Black Box Hardware

The Black Box houses a small form-factor (115 x 101 x 27 mm) industrial PC (Fit-PC2, Anders Electronics Plc., London, UK) with an anodised die cast aluminium casing, which acts as a heat sink, within a modified aluminium enclosure (Deltron 484 series, 484-0070, DEM Manufacturing Ltd., Scunthorpe, UK). The complete unit is solid state, robust, and weighs approximately 1.6 kg. It has dimensions of 222 x 146 x 106 mm, including a mounting flange, and is waterproof, being cooled passively by means of a heat sink on the face of the unit.

The Fit-PC2 is a miniature (104 x 96 x 23 mm) single-board computer (SBC-FITPC2, Compulab Ltd., Technion, Israel), at the heart of which is computer-on-module (CM-iAM, Compulab Ltd., Technion, Israel) based upon an Atom Z530 processor (Intel Corporation Plc., CA, USA) and US 15W chipset (Intel Corporation Plc., CA, USA). The SBC-FITPC2 is powered by a single 12V DC supply, drawing 8W under full load. Networking is supported by an integrated Gigabit PCI-Express Ethernet controller (Realtek RTL811), and a 2.4 GHz 802.11b/g WLAN (Ralink ST3090, using a WMG2503 mini PCIE module, based on Realtek TYL8187 chipset), mounted alongside 1GB of DDR2 RAM. In the Black Box, the standard magnetic hard drive is replaced by a 120GB capacity solid state drive (Vertex 2 SATA2, OCZ Technology Inc., San Jose, CA, USA) mounted in the 2.5” bay of the FIT-PC2 aluminium casing.

The Deltron 484 series enclosure used to house the Fit-PC2 is sealed with a neoprene gasket and six isolated screws, providing the highest possible level of Ingress Protection (IP68, IEC standard 60529: capable of withstanding submersion at 5m metres for 30 minutes). Pre-drilled external mounting flanges allow easy installation, and a polyester powder-coating protects the unit from corrosion. For the Black Box, the enclosure lid was machined by DEM-Manufacturing Ltd., Scunthorpe, UK, to incorporate an external heat-sink with a thermal resistance of 0.3 °C cm²W⁻¹ (DEM Manufacturing Ltd., Scunthorpe, UK) over its entire outer area. A bespoke brace is mounted on the interior of the enclosure, on the lid underside, allowing the FIT-PC2 to be clamped within the enclosure, directly under the external heat sink, with heat transfer between the two surfaces being conducted through ‘gap pad’ (Tpli 225, Laird Technologies Plc., MI, USA), which sits between the underside of the enclosure lid and the surface of the FIT-PC2, and, externally, also between the top of the lid and underside of the heat sink. Gap-pad is a thermally conductive pad (0.28 °C cm²W⁻¹) which has a dough-like consistency to conform and fill in between inconsistent surfaces, thus allowing efficient CPU heat transfer from the FIT-PC2 inside the Black Box housing to the external heat-sink via the enclosure lid.

Connections are made to the recording and processing unit through IP68-rated connectors (Bulgin Bucaneer 400 Series Micro-Connectors, Bulgin Components Plc., Essex, UK) mounted in holes machined from the enclosure walls. Four mini-USB ‘B’ type rear panel mounting connectors (PX0446, Bulgin Components Plc., Essex, UK) allow connection to USB peripherals through sealed mini USB ‘B’ type cables offering a standard ‘A’ type connection (PX0441, Bulgin Components Plc.,
A single standard panel mount USB ‘A’ type connector (PX0849/A) is also included for the permanent connection of a HSDPA USB modem (e1550, Huawei Technologies Co. Ltd., Shenzhen, China) within a flash-drive sheath (PX0852, Bulgin Components Plc., Essex, UK) offering IP68 ingress protection when mated with the panel mount PX0849/A connector. All USB panel-mount connectors are exterior-facing, and are terminated inside the enclosure with a lead terminated by a 5-way header. Each header is connected to a 5-way PCB adaptor lead (141193, Bulgin Components Plc., Essex, UK), itself terminating with a standard USB ‘A’ type male connector, mating with standard female connectors on the Fit-PC2.

To allow wireless access to the machines, a panel-mount IP68 SMB connector (PX0414, Bulgin Components Plc., Essex, UK) is mounted on the enclosure exterior, with a pig-tail attached to a reverse-polarity SMA connector (RG174, Amphenol RF, Danbury, CT, USA) allowing connection to the FIT-PC2 inside the enclosure. An external SMB, IP68, 2.4 GHz, 2dBi wireless antenna (PX0407, Bulgin Components Plc., Essex, UK) is mated to the SMB panel connector on the top of the unit.

Each Black Box is powered by a bespoke 35W, 12V, constant voltage LED driver (LXV35-012SW, Excelsys Technologies Ltd., Cork, Ireland) terminated on the supply side by a 3-pin 13A industrial plug for 240V AC domestic connection, and to a Bulgin Buccaneer 400 series in-line 3-pole micro-connector plug (PX0410/S, Bulgin Components Plc., Essex, UK) for 12V DC provision to the Black Box processing unit via the equivalent panel mount socket on the box exterior (PX0412/03P, Bulgin Components Plc., Essex, UK). Inside the Black Box, each of the three pins held captive in the panel-mount socket are terminated by a 2.5mm jack plug which connects to the FIT-PC2 power socket. Ingress protection for the power supply is IP67 (EN61347-1, -2, -13 compliant, UL8750 recognised), and operating temperature is -35 – 55 °C.

Bespoke Cameras

Waterproof cameras were built using C120 web camera (Logitech International S.A. Plc., Romanel-sur-Morges, Switzerland) circuit boards potted within a polycarbonate capsule using CT1 hybrid polymer construction adhesive (C-TEC N.I Ltd., Co. Down, Ireland). A potable water-grade rubber sheet gasket is used to seal the capsule onto an anodised aluminium ‘top-hat’ mounting, which itself screwed onto a 20cm anodised aluminium gooseneck. A USB 2.0 lead from the Logitech circuit board runs down the gooseneck from the head capsule, exiting through another ‘top-hat’ mounting, which acts as a mounting base for the camera unit.

The Black Box- Operating System
The Black Box operating system is an Ubuntu 10.04 (www.ubuntu.com) 2.6.31 kernel which was customised using patches developed by Ubuntu and Compulab Ltd. (Technion, Israel). For the CM-iAM computer-on-module pertaining to the Fit-PC2, the most significant features are presented here: (http://www.compulab.co.il/workspace/mediawiki/index.php5/Ubuntu_Linux_for_CM-iAM). The following modifications are essential in industrial environments, where back-up generators are regularly tested: (i) The Basic Input Output System (BIOS, Phoenix Technologies Ltd., CA., USA) was programmed in house by Compulab Ltd. so that the FIT-PC2 automatically boots upon a power connection, (ii) The Grand Unified Boot loader (GRUB2, www.gnu.org)/etc/grub.d/00_header was modified to remove a known bug (https://help.ubuntu.com/community/Grub2), allowing the kernel to automatically boot upon power re-connection following a power supply failure.

The Black Box- Firmware

Video streaming and storage by the Black Box is mediated through FFMPEG (www.ffmpeg.org), a cross-platform command line tool to convert multimedia files between formats. FFMPEG commands are issued via a BASH script, which records a time and date stamp before comparing them with conditional statements to determine whether the main program is executed within a user-defined time period. Upon satisfaction of the conditions, FFMPEG is instructed via the BASH program to record 3600 video frames at 4 frames per second in raw grey scale video format at a resolution of 320 x 240 pixels. An embedded C program to analyse bird movement is then initiated to extract apparent motion between video frames using the optical flow algorithm (Beauchim and Barron, 1995; Fleet and Weiss, 2005). Optical flow statistics, the details of which are presented below, are saved in ASCII format, whereupon the BASH script calls FFMPEG again to compress and archive the analysed raw video data in AVI format, ensuring for optimal video archiving. The process is iterated between two webcams attached via USB 2.0 to each Black Box, alternating between the two throughout the desire period of operation.
PHYSICAL DESCRIPTION
Dimensions: 222 x 146 x 106 mm.  Weight: 1.6kg (1.8kg with power supply).
Ingress Protection: IP68 rated components (IEC standard 60529: capable of withstanding submersion at 5m metres for 30 minutes).
Operating Temperature: 10-60 °C.
Casing: 2mm thick polyester-coated aluminium with drilled mounting flange.

COMPUTING UNIT
Processor: 1.6 GHz Atom Z530.
Chipset: US 15W.
Memory: 1 GB DDR2 RAM.
Ethernet: Realtek RTL811 Gigabit PCI-Express.
WLAN: RaLink ST3090 802.11b/g WMG2503 mini PCIE module, based on Realtek TYL8187 chipset.

STORAGE
120 GB OCZ Vertex 2 solid state drive (SATA2).

POWER SUPPLY
IP67 Power Supply: 35W @ 12V terminated with 3-pin 13A industrial plug.
Power Consumption: 8W (full load), 5W (idle), 1W (standby).

CONNECTIVITY
3 x Micro-USB type ‘B’, 1 x USB type ‘A’, 1 x Ethernet, 1 x 12V Power, 2 x 9-pin circular, 1x 2dBi 2.4 GHz wireless antenna.