# Solar Computing

**Giovanni Lostumbo - September 2024**

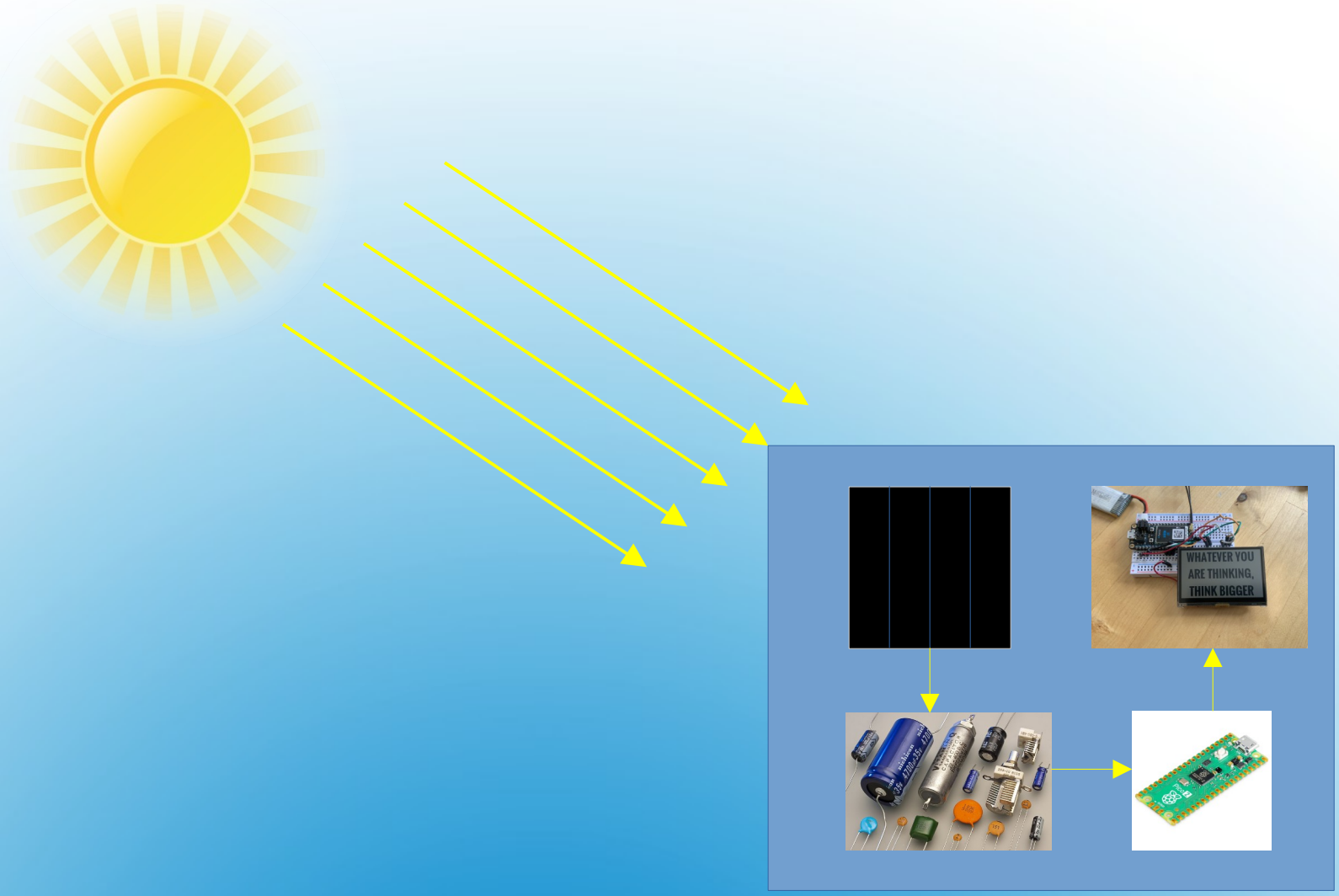
# Solar Computing- What is it?

- Just one type of energy autonomy/harvesting for PC- others are RF, Thermal, Vibration, but less efficient
- Sun rays reach a small solar panel on the computer chassis and charge a capacitor/battery
- A hybrid capacitor (Lithium Ion Capacitor, Sodium Ion Capacitor) can store charge like a small battery, but charge quick like a capacitor
- Use Cases: (next slide) -->

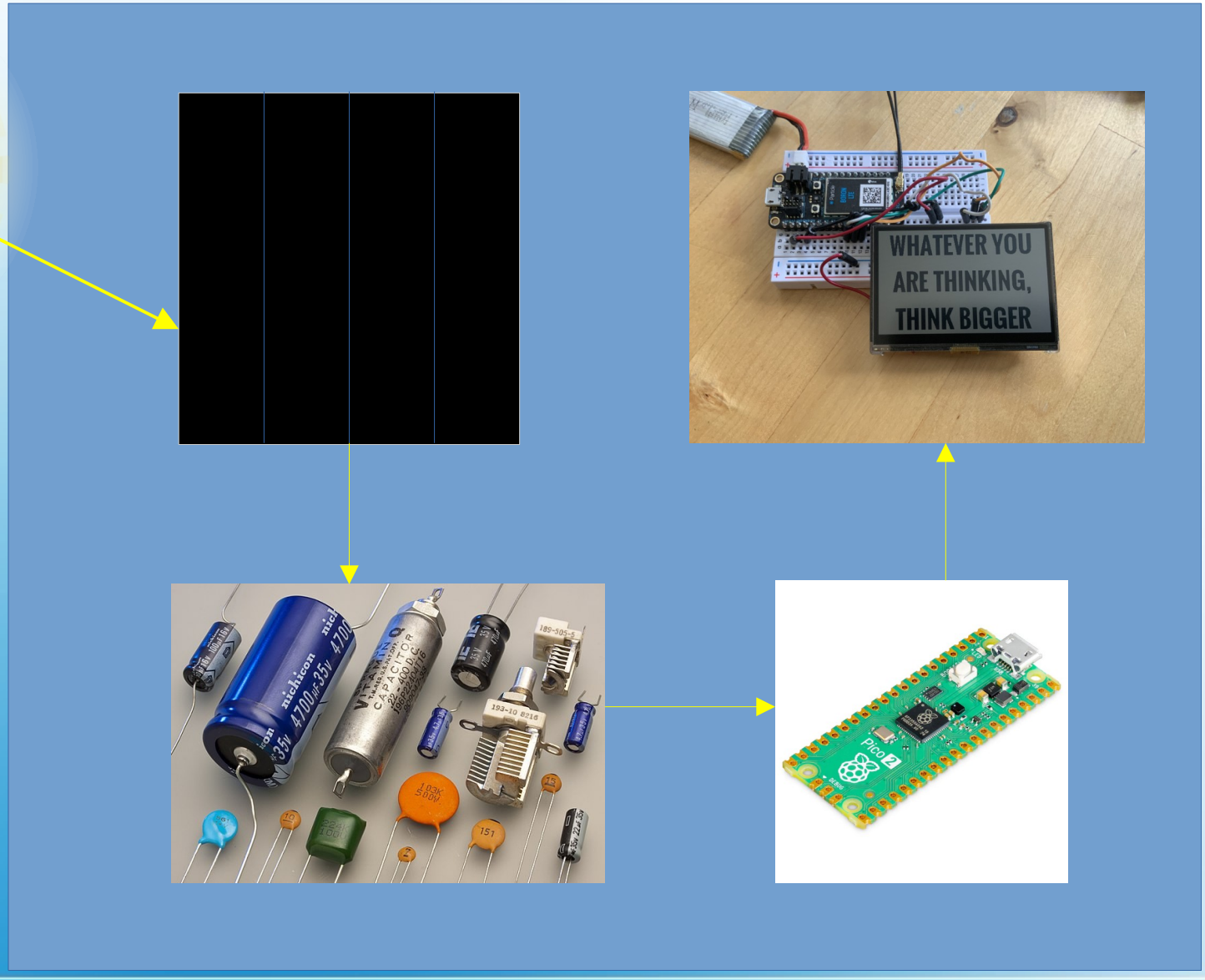

let's get down to it but would you like
to know under what circumstances would your solar computer stop working?


sad upon on what exactly whether I make
a plans to invade Switzerland in and the sun stops shining, permanently.

# Use Cases

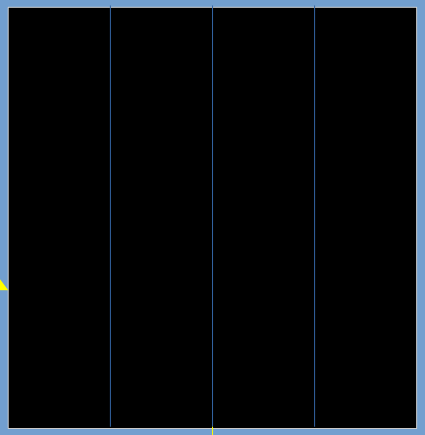



# Charge Cycle

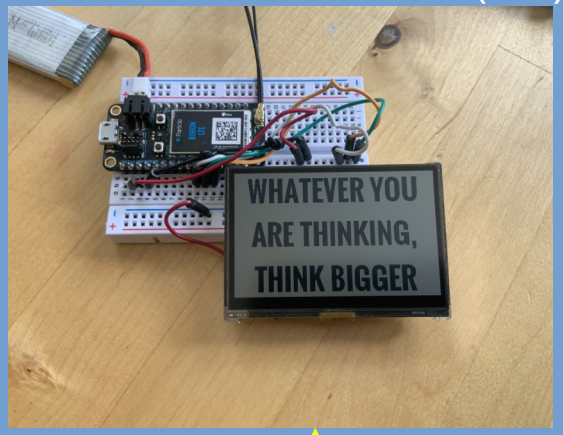



# Charge Cycle- Detailed

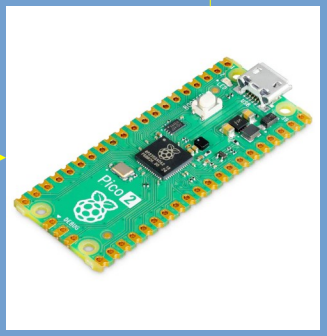
Photovoltaic Panel- 50uA-20mA
(500lux-outdoor sun- 30mm^2-70mm^2



Memory-In-Pixel
250uW/2Hz/89mmx67mm (4.4”)




Hybrid Capacitor (30F-250F=10-90mAh)



RP2350 - 16mAh= 37 min-
5.62 hrs (w/30F-250F)

# Charge Cycle- Detailed

Macbook Air M3 13” (2024)

# Microcontrollers can be solar powered today with tiny panels. What about laptops?

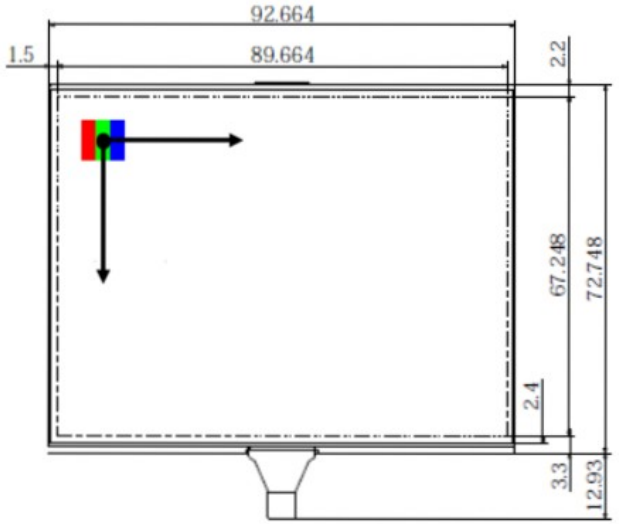
## 4.4” MIP Reflective Color LTPS TFT LCD

LPM044M141A

As of 2017.06.20

➢ Features:

- Ultra low power consumption
- 8 colors, SPI I/F
- Super high reflectance (18%)
- Ultra slim & compact design




Unit: mm

**MP now**

| | | Spec |
|---|---|---|
| General | LCD type | ECB, Full Reflective |
| | Diagonal size | 4.4" |
| | Resolution | 640RGBx480 |
| | Active area | 89.664mm(H) x 67.248mm(V) |
| | Pixel Pitch | 46.7um(H)(Ave.) x 140.1um(V) |
| | PPI | 181.3 |
| Electrical | Interface (Note-1) | SPI **Max refresh frequency (2) Hz** |
| | Power Supply | VLCD=3V |
| | Power Consumption (Note-2) | Typ. 14μW @ MIP Static Image<br>Typ. 123μW @MIP 1fps Image<br>Typ. (250μW) @MIP 2fps Image Refresh |
| Optical @Reflective mode | Color gamut | Typ. 23% (NTSC ratio) |
| | Contrast ratio | Typ.40:1 |
| | Number of colors | 8 (1bit) |
| | Reflectance | 18% |
| Mechanical | Glass size | 92.664mm(H) x 72.748mm(V) x 1.0mm(T) |
| | Module structure | LCD panel + FPC |
| | Module dimensions | 92.664mm(H) x 72.748mm(V) x 1.39mm(D) |
| Feature | Feature | Memory In Pixel |
| Schedule | Sample | Available |

Note-1: Room Temperature, 3V drive
Note-2: Room Temperature, White Image

JDI Japan Display Inc. Group

Spec is subject to change without prior notice.



Displays consume a large portion of a system power consumption budget, and Memory-In-Pixels are not manufactured in sizes larger than 4.4” and inventory appears to be obscure/low, special order and/or very expensive ($95+ for 4.4”). But can it scale? See next slide

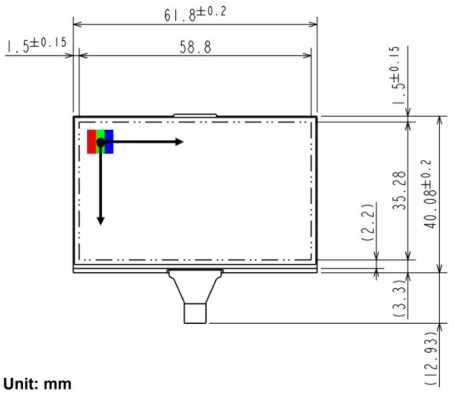
# Microcontrollers can be solar powered today. What about laptops?

## 2.7” MIP Reflective Color LTPS TFT LCD — LPM027M128B

As of 2017.12.14

- Features:
  - Ultra low power consumption
  - 8 colors, SPI
  - Super high reflectance 19%
  - Ultra slim & compact design

**Sample Available**




Unit: mm

| | | Spec |
|---|---|---|
| General | LCD type | ECB, Full Reflective |
| | Diagonal size | 2.70” |
| | Resolution | 400RGBx240 |
| | Active area | 58.8mm(H) x 35.28mm(V) |
| | Pixel Pitch | 49um(H) x 147um(V) |
| | PPI | 172.8 |
| Electrical | Interface (Note-1) | SPI **Max refresh frequency (6.5) Hz** |
| | Power Supply | VLCD=3V |
| | Power Consumption (Note-2) | Typ. 5μW @ MIP Static Image<br>Typ. 30μW @MIP 1fps Image Refresh<br>Typ. (180μW) @6.5fps Image Refresh |
| Optical | Color gamut | Typ. 23% (NTSC ratio) |
| | Contrast ratio | (Typ.40:1) |
| | Number of colors | 8 (1bit) |
| | Reflectance | 19% |
| Mechanical | Glass size | 61.8mm(H) x 40.08mm(V) x 1.0mm(T) |
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| Feature | Feature | Memory In Pixel |
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Note-1: Room Temperature, 3V drive
Note-2: Room Temperature, White Image

JDI Japan Display Inc. Group

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3

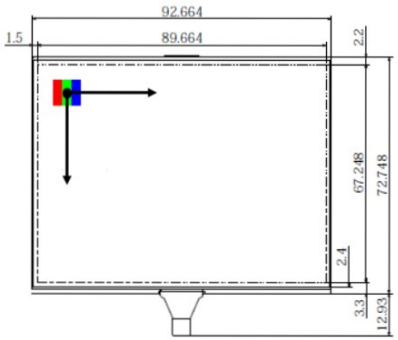
This 2.7” display uses 30uW for 1fps, and 180uW for 6.5fps

## 4.4” MIP Reflective Color LTPS TFT LCD — LPM044M141A

As of 2017.06.20

- Features:
  - Ultra low power consumption
  - 8 colors, SPI I/F
  - Super high reflectance (18%)
  - Ultra slim & compact design

**MP now**




Unit: mm

| | | Spec |
|---|---|---|
| General | LCD type | ECB, Full Reflective |
| | Diagonal size | 4.4” |
| | Resolution | 640RGBx480 |
| | Active area | 89.664mm(H) x 67.248mm(V) |
| | Pixel Pitch | 46.7um(H)(Ave.) x 140.1um(V) |
| | PPI | 181.3 |
| Electrical | Interface (Note-1) | SPI **Max refresh frequency (2) Hz** |
| | Power Supply | VLCD=3V |
| | Power Consumption (Note-2) | Typ. 14μW @ MIP Static Image<br>Typ. 123μW @MIP 1fps Image<br>Typ. (250μW) @MIP 2fps Image Refresh |
| Optical @Reflective mode | Color gamut | Typ. 23% (NTSC ratio) |
| | Contrast ratio | Typ.40:1 |
| | Number of colors | 8 (1bit) |
| | Reflectance | 18% |
| Mechanical | Glass size | 92.664mm(H) x 72.748mm(V) x 1.0mm(T) |
| | Module structure | LCD panel + FPC |
| | Module dimensions | 92.664mm(H) x 72.748mm(V) x 1.39mm(D) |
| Feature | Feature | Memory In Pixel |
| Schedule | Sample | Available |

Note-1: Room Temperature, 3V drive
Note-2: Room Temperature, White Image

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This 4.4” display uses 123uW for 1fps, and 250uW for 2fps.

# Can it scale? (the display, that is)

## 2.7” MIP Reflective Color LTPS TFT LCD — LPM027M128B

As of 2017.12.14

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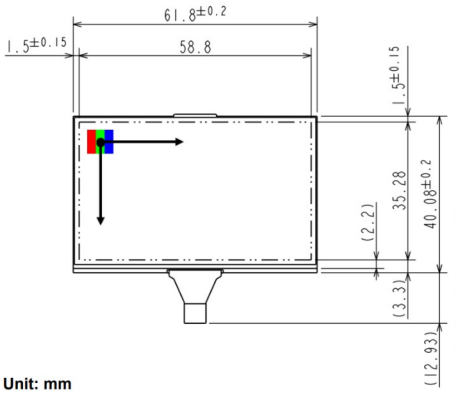
**Sample Available**




Unit: mm

| | | Spec |
|---|---|---|
| General | LCD type | ECB, Full Reflective |
| | Diagonal size | 2.70” |
| | Resolution | 400RGBx240 |
| | Active area | 58.8mm(H) x 35.28mm(V) |
| | Pixel Pitch | 49um(H) x 147um(V) |
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| Feature | Feature | Memory In Pixel |
| Schedule | Sample | Available |

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Note-2: Room Temperature, White Image

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This 2.7” display uses 30uW for 1fps, and 180uW for 6.5fps

## 4.4” MIP Reflective Color LTPS TFT LCD — LPM044M141A

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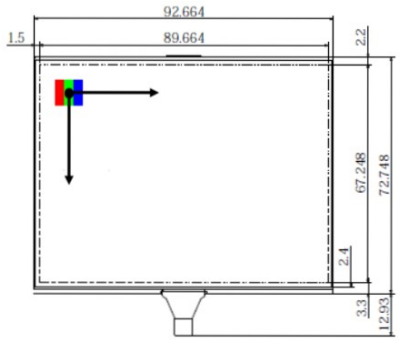


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Note-2: Room Temperature, White Image

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This 4.4” display uses 123uW for 2fps, and 250uW for 2fps.

Logic suggests Yes

# Can it scale? (the display, that is)

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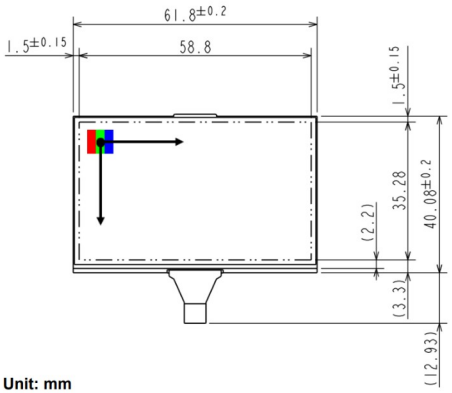


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| Feature | Feature | Memory In Pixel |
| Schedule | Sample | Available |

Note-1: Room Temperature, 3V drive
Note-2: Room Temperature, White Image

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Spec is subject to change without prior notice.



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This 2.7” display uses 30uW for 1fps, and 180uW for 6.5fps

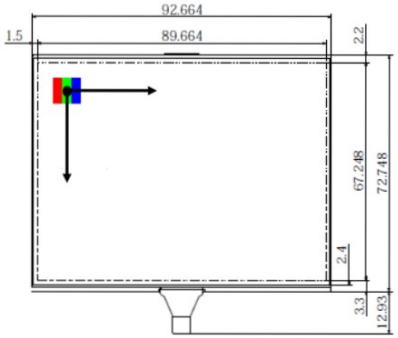
## 4.4” MIP Reflective Color LTPS TFT LCD

LPM044M141A

As of 2017.06.20

- Features:
  - Ultra low power consumption
  - 8 colors, SPI I/F
  - Super high reflectance (18%)
  - Ultra slim & compact design

**MP now**




Unit: mm

| | | Spec |
|---|---|---|
| General | LCD type | ECB, Full Reflective |
| | Diagonal size | 4.4” |
| | Resolution | 640RGBx480 |
| | Active area | 89.664mm(H) x 67.248mm(V) |
| | Pixel Pitch | 46.7um(H)(Ave.) x 140.1um(V) |
| | PPI | 181.3 |
| Electrical | Interface (Note-1) | SPI **Max refresh frequency (2) Hz** |
| | Power Supply | VLCD=3V |
| | Power Consumption (Note-2) | Typ. 14μW @ MIP Static Image<br>Typ. 123μW @MIP 1fps Image<br>Typ. (250μW) @MIP 2fps Image Refresh |
| Optical @Reflective mode | Color gamut | Typ. 23% (NTSC ratio) |
| | Contrast ratio | Typ.40:1 |
| | Number of colors | 8 (1bit) |
| | Reflectance | 18% |
| Mechanical | Glass size | 92.664mm(H) x 72.748mm(V) x 1.0mm(T) |
| | Module structure | LCD panel + FPC |
| | Module dimensions | 92.664mm(H) x 72.748mm(V) x 1.39mm(D) |
| Feature | Feature | Memory In Pixel |
| Schedule | Sample | Available |

Note-1: Room Temperature, 3V drive
Note-2: Room Temperature, White Image

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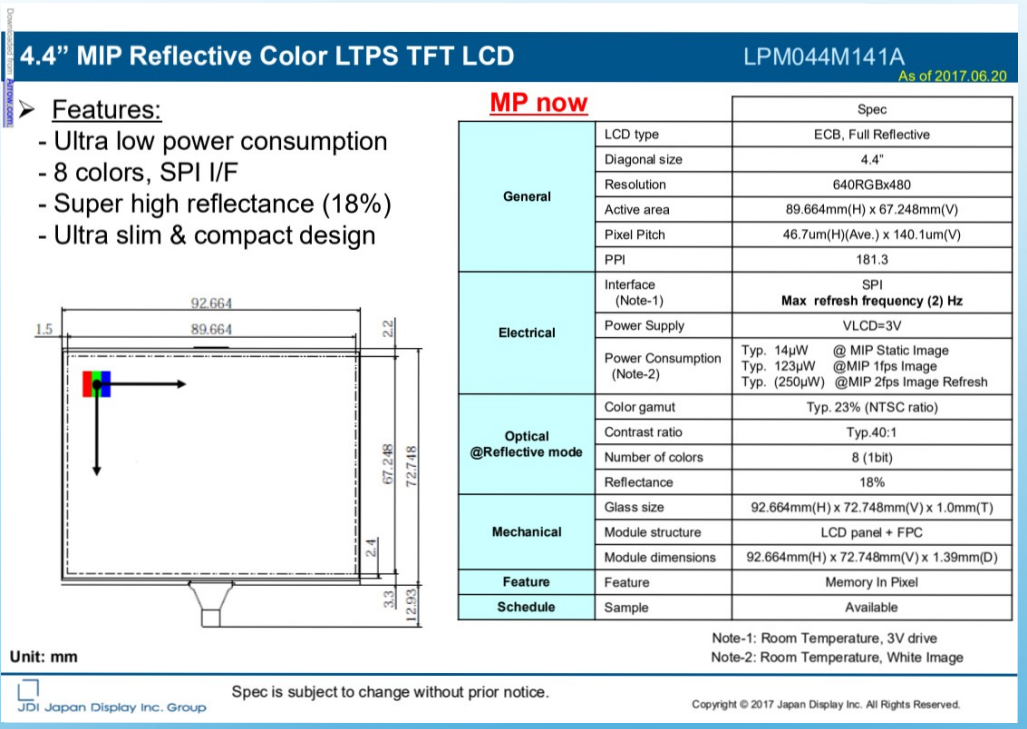
This 4.4” display uses 123uW for 2fps, and 250uW for 2fps.

Is scaling it to 13.2” (relatively) easily solar powerable?(A Macbook Air is 13.6” diagonal)



**4.4” MIP Reflective Color LTPS TFT LCD** LPM044M141A

As of 2017.06.20

➢ Features:
- Ultra low power consumption
- 8 colors, SPI I/F
- Super high reflectance (18%)
- Ultra slim & compact design



**MP now**

| | | Spec |
|---|---|---|
| General | LCD type | ECB, Full Reflective |
| | Diagonal size | 4.4" |
| | Resolution | 640RGBx480 |
| | Active area | 89.664mm(H) x 67.248mm(V) |
| | Pixel Pitch | 46.7um(H)(Ave.) x 140.1um(V) |
| | PPI | 181.3 |
| Electrical | Interface (Note-1) | SPI **Max refresh frequency (2) Hz** |
| | Power Supply | VLCD=3V |
| | Power Consumption (Note-2) | Typ. 14μW @ MIP Static Image<br>Typ. 123μW @MIP 1fps Image<br>Typ. (250μW) @MIP 2fps Image Refresh |
| Optical @Reflective mode | Color gamut | Typ. 23% (NTSC ratio) |
| | Contrast ratio | Typ.40:1 |
| | Number of colors | 8 (1bit) |
| | Reflectance | 18% |
| Mechanical | Glass size | 92.664mm(H) x 72.748mm(V) x 1.0mm(T) |
| | Module structure | LCD panel + FPC |
| | Module dimensions | 92.664mm(H) x 72.748mm(V) x 1.39mm(D) |
| Feature | Feature | Memory In Pixel |
| Schedule | Sample | Available |

Note-1: Room Temperature, 3V drive
Note-2: Room Temperature, White Image

Unit: mm

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- Six 4.4” panels in a 3x2 array would produce a 13.2” display with 1920x960 resolution
- Ignoring SPI bandwidth limits, tiling drivers, bezels, and the manufacture of an un-segmented 13.2” for the time being, six 4.4” MiP displays would consume 1.5mW at 2fps, 3mW at 4fps & 6mW @8fps.
- 8fps is not super fast for typing or browsing
- However, it could be an option for solar power.
- A 30fps hack does exist (for 2.7”): https://www.youtube.com/watch?v=X6Si2pwZe18
- A 250F, 90mAh Hybrid Capacitor could power a 2mA microcontroller connected to a 2mA 13.2” display for 22.5 hrs (6mW/3V=2mA) *[P=IV]*
- In practice, a low power keyboard, radio, and PS2/serial mouse would consume a little more.

This 4.4” display uses 123uW for 2fps, and 250uW for 2fps.

# Is scaling it to 13.2” (relatively) easily solar powerable? Logic suggests Yes


- A low-efficiency, inexpensive (<$2) 70mm^2 monocrystalline panel can generate 20mA in full sun. That suggests it would take 4hrs to charge a laptop's 80mAh/250F hybrid capacitor to 89%
- More efficient panels exist: One of the highest efficiency panels is made by ANYSOLAR:
- https://www.digikey.com/en/products/detail/anysolar-ltd/KXOB201K04TF-TR/13999209
- Up to 25% efficient: 78.7 mA  (23mm x 42mm)
- The largest panels can produce up to 409mA within 5.2"x2.0" (133mm x 52mm) - $29, small enough to fit on a laptop lid/bezel
  i.e https://www.digikey.com/en/products/detail/anysolar-ltd/SM102K06TF/14311425
- A 409mA 5.2" panel in full sun would charge a 90mAh battery/lithium ion capacitor in 13 minutes.

# Is scaling it to 13.2" (relatively) easily solar powerable? Answer: Yes


- Premium for highest efficiency PV panels, MiP displays, & chip development (e.g. 22/14nm nanometer TSMC /Global Foundries, but paying for energy independence
- Efforts to reduce cost of lowest power displays would benefit industry firsts (e.g. improving yields from defects such as single dead pixels in large displays), but requires additional capital
- Lowering energy consumption of CPU and RAM has more immediate production benefits= smaller, wider applications than consumer/medical/automotive displays- can be used as IoT, without human interaction
- Display manufacturing is a human priority-aesthetics are often a secondary concern for Machine to Machine products, but can have a protective effect(e.g. eye health) for consumers
- Modularity is key to allowing platform to evolve/upgrade to faster processors, modems, and storage <80mA. Speed of processing exceeds human readability in Solar-powerable microcontrollers
- Integration of components =$$-$$$

Is scaling it to 13.2” cost-effective? Depends on customer

# Thanks for your time

giovanni dot lostumbo at gmail.com