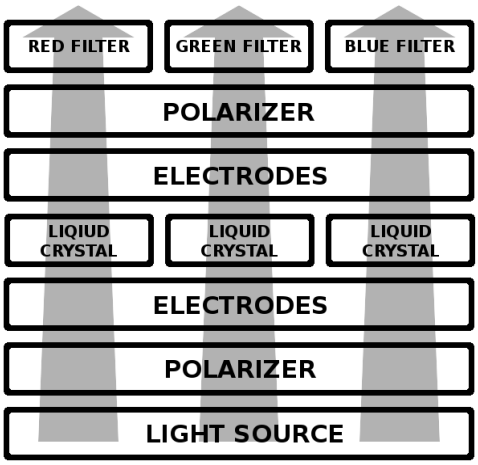
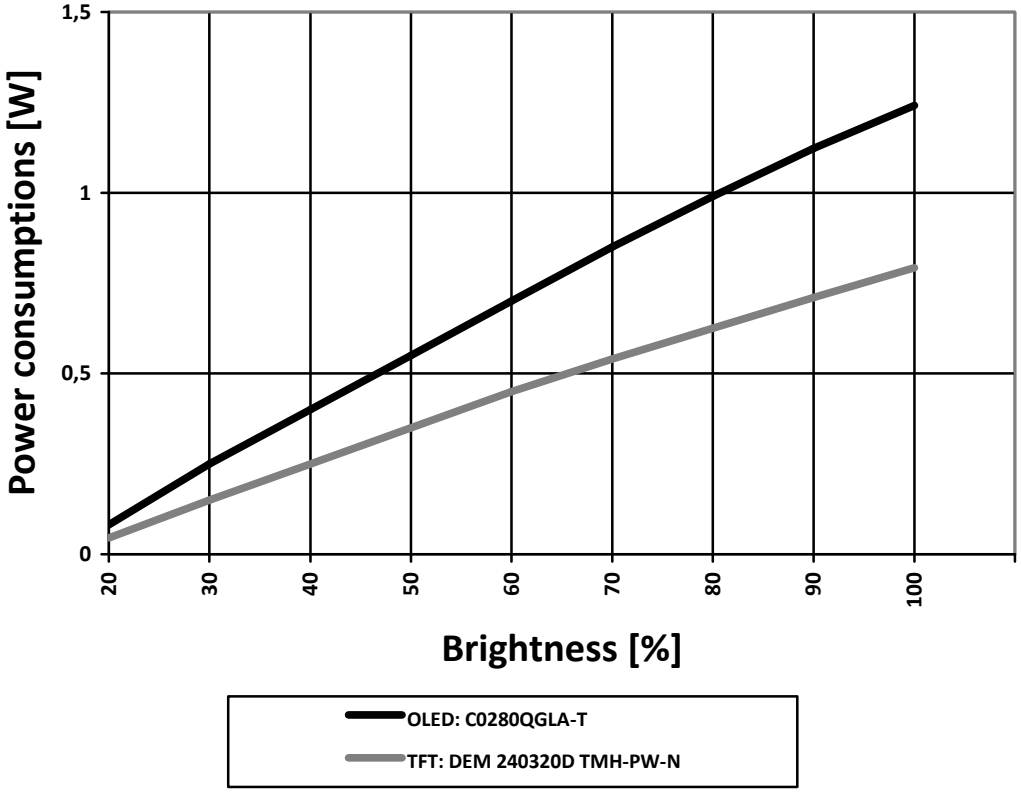


Fig. 2. Simplified TFT LCD structure

In OLED display power consumption also can be reduced by decreasing display brightness as shown on Graph 2. This two possibilities gives great opportunity to reduce device power consumption to level unavailable for devices with TFT display.



Graph 2. Power consumptions in function of screen brightness

One can easily obtain a half of the TFT display power consumption and by the proper display content preparation one can even reach one-tenth of TFT display power consumption. Main rule is: the less pixels are turned on the less power is needed. As we can see on Graph 1, maximum power consumption of OLED display is higher than TFT display, but usually not all of display area is used to display information. Even if one display many informations, only 20 to 40 % of display area is used, and then the maximum power consumption of OLED display is 0,34 to 0,62 W.

In the Table 3 and Table 4 the percentage usage of pixel matrix for appropriate letter and digit is shown. Maximum matrix usage is 32 % for letter "l" and minimum matrix usage is 16 % for letters "Y" and "x". As should be expected for digits minimum usage is for digit "1" and maximum usage is for digit "8". Medium matrix usage for letters is 23 % and for digits is nearly 25 %. Basing on this it can be assumed that the typical text may use only 20 up to 28 % of display area including spaces and special characters.

Displaying information on dark or black background also can reduce power consumption of OLED display. Knowing that, one should use dark background colors.

If display content will be displayed monochromatic, then the power consumption can be reduced to 100 mW, which is eight times lower than TFT display power consumption. If it is assumed that not all of display area is text message, but part of this area is graph or other similar content, than the power consumption can be reduced down to 80 mW. During normal operation with unprepared display content the power consumption of OLED display can be reduced to 20-25 % of TFT display power consumption, which is about 180 mW.

Table 3. Percentage matrix usage for letters

Letter	Matrix points	Used points	Percentage matrix use	Letter	Matrix points	Used points	Percentage matrix use
A	286	64	22	a	242	61	25
B	286	85	30	b	242	64	26
C	308	59	19	c	220	38	17
D	308	74	24	d	242	64	26
E	286	74	26	e	242	57	24
F	264	54	20	f	132	39	30
G	330	74	22	g	242	76	31
H	308	70	23	h	220	55	25
I	110	28	25	i	88	24	27
J	220	38	17	j	132	35	27
K	286	59	21	k	220	50	23
L	242	42	17	l	88	28	32
M	352	108	31	m	352	70	20
N	308	78	25	n	220	47	21
O	330	68	21	o	242	52	21
P	286	64	22	p	242	64	26
Q	330	76	23	q	242	64	26
R	308	80	26	r	132	26	20
S	286	68	24	s	220	44	20
T	264	44	17	t	110	34	31
U	308	62	20	u	220	47	21
V	286	54	19	v	220	38	17
W	396	106	27	w	308	73	24
X	286	52	18	x	220	36	16
Y	286	46	16	y	220	45	20
Z	264	62	23	z	220	48	22

Table 4. Percentage matrix usage for digits

Digit	Matrix points	Used points	Percentage matrix use
0	242	64	26
1	242	34	14
2	242	56	23
3	242	61	25
4	242	58	24
5	242	67	28
6	242	70	30
7	242	42	17
8	242	78	32
9	242	69	28

As one can see, the OLED displays provide many features which allow significant device power consumption reduction.

3. CONCLUSIONS

OLED displays have a feature which makes them more difficult to use in some applications, the power consumption is dependent on displayed content. From one point of view this feature is reducing power consumption in application which display less information. On the other hand this feature causes the problem that one don't know the exact power being consumed by the display. It can be problematic, but by using additional components like gas gauges one can handle accurately measuring display power consumption.

There are a few disadvantages of OLED display. Only small diagonal size OLEDs are offered. Still too high price do not reflect simplicity of display structures. As one can see in Table 1, OLED display has low brightness and short lifetime. In the near future new manufacture techniques like printing OLED layer similarly as inkjet printer device shall change this situation.

Even so, OLED displays have many advantages, like: low power consumption, great contrast ratio, wide viewing angle, outstanding color representation; which make them the best choice for modern low power medical devices.

However, in case of medical devices like ECG and EEG monitors, ultrasonic scanners, life-signs monitors, X-ray scanners, which need larger display area and good sunlight readability, using of TFT LCD have to be taken under consideration.

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