HOW TO DELIVER ADVANCED GRAPHICS AND EXTENSIVE CONNECTIVITY IN A HIGHLY INTEGRATED WEARABLE PLATFORM

By Toshiba Electronics Europe

How to deliver advanced graphics and extensive connectivity in an integrated wearable platform

An appealing design, reliable functions and all-day usability are key features that make the latest wearable devices "must-have" technology. We are increasingly reliant on these devices to help us do so many things from monitoring our health through to communicating with friends, family and work colleagues.

Today's high-end wearables such as smart watches are characterized by a rich functionality, a sophisticated graphical user interface (GUI) with touch operation, and communication interfaces to a smartphone, tablet or PC. However, they are also prone but to extremely short battery life times - typically one or two days. On the other hand, simple Fitness Trackers without a graphic display have limited user interaction capabilities, but offer the convenience of device charging only once per week or month.

Here we look at the conflicting performance/functionality/battery-life/size requirements for the different categories of wearable devices. We then consider how to deliver both high-performance graphics-based user interfaces and long battery life by selecting low-power processor architectures and integrated graphic accelerators.

Introduction

Demand for wearable devices is growing rapidly, driven by their ability to readily collect, analyse and utilize health and environmental data. Although the market is still in its relative infancy, annual revenues from the wearable sector (meaning any electronic products that are designed to be worn on the person - e.g. smartwatches, fitness trackers, smart eyewear, smart clothing, medical devices and more) are forecast by IDTechEx to ramp up beyond the $150 billion mark by 2026. A significant proportion of these devices will be "connected". In fact according to Gartner, over 4 billion devices are already connected and 5.5 million devices are being added each and every day. Predictions indicate 20 billion connected devices by 2020, equating to several devices for every person.

To sustain this growth wearables manufacturers seek to develop ever-smarter devices and more integrated devices that elegantly balance cost, form and function with the minimum of user overhead in terms of re-charging.

The key to developing a compelling wearable device is generating something that is often referred to in marketing circles as 'stickiness'. According to research, half of all activity trackers purchased are no longer used, and a further third were discarded in the first six months of ownership. Among the reasons for losing interest are lack of functionality, operating difficulties, and inconvenience - not least in terms of time between battery charges.

As processor technology advances, code structures become ever more efficient and sensors reduce in size, delivering advanced functionality is possible in ultra-miniature wearable devices. Convenience often equates to longevity of battery life achieved through improving battery, processor and display technology and intelligent power management schemes. Users want wearable devices that boast operating times measured in weeks and even months without compromise in functionality.

Single-function wearable devices, such as fitness bands, use Bluetooth Low Energy wireless communication to a smartphone for data exchange or device software updates. They often incorporate sensors for counting steps walked or optical heart rate measurement. Smartphone apps usually analyse the gathered sensor data and indicate the sleep quality, calories burned, or track the heart rate over time.

In the middle of this sector, between the single function devices and the high-end wearables, is the next significant growth area for wearable technology. While simpler than smartphones, users increasingly expect devices in this space to have fashionable colour displays and intuitive and flexible user interfaces. The wearable in this segment becomes a life-style product that can be worn as a classical watch with 'smart' functions.

Today's toughest wearable device design challenge surrounds the area of ergonomics or operator convenience, both of which are defined by the user interface.

A dilemma for designers as more advanced graphics meant using more powerful processors with higher clock frequencies and, consequently, higher power demands. However, by incorporating advanced graphics capabilities the latest application processors for wearables are offering novel architectures that can satisfy these competing demands.

An application processor for next-generation wearables

Take, for example, the latest addition to Toshiba's line-up of ApP Lite™ application processors for wearable and other IoT devices. The TZ1200 is a compact 8mm x 8mm x 0.6mm device based on a high-performance 32-bit ARM® Cortex®-M4F processor with floating-point unit, memory protection unit and flexible interrupt processing capable of operating at frequencies of up to 120MHz. This core, in combination with the on-board power management functionality, allows the TZ1200 to have an low power consumption of just 70µA/MHz in active mode. With a 350mAh battery, suitable power management software, and a low-power colour display, this translates into a time between battery charges of about one month in 'watch' applications.

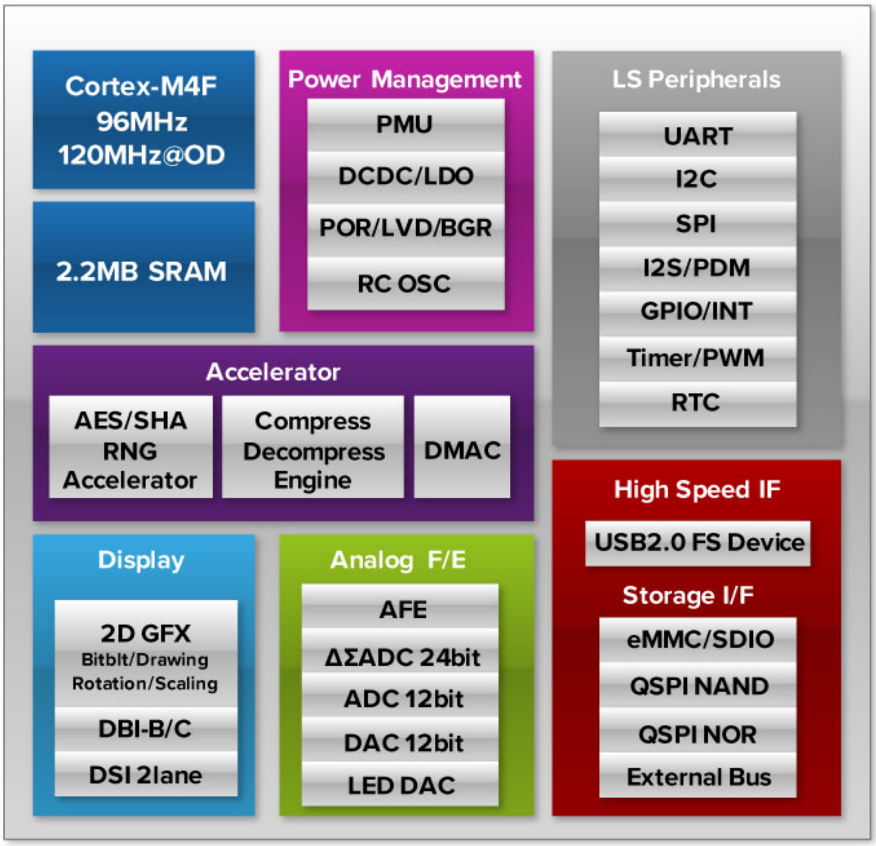

Figure 1: TZ1200 highly integrated solution for wearable devices

Together with 2.2MB of embedded high-speed SRAM, an advanced LCD controller and a total of four state-of-the-art 2D graphics engines, the TZ1200 offers class-leading graphics performance for watch applications requiring long battery life. Supported by an integrated MIPI Display Bus Interface (DBI) and Display Serial

Interface (DSI) it offers support for a range of display resolutions of up to HVGA (480x320) at 30fps or QVGA (320x240) displays at up to 60fps.

The 2D Graphics (GFX) Accelerators provide a powerful platform for drawing, rotating, texturing and resizing images on a display as well as performing on-the-fly colour conversion. This removes almost the entire load on the processor and contributes significantly to further power efficiencies.

Use of external sensors and peripheral devices that can monitor activity and movement are supported by integrated USB, UART, SPI and I2C interfaces, while 120 free GPIOs meet the needs of even the most complex devices.

The TZ1200 provides designers with the flexibility to specify the most suitable memory ICs and capacities for their devices. Together with the embedded data compressor, it enables large-capacity data storage for long periods of time without frequent uploading of data.

A particularly important element of the new processor is the high-precision analogue front-end (AFE) that brings together a 24-bit delta-sigma ADC, 12-bit ADC, 12-bit DAC and an LED DAC. One of the big benefits of the AFE is that it supports direct sensing. The ability to connect analogue sensor outputs directly to the device's high-resolution ADC offers the potential for significant space and power savings – as well as EMI reduction and simplified design - by eliminating the traditional 'pre-conditioning' elements of high pass filter, high gain amplifier and low pass filter. In the direct sensing scenario, these conditioning functions are performed in software running directly on the processor.

Supporting demanding graphics

Supporting the graphics needs of today's sophisticated user interfaces is critical. In the case of the TZ1200, integrated GFX accelerators offers some exciting animation possibilities. Possibilities that, until now, were reserved exclusively for smartphones and high-end smart watches using power hungry gigahertz-class processors with full-blown 3D accelerators.

Toshiba's TZ1200 contains a total of four hardware graphics engines, each with a dedicated role; blitting, rotation, transformation and drawing. A number of colour spaces are supported including Adobe RGB 1555, Adobe RGB 8888 and RGB 565 giving designers flexibility and excellent colour rendition.

The drawing engine is capable of 1/16 sub-pixel accuracy and draws the shapes necessary to create the user interface - a combination of lines, rectangles and triangles. In order to deliver the highest quality graphics, the drawing engine carefully calculates the specific transparency of each pixel when applying antialiasing. This engine is able to draw and crawl multiple anti-aliased shapes with varying transparency with minimal CPU loading (<1%) at high frame rates as shown below.

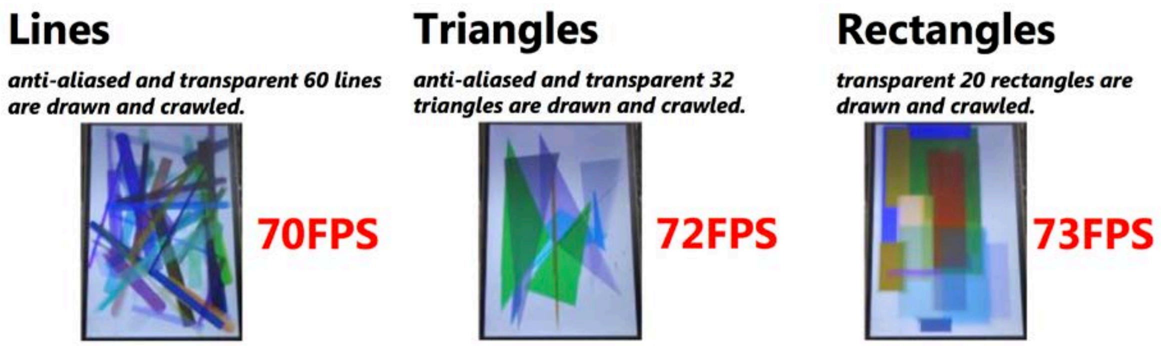

Figure 2: The drawing engine executes powerful and fast operations with minimal CPU load

During operation, the blitting and rotation engines work together to provide Bit BLock Transfer (BitBLT), alpha blending and rasterizing as well as image scaling, shearing and rotation. Using this approach, only the elements of the display that have changed or moved are refreshed (for example the second hand on a smart watch), thus saving processing power and, ultimately, battery life. The transformation engine gives high-quality and flexible image transformation through Look Up Table (LUT) mapping. Together with the rotation engine, it creates the so-called 3D perspective transformation capable of rendering an image into a custom 3D perspective, thus enabling a variety of very attractive 3D-like animations: menus, lists or coverflows (such as creating a '3D' globe from a 2D map of the Earth).

In summary, through combinations of the multiple 2D engines, the TZ1200 offers exciting 3D-like graphics animation possibilities, at low CPU load and low power consumption.

Moving from one display to another smoothly and seamlessly can be achieved through a combination of the blitting and rotation engines. In the example below, the watch display requires blitting and rotation to move the hands. Blending then fades out the watch display and brings in the pulse display, which then relies on just the blitting engine.

Figure 3: Enabling smooth transitions in multi-function devices

In other applications where a display is required temporarily; for example a pop-up menu, additional layers can be blended with transparency. This retains the basic functions while enabling additional information to be displayed. In the example below the watch display is simplified. However, the basic hands are retained to de-clutter the display yet retain the watch function while additional information is displayed.

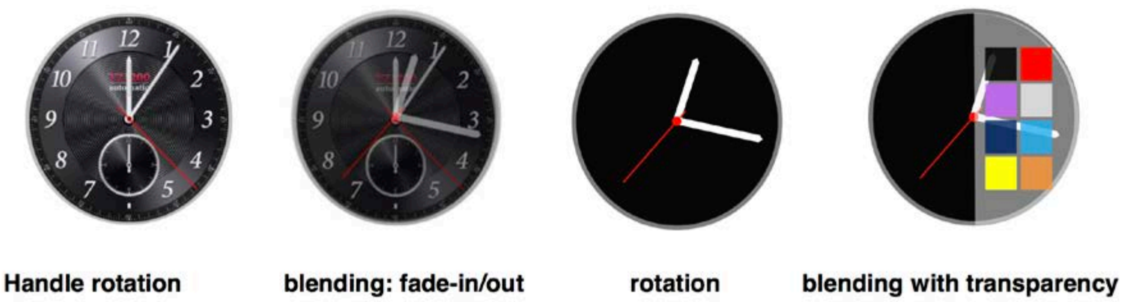

Figure 4: Temporary overlays can be blended while retaining basic device functionality

Using the transformation engine, developers can support a number of sophisticated functions including object scaling and pseudo-3D effects. Menu selection can be achieved graphically by scaling display items, giving the front-most display prominence through scaling. In the example below, the transformation engine creates the scaling and the rotation engine enables the operation of the menu by rotating the currently selected display to the front.

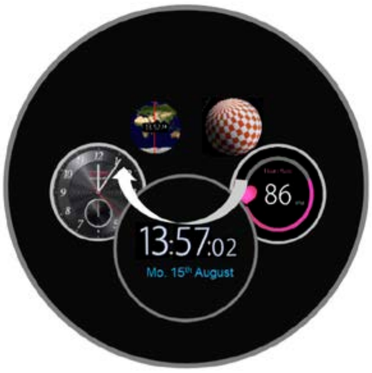

Figure 5: Scaling can be used to give selected menu items prominence in the display

One of the most powerful capabilities of the transformation engine is the ability to merge flat 2D images with 3D rendering to create images with depth – for example, rendering a pseudo-3D globe from a flat map. Shadow blending completes the effect giving the feel of directional light to the display.

Figure 6: The transformation engine creates sophisticated pseudo-3D animations

Bus architecture

While the GFX provides the functionality and enables highly sophisticated, feature rich user interfaces, the real strength of the TZ1200 comes from its dual-bus architecture. With this approach, the GFX is, in effect, an autonomous sub-system with its own SRAM and display interface. The CPU prepares a command list, based upon the needs of the device and the application software sends this short set of instructions to the GFX. The GFX interprets these high-level instructions into tasks for each of the graphics engines and then executes them directly to the display interface.

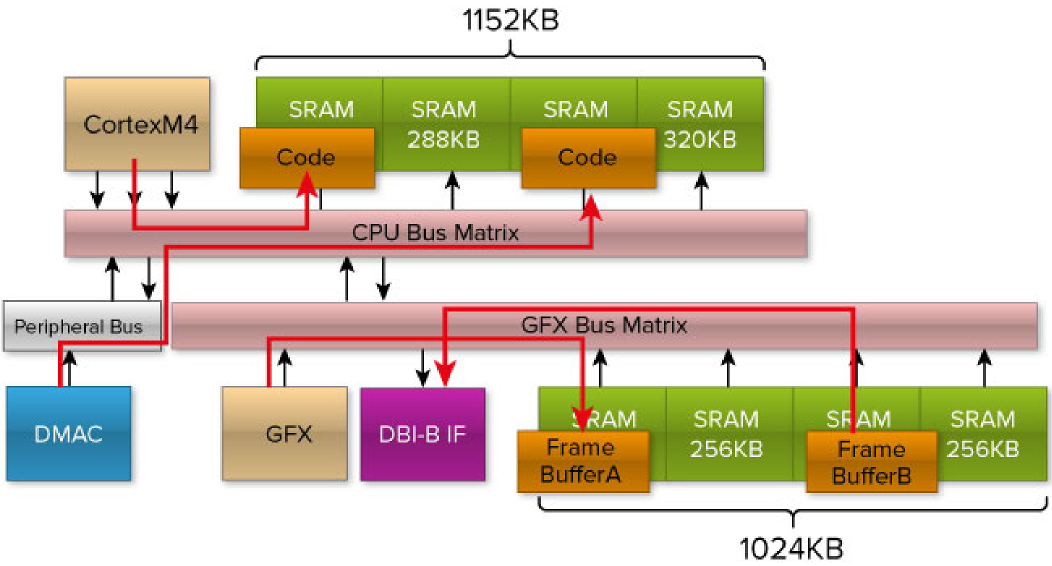

Figure 7: The TZ1200 features separate bus matrices for CPU and graphics operations

The power of the GFX accelerators allow the TZ1200 to render realistic graphics displays at high frame rates (fps or frames-per-second). These exceed the needs of most wearable applications (a moving second hand on a watch is, by definition, 1fps). Yet, due to the efficient, segregated, architecture performing complex graphical manipulation (including drawing, filling, fading, blending, scaling and rotation) the load on the main Cortex CPU is minimized. CPU capacity can, therefore, be employed for application-oriented processing. The actual CPU load depends heavily on the desired GUI and the effectiveness of GFX usage. As a reference, for typical GUI implementations with 2D and 3D animations measurements show a CPU load between just 3% and 8%.

Its highly efficient architecture allows the TZ1200 to achieve throughput performance typically associated with CPUs with significantly higher clock frequencies. This, along with advanced features such as the ability to power down memory banks and on-chip peripherals individually, contributes significantly to the device’s low power consumption. This is illustrated by testing an 'always on' watch application powered by a 350mAh battery that provided display updates every second. The TZ1200-based solution including colour display with memory in pixel (MiP) technology, expected operation for 34 days between charges.

Multiple IOs convenience

Beyond the advanced graphics capabilities, the highly integrated architecture of the TZ1200 enables a whole plethora of external devices to be connected, allowing designers to create a variety of highly sophisticated, low-power, wearable devices. Take, for example, a wearable biomedical sensing device that connects to both the real world and the IoT. This type of product demands a fully integrated solution in a small, low-power package.

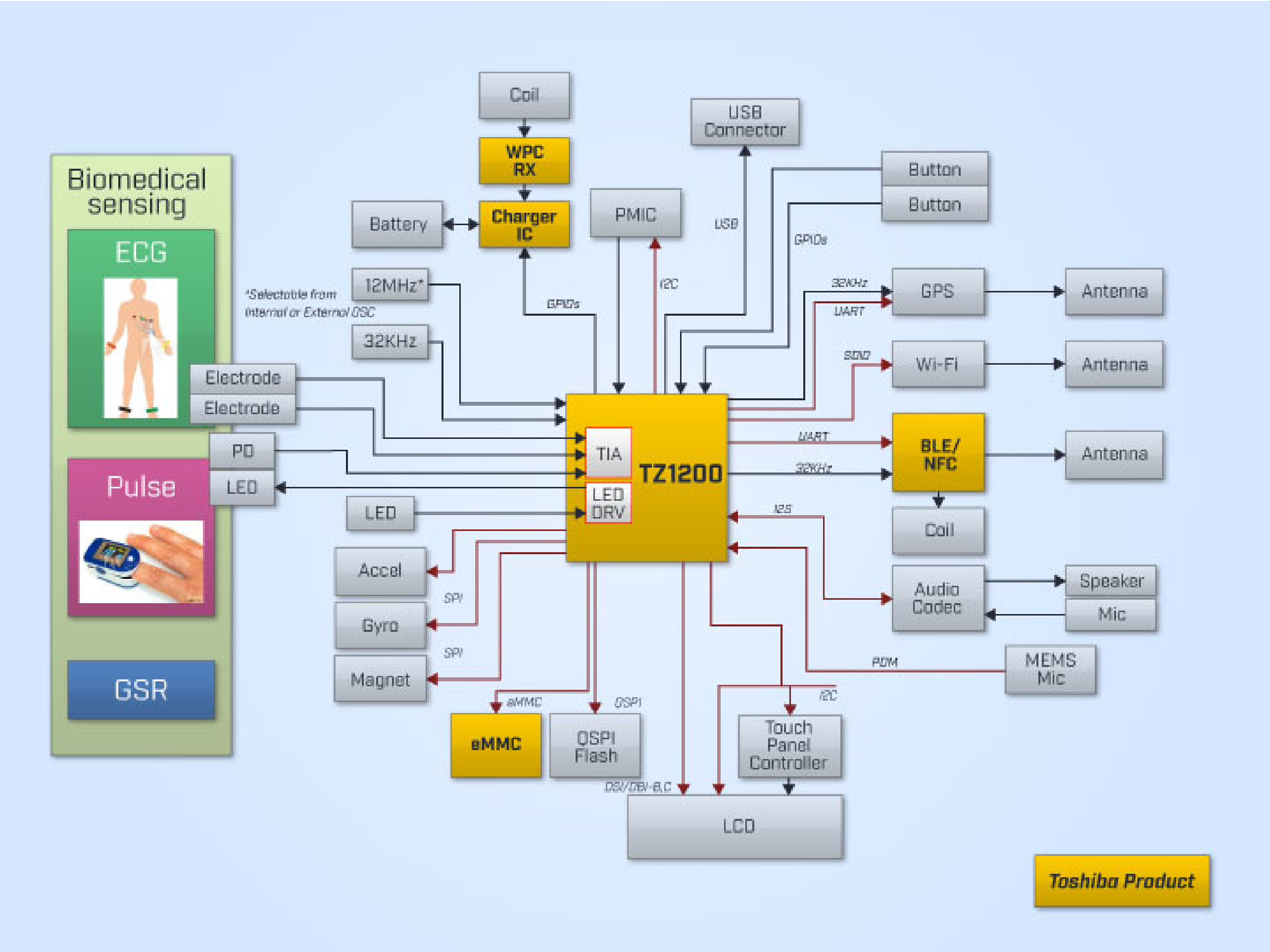

Figure 8: The TZ1200 forms the heart of many sophisticated wearable devices

By choosing the TZ1200 the SPI interface can be used to provide the connection of accelerometers, gyroscopes and magnetometer giving spatial and motion inputs. A GPS module connected via the in-built UART performs absolute positioning.

A range of GPIO connections as well as various analog circuits, including an integrated TIA (Trans Impedance Amplifier), provide interfacing for biomedical sensing in health care application. In the application-specific case of heart pulse detection, the LED driver controls the LED that detects pulse as well as providing more general visual indication of operation and alarms.

The GPIOs also allow for simple tactile user input through buttons and an I2C interface provides for more sophisticated context-based user input via a touch-sensitive LCD panel. The I2S interface allows the connection of an audio codec, thus bringing the opportunity for voice control and audible user alerts. Close proximity communication is covered by a combination of the UART and I2S interface, with both Bluetooth LE (BLE) and Near-Field Communication (NFC) interfaces available. This enables peer-to-peer connections (such as IoT access via a smartphone) as well as highly secure contact-based data transmission. For more sophisticated devices requiring direct connection to the IoT, the SDIO interface facilitates a Wi-Fi connection.

While not all wearable devices will require all of the functionality described, such an application clearly illustrates the power and capability of the TZ1200. This brings designers a range of options for creating a suite of different types of wearable devices; all based upon a common platform. It also allows for product options to be added or omitted to create entry-level, mid-level and premium versions of any wearable device using the same underlying technology.

Conclusion

In the fast-changing and highly competitive world of wearable technology, the intelligent approach of separating the graphics engine from the general processing delivers real benefits in terms of high performance at a reduced clock frequency. This allows designers to meet the power budget AND deliver the high-functionality, eye-catching, graphical user interfaces that will define the compelling wearable products of the future.

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