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Embedded System Solutions for Controlling Added Functionality on Quadcopters

I. Introduction

Capable of flying hundreds of feet off the ground in an instant in a small form factor, quadcopter drones have seen a meteoric rise to prominence in the last decade. From recreation to warfare, the portability, low cost, ease-of-use, and utility of these drones has led to their use in numerous applications. Enabling these drones to operate in such a fashion requires a flight controller, which prescribes electronics capable of producing such computational power. Embedded processers are the answer to this problem, as their low cost, energy efficiency, and small size are ideal. They are similarly ideal for modifying existing drones with additional functionalities that require computational power. This technical review briefly summarizes some commercially available embedded chips and microcontrollers, explains the underlying technology, and provides methods of implementation.

II. Commercial Applications of Embedded Processors in Quadcopters

Even though there are many different quadcopter archetypes available on the commercial market today, ranging wide in size and capabilities [1], they all use some sort of embedded processor as a flight controller, the complexity of which is dependent on the drone. Considering a quadcopters' flight time is limited by its battery's charge, it is clear to see why. Different from general purpose processors found in desktop computers, embedded processors can be more specialized – prioritizing a low power-to-performance ratio fitting for mobile applications. Currently, the market is dominated by ARM processor based boards, which are bought through manufacturers such as Texas Instruments, STMicroelectronics, NXP, and Microchip [2]. The unparalleled ecosystem surrounding ARM chips (development tools, support, documentation, etc.), makes them the preeminent choice for any application.

Any flight controller needs to be able to operate in real-time, and Arm's Cortex-M series processors are particularly prevalent as real-time processors used in a variety of applications. They are based on the Arm-M architecture characterized by reliability and optimization for low power, high performance CPUs [3]. The most popular M series processor is the Cortex-M3. It can control the flight of a simple drone, providing all necessary I/O ports with clock speeds of 96 MHz, while consuming only

141 μW/MHz [4]. A small 14 x 14 mm microcontroller development board produced by NXP with this capability, the LPC1768, is marketed at $54.95 [5, 6].

If more processing power is needed, another in-class design is the Cortex-M4. Specifically developed to address situations calling for a blend of control and signal processing capabilities, such as motor control. Consuming 151 μW/MHz, the chip can provide more than the M3 can for a slightly higher energy cost, but roughly equivalent monetary cost. In the same form factor as the LPC1768, the FF-LPC546xx microcontroller development board produced by L-Tek has clock speeds of 180 MHz and is marketed at around $54 [7]. If used to make changes to existing products, the small size of both these solutions is ideal for drones that are often lacking space and sensitive to changes in center of gravity.

III. The Technology of Embedded Systems

Processors

An embedded system is any device that incorporates a computer in its implementation; essentially sized down and simplified versions of what would be found in a computer desktop processor. There are over 100 times more embedded processors than desktop processors, yet they are not as well known. This is due to the unique requirements of reliability, performance, power, and cost that shape how various embedded processors are developed [8]. They can be designed for a variety of applications, but when it comes to deciding on a processor for a particular application processing power and functionality come first and foremost. These factors are quantified through memory (SRAM, DRAM, Flash) size, clock speeds, real-time performance, and I/O pins. Once minimum specifications to perform the task are determined, it is likely that energy efficiency will be of next concern for battery powered applications. Possible due to their simplicity, embedded processors can get such low power-to-performance ratios through low power modes. By putting unused clock nodes into a sleep mode, power consuming clock cycles are prevented from being wasted. Nodes include the CPU, flash memory, any peripherals, and the system itself. Even if modules are asleep, they can be woken up by interrupts, as they are kept aware by micro to nanoamps of current. However, how fast they awake is dependent on the depth of sleep [9].

Microcontrollers

Microcontrollers are integrated circuits incorporating an embedded processor. They typically include additional memory and multiple I/O peripherals (Serial, SPI, I2C, UART, CAN, PWM, Ethernet, Analog, Digital, USB, etc.), taking care of much of the work involved with conditioning inputs to a processor. This facilitates programming of the embedded processor as well as implementation into a larger system [8]. Commercially, they are sometimes used as development boards that allow for rapid prototyping with a selected processor. Thus, they are often used to add functionality to existing products.

IV. Implementing Additional Embedded Processors into Quadcopters

Adding functionality to an existing quadcopter drone is a complicated task, as there are strict constraints on volume and weight of an already completed product. Both hardware and software work are required to configure the processor's behavior. Hardware knowledge is needed to wire any additional mechanisms to the embedded processor controlling it, or even to design a custom PCB. Real-time microcontrollers make the hardware effort easier by possibly offering an off the shelf solution, but controller memory, power usage, clock speeds, and I/O pin specifications must be carefully considered based on project requirements. As drones run on batteries, the chosen microcontroller would need to operate at the lowest power possible for its performance specification. Otherwise, a significant decrease in flight time could be observed. Software knowledge is needed to code the processor's behavior in C/C++, due to the languages' high speed and ubiquity in real time operating systems [2]. This code should be optimized to further reduce power consumption. Finally, the system must be thoroughly tested in a simulated environment to proactively avoid crashes during actual flight.

References

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