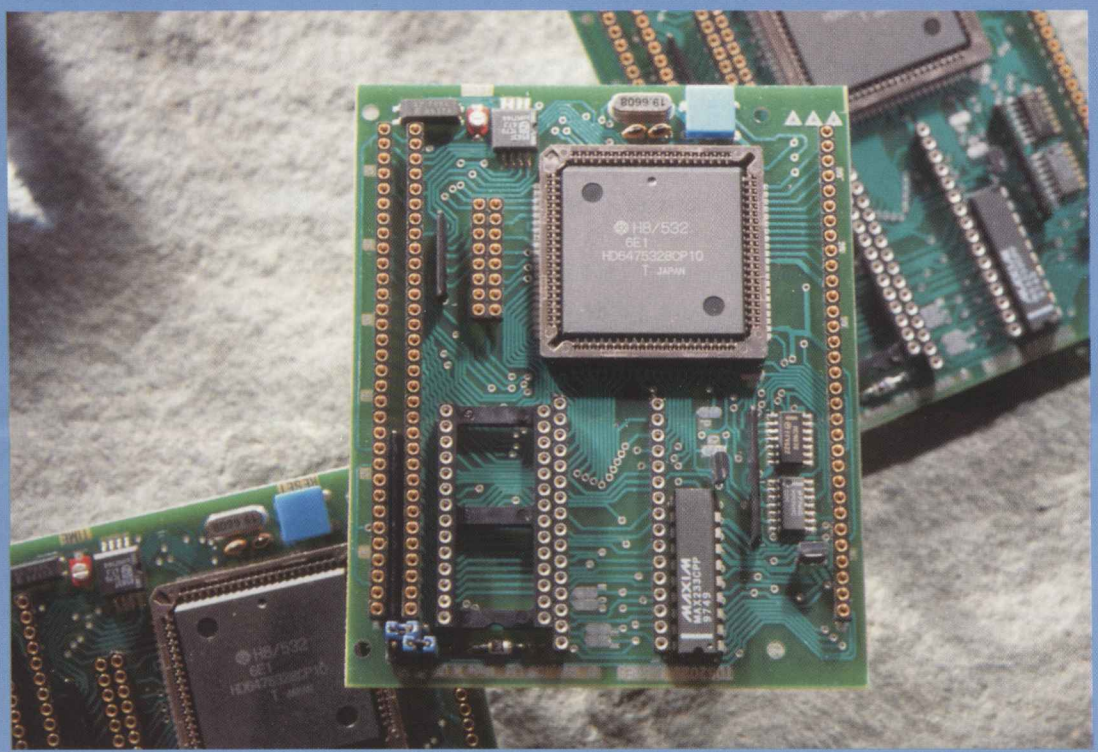
TDS2020F

16-bit Interactive Embedded Computer

AT LAST – the card computer that doesn't need a PROM programmer. FAST results for experts and non-programmers. TDS2020*F* is an ideal way to develop instruments and data loggers.



As a **Data Collection Module** with removable Card Memory option, you've little to add to its 10-bit 8-channel analog to digital converter, real time clock and memory of up to a gigabyte.

Applications include:

- Tide measurement
- Electric vehicle control
- Patient -worn medical recorder
- Geological instrumentation
- Black-box ship safety logger
- Road monitoring
- Pollution recording
- Pattern weaving
- Animal behaviour recorder
- Portable concrete logger

As a **High Performance 16-bit Control Computer** its on-board assembler and Forth high-level language make programming and debugging a pleasure, yet gives the execution speed you need in a real time system.

Applications include:

- Engine testing
- Food process machinery
- Weilding control
- Robotics
- Telephone exchange
- Under-sea remote control
- Electricity generator
- Weighing machine
- Motor speed controller

Triangle Digital Services

Technical Data

Latton Bush Centre
Southern Way · Harlow
Essex CM18 7BL
Tel 01279 639471
Fax 01279 639489
E-mail Business@TriangleDigital.com
Web www.TriangleDigital.com

Technical Data

TDS2020*F*

16-bit Interactive Embedded Computer

CONTROL COMPUTER & DATA COLLECTION MODULE

OVERVIEW

The TDS2020*F* is a powerful 16-bit control computer based on the Hitachi H8/532 microprocessor. Despite small size and low power consumption, it is packed with important features that make it easy to use in solving control and data collection problems.

Rapid application development is assured by the interactive nature of development and debugging. A library of software provides instant solutions to many application problems. Source code, written in the high-level language Forth, is directly compiled into Flash-EEPROM non-volatile memory. Coupled with the ready-made software modules, designs can be completed very quickly, even without a prior knowledge of Forth.

WHY FLASH?

Direct compilation to Flash-EEPROM is convenient and avoids the cost and development cycle of a PROM programmer. There is a further advantage - you can zap the program remotely over a modem and recompile. Suppose the TDS2020*F* were embedded in a vehicle or a pressurised vessel, you could update the program without even removing the computer.

WHY FORTH?

The reason for programming card computers in Forth is productivity - you get results faster with less cost. It is closer to the machine than 'C' but is a higher-level language than assembler. Unlike either, it is interactive, giving quicker development. The multitasking Forth specially written for the board gives easy access to all its features and allows software to be written quickly. It is American National Standard Forth with many extensions to exploit the hardware features of TDS2020*F*. The 16k-byte Forth includes LCD and keypad drivers, together with many other utilities and a full symbolic assembler. You write programs in high-level language, mixing it with assembler if required.

WHAT HARDWARE?

The TDS2020*F* is based on the Hitachi H8/532 microprocessor. There are 45k bytes of space for your compiled program and up to 512k bytes of Flash memory to keep vital data while the board is not working. This can be expanded to over a gigabyte with plug-in PCMCIA or Compact Flash cards.

A Controller Area Network adapter (CAN bus) allows fast interconnection of TDS2020*F* computers, with a PC in the network if required.

The board has between 26 and 41 Parallel I/Os depending on the other options selected and there are two RS232 Serial Ports. The Analog to Digital converter has eight channels of 10-bit resolution (better than 1 in 1000) and there are three channels of 8-bit Digital to Analog (1 in 250).

Additional features include four hardware Counter-Timers (three are 16-bit), two separate Watchdog Timers, non-volatile Time-of-day Clock and Multitasking. The single power supply draws 32mA with only 155µA in a low power operational mode for applications like datalogging. The TDS2020*F* measures just 100 x 80mm.

SPEED

The TDS2020*F* clock frequency is 19.6608MHz. Instructions are processed at an average of around 3 million per second (MIPS).

MEMORY

Inside H8/532: 32k-byte one-time programmable PROM carrying 16k Forth high-level language and 16k blank space for additional user application program. A TDS2020DV development piggyback board is available to emulate this memory but is not usually needed.

STAND ALONE SYSTEMS

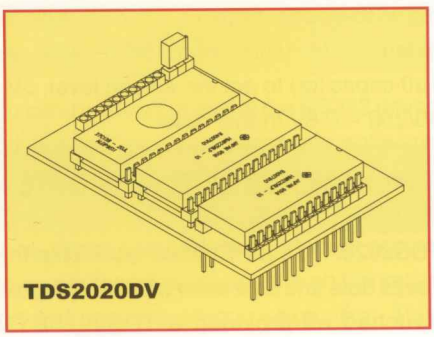
The TDS2020*F* card computer is incorporated into products. Forth compiled code ends up in non-volatile memory making the software a permanent feature of the system, even if the power is removed. You develop like this:

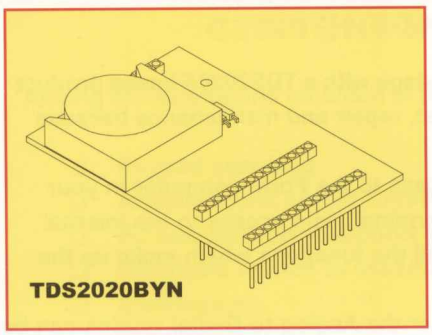
- ❑ Compile into RAM for initial tests and during most of the development.
- ❑ To debug, just type the name of the procedure, whether it is written in high-level language or assembler.
- ❑ When the application is working, put a Flash-EEPROM in place of the RAM chip.
- ❑ Recompile the source code into Flash-EEPROM.
- ❑ Tell the system the name of the infinite loop you want the card to execute on power-up. The Flash-EEPROM has now been protected—it is locked against accidental writes.
- ❑ Switch off the TDS2020*F*, disconnect it from both power supply and PC.
- ❑ You can now power-up into the stand-alone application.
- ❑ Escape to interactive Forth if there is a problem. All the application procedures are available to you. You can use them for testing and debugging.
- ❑ If you want to start again from scratch, you can unlock the Flash-EEPROM. You could now re-start from the beginning.

Once the prototype is complete, manufacturing can use copies of the Flash-EEPROM or the cheaper 27C256 EPROMs.

Technical Data
TDS2020*F*

16-bit Interactive Embedded Computer


TDS2020DV


TDS2020BYN

Inside H8/532: 1k-byte RAM, of which half is needed for the system leaving 512 bytes free for use as variables by the application program. Many control uses will need no further RAM memory.

28-pin socket: 32k-byte non-volatile Flash-EEPROM for the user application program. with 29k bytes available for code. The TDS2020*F* is priced with this socket empty, although the TDS2020*F*-SP Starter Pack includes a 32k Flash-EEPROM for this position. In other configurations, this socket can host a 32k-byte RAM or 27C256; choose from the price list.

32-pin socket: 512k, 128k or 32k RAM, EEPROM or Flash memory for additional variables, scratchpad arrays or data storage. EEPROM and Flash keep data with power off; the RAM can be made non-volatile by adding the TDS2020BYN piggyback battery board or an external lithium cell. Circuitry to ensure that data will not be corrupted is built into the TDS2020*F*. Signals are available to indefinitely expand the memory off the board. The TDS2020*F* is priced with this socket empty.

Clock chip: The on-board clock chip has 239 bytes of free RAM that are accessible over the I²C bus. If the TDS2020BYN (or other) battery is added, this RAM (as well as the real time clock and RAM in the 32-pin socket) will be retained while power is off.

PARALLEL INPUT-OUTPUT

The parallel port capability of TDS2020*F* depends on whether the analog and other facilities are used or not.

TABLE SHOWING SOME OF THE POSSIBLE I/O PLANS

Plan	Inputs	I/O	Clock/I²C	A/D	D/A	External Interrupts
0		26	yes	8	3	3
1		29	yes	8		3
2		31	yes	8		1
3	8	29	yes			3
4	8	31	yes			1
5		28	no	8	3	3
6		31	no	8		3
7		33	no	8		1
8	8	31	no			3
9	8	33	no			1

Pins can be set for different functions so the number of free parallel inputs and outputs depends on whether Analog to Digital conversion, non-volatile Time-of-Day Clock etc. are needed. From this table you can check how many spare ports are available. In summary, the number of parallel input or output bits is between 26 and 41 depending on other facilities used. The number is easily expandable.

I²C BUS

This is a two wire system for use with low cost peripherals such as A-D converters, clocks, I/O, RAMs, EEPROMs etc marketed by Philips, Signetics, Xicor, Microchip Technology and others. The board has a PCF8583 clock chip and RAM connected on this bus. Other I²C chips can be added externally.

MICROPROCESSOR

The microprocessor is an H8/532, a 16-bit device with eight general-purpose 16-bit registers, hardware 16-bit multiply & divide and 8 & 16 bit instructions. Direct bit manipulations operate with registers, all memory and input-output. The crystal frequency is 19.6608MHz and the device runs in the expanded maximum mode with a 1024k-byte memory space.

It has much on-chip hardware including three 16-bit counters or timers, one 8-bit counter/timer, synchronous or asynchronous serial port and a very versatile interrupt system (65 interrupts and DTC vectors, 8 priority levels). The Data Transfer Controller (DTC) enables transfers between I/O and memory without any software.

All the capabilities of the processor are available to the TDS2020*F* user, but through the high-level language Forth, which makes them easier to employ. Access to some of the microprocessor hardware facilities is already built into the Forth system but the user is free to use them in his own independent way, via Forth or assembler.

16-bit Interactive Embedded Computer

USING FORTH IN THE FIELD

When you finally reach the manufacturing stage with a TDS2020*F* based product it is not the end of Forth. Use it for final test, repair and maintenance because the language is on-board.

Build in a connector that gives serial access to the Forth computer in your instrument. Now, with a PC or hand-held terminal, gain access to the internal language system. You can have available all the functions which make up the application.

For example, in an electronic thermometer the Analog to Digital routine can be separately exercised to see if the fault is in the input transducer or amplifier. If not, follow with a test of the LCD by writing a few characters to it. Likewise, test the keypad by pressing a key to see if it returns the expected code.

If necessary, the whole of the compiled code can be erased from the Flash-EEPROM. New source-code can then be recompiled, even remotely over a modem (or into an inaccessible location). No chip or link change is needed to make a stand-alone system.

On-board Forth is very useful during design, but the ability to access an individual software procedure in a finished product is unique and invaluable.

See the TDS2020HM Hardware Manual for full details of the microprocessor.

KEYPAD SUPPORT

A unique software and hardware system enables up to 64 keys to be connected to the computer and only eight of the parallel input/output lines are required. You connect a particular parallel output port to one side of an 8 x 8 key matrix via diodes. The other side is returned via another eight diodes to the data bus. The Forth system has words that scan the keypad and return 0 if no key is pressed and 1 to 64 otherwise.

LIQUID CRYSTAL DISPLAYS

Any alphanumeric LCD based on the HD44780 chip connects directly to TDS2020*F*; software to drive it is built into the card. One external chip enables up to eight LCDs to be connected and the software caters for them all simultaneously. Graphics LCDs also connect without any extra hardware; driver software is supplied on disk for displays based on the HD61830, T6963C and other graphics controllers. With extra hardware incorporating a controller chip, 1/4 VGA to full VGA displays can be attached to TDS2020*F*.

EXTERNAL PERIPHERALS

The full data and address buses as well as five uncommitted decoded addresses for use as chip selects of peripherals are provided. LCDs, extra parallel I/O, a quad serial port chip or similar devices can be added without any interface chip.

ANALOG TO DIGITAL CONVERTER

The TDS2020*F* has an eight channel 10-bit A to D converter giving one part in 1024 resolution. Conversion time is 27µs using a supplied library program. An input voltage of 0V gives 0 and + 5V gives 1023. The on-board reference is 5V±0.05V and there is facility for connection of an external reference. If the A to D is not used, the eight pins automatically become extra parallel input ports.

DIGITAL TO ANALOG CONVERTER

There are three channels of 8-bit Pulse Width Modulated (PWM) D to A conversion that act as three extra bits of parallel I/O when not used. For example, you could choose to output a 20kHz waveform with a mark-to-space ratio of 40:210. Add an external filter (such as a 10K resistor and 1µ0 capacitor) to get the analog level, 5V x 40/250 = 0.8V in this case.

NON-VOLATILE TIME & DATE

TDS2020*F* has a PCF8583 clock chip that keeps date and time even with the computer switched off provided a TDS2020BYN, TDS202BYD or external battery is added. The battery is also used to maintain up to 512k bytes of non-volatile RAM. A typical consumption is 3.5µA.

Date & time are accessible to a resolution of 813 nanoseconds because another clock running under interrupt mirrors the chip clock. Both European and USA date formats are supported.

The clock chip generates a one-second Non Maskable Interrupt (NMI). This does nothing by default, but it can be redirected to execute a user routine in either high-level Forth or Assembler. The repeat time can be changed in very small steps to give intervals from 30ms to a year.

TIMER-COUNTERS

There are four hardware timers (plus the clock chip); one is 8-bit and the other three 16-bit. Each can be clocked internally at any of three rates, or externally for event counting. They all have two output capture registers and the three 16-bit timers have an input capture mode. Multiple interrupts are associated with the timers to process asynchronous events in high-level Forth or assembler.

WATCHDOG TIMERS

If the microprocessor crashes through a power spike or otherwise, one of the watchdog timers will reset the system. The application program will be started again. There is an internal watchdog and a counter external to the microprocessor. Both are reset by many Forth words and will time-out and re-start the system if something goes wrong.

Technical Data

TDS2020*F*

16-bit Interactive Embedded Computer

LOW POWER MODE

You can switch off power to the RS232 driver and put the microprocessor into software standby mode. Current consumption is now down to typically 155µA plus any external loads. When a Non-Masked Interrupt occurs the computer will wake up, turn on the serial port and continue program execution. This makes the TDS2020*F* ideal for portable and data collection applications.

POWER SUPPLY

A single supply of +6V to +16V is used, typical current 32mA. A low power operational mode consumes only 155µA and needs no external hardware support. The board has a ±8V generator for use by the serial ports and this can be turned off by software to save power. The negative supply is also useful for some external peripherals. The regulator on the board can supply up to 100mA so there is extra current available to power any external circuitry particular to the application.

BUS INTERFACE

The TDS2020*F* bus is compatible with almost any peripheral chip such as A-D converters and multiple serial port devices.

PHYSICAL

The board size is 100mm x 80mm with mounting holes for 2.5mm screws. Maximum height, excluding pin connectors, is 15mm. With the TDS2020*F* in pin sockets of the type stocked, the distance between the computer and the motherboard is 11±1mm. This should be the length of spacers, if used. The operating temperature is –10 to +70°C (others to special order). Pin connectors are standard (TDS2020*F*) with a DIN 41612 type C connector optional (TDS2020*F*-PLUG).

FORTH ROM EXTENSIONS

Among the extensions included in the Forth ROM are:

- **Keypad scanning**
- **Alphanumeric Liquid Crystal Displays**
- **I²C bus peripheral support including on-board clock & RAM**
- **Interrupts written in assembly code or Forth**
- **Multitasking**
- **Time-of-day Clock**
- **Watchdog timer servicing**
- **Low power operation**
- **Complete symbolic assembler**
- **Vectored serial I/O and several other vectored words**
- **Double number (32-bit) arithmetic and stack handling**
- **Execution time measurement accurate to 1µs**

ANS FORTH SYSTEM

The language is a full implementation of American National Standard Forth, including floating point (extra charge). There are many extensions useful to developers of single board systems. For example, the number of microseconds taken by any Forth word can be accurately measured in real time. The language has been specifically implemented for the H8/532 microprocessor. It uses the chip's facilities wherever possible, e.g. Forth multiplies and divides are built up from the 16-bit hardware multiply/divide instructions. Its bit manipulation instructions are also employed, they are especially useful for detecting and switching single I/O lines.

The application code is compiled into non-volatile Flash-EEPROM to instantly create a stand-alone system. Apart from Forth, the system ROM has a symbolic assembler enabling you to write machine code directly on the board. No cross-software is necessary so an assembler routine can be tested immediately without any downloading step. Interactive debugging of assembler code is very powerful.

MULTITASKING

Develop printer, display and communications programs as separate entities, then using the pre-emptive multitasker let them run all at once on the TDS2020*F*.

Debugging of each task can be done independently of the others using the interactive Forth facilities that allow running of a sub-program just by typing its name. The final stage is to combine the individual programs, essentially a mechanical step following rules.

Perhaps the most important use is to make interactive Forth language one of the tasks. This adds an exciting new dimension to debugging embedded systems. For example in an electric vehicle you could monitor and adjust performance while in motion via common variables. While you type in new commands, other tasks will continue controlling motors, displaying results on a graphics LCD and collecting performance data on a Compact Flash card.

INSTANT SOLUTIONS

Software modules that easily connect can form the major part of your application program. Ready-made routines are available (see table on page 6). For more details see the Applications Software

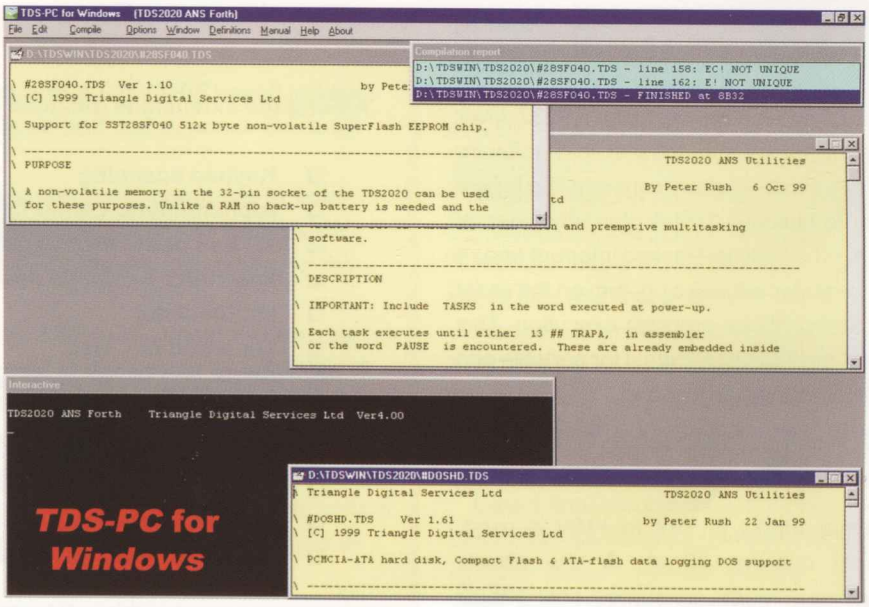
16-bit Interactive Embedded Computer

datasheet. Most are free on the Starter Pack CD but extended multitasking and other utilities are available through the Update Service (see page 8). In addition, for a fee there is a fully featured floating point package for the TDS2020*F*, order code TDS-FLOAT-ANS.

DEVELOPMENT REQUIREMENTS

The development environment *TDS-PC for Windows* is PC software with terminal emulation and multiple-window editing facilities. Source code is stored on the PC disk, although compilation takes place inside the TDS2020*F*. The source program you write is automatically sent from the PC's serial port to the TDS2020*F* for compilation there. The code is then debugged interactively in the TDS2020*F*. *TDS-PC for Windows* also runs on Macintosh PC emulators.

Once your program is developed and working nothing else is needed for the standard development arrangement. No PROM programmer is needed because the code has been compiled into non-volatile Flash-EEPROM.



PCMCIA & COMPACT FLASH DATA LOGGING

For full details see the separate Data Logger datasheet.

The TDS2020CM2 sits on top of a TDS2020*F* board to form a data logger module complete with ejector mechanism. PCMCIA memory cards and Hard Drives can be used. A PC can read the data directly from the card into an Excel spreadsheet or Access database.

Compact Flash cards as used in digital cameras also fit into the TDS2020CM2 using a TDS2020CFA converter. One advantage of Compact Flash is that the edge of the card is flush with the edge of the TDS2020*F*. It is easier to mount the module in a sealed box.

NETWORKING

Controller Area Network (CAN bus) sends messages of up to eight bytes. Both low level and high-level widely used CAN protocols are provided. The bus is the basis of CAL, DeviceNet, and the network used by the automotive industry in cars and trucks. For full details, see the CAN bus datasheet.

The network may have up to 110 daisy-chained nodes with a total network length up to 1000m. It typically uses two twisted pairs, one for signal, one for power.

BACKWARD COMPATIBILITY

PROM programmers are outdated in many applications. The Flash Forth kernel has direct compilation to a Flash-EEPROM non-volatile memory chip. It is not necessary to blow an EPROM any more. The last hurdle in developing with TDS2020 has been eliminated.

Ready Made Routines

- Analog input
- Analog output
- ANS Forth
- Audio
- Battery power
- Benchmarks
- CAN bus
- Compact Flash
- Control loops
- Counters
- Data logging
- Date & time
- Digital input
- Digital output
- EEPROM memory
- FFTs
- Flash memory
- Floating point
- Forth extensions
- Frequency
- GPS positioning
- Hard disks
- I²C Bus
- IEEE-488 bus
- Integer maths
- Interrupts
- Keypads
- LCDs-CAD drawings
- LCDs - character
- LCDs - colour
- LCDs - graphic
- LCDs - pictures
- LCDs - touch
- LCDs - VGA
- Light input
- Memory expansion
- Microphone
- Modems
- Motor control
- Multitasking
- Networking
- NV-Memory
- Operator input
- Opto-isoloation
- PC cards (PCMCIA)
- Portable use
- Printers
- Protocol conversion
- PROM programming
- Quad UART
- Radio clock
- Regular events
- Resource locks
- Serial communications
- Shaft encoders
- Speech
- Stepper motors
- Strings
- System security
- Temperature sensing
- Timekeeping
- Timer-counters
- Touch-screens
- Trigonometry
- VGA screens
- Video
- Watchdogs

Technical Data
TDS2020*F*

16-bit Interactive Embedded Computer

The new version 4 kernel is an update to ANS Forth version 3.06 and 3.06A. This Flash Forth is the version for new developments. It is not binary compatible with earlier versions - applications should be recompiled.

Previous TDS2020 users can enjoy Flash Forth. Ask for details of the small modification that you can make yourself.

TDS2020*F* FORTH CHIPS

As well as forming the basis of the TDS2020*F* computer, the microprocessor, gate array and software are also available as a chip set for use in other embedded systems. For details including circuit diagrams and ordering information ask for the Components for Embedded Computers datasheet.

TDS9092 EMBEDDED COMPUTER

This is the TDS2020*F*'s smaller brother, not quite as powerful but cheaper. Ask for the datasheet.

Especially low prices can be quoted for TDS9092 in quantity.

ON THE WEB

Latest support software for TDS2020*F* is available on the Web at **www.TriangleDigital.com**. Both the *TDS-PC for Windows* development environment and ready-made software modules can be downloaded. Apart from files reserved for Update Service customers all the web software is free of charge.

The Web pages also contain the text of principal datasheets. There is a summary of each library routine, readily accessible from an index. The site includes details of many TDS2020*F* applications and links to the pages of some customers.

Starter Pack

ORDERING INFORMATION

SUGGESTED FIRST ORDER

TDS2020*F*-SP Starter Pack contains most of what you need for TDS2020*F* development. Also required are the book **STARTING-FORTH** (if Forth is new to you) and a PC. For data-logging applications you also need to order a RAM or Flash chip to hold the collected data. Alternatively, add a **TDS2020CM2** PCMCIA adapter (with Compact Flash converter **TDS2020CFA** if required) and an appropriate RAM, Flash or hard disk card. If you choose Flash or disk, add a 128k or 512k RAM to act as cache memory. Also, add a **TDS2020CAN-PIN** bus adapter if needed.

MANUFACTURING

These order codes are for use in manufacturing once development is complete:

- **TDS2020*F*** version with 64 way pin header connector
- **TDS2020*F*-PLUG** version with 64/96 DIN41612 connector type C

Starter Pack

The order code **TDS2020*F*-SP** includes

- **TDS2020*F*** card computer with Forth in the microprocessor
- **RAM32K** RAM for holding program during development
- **EEPROM32K** Flash-EEPROM for compilation in the latter stages
- **PINSOCKETSET** set of sockets for the prototype application
- **TDS2020TM** TDS2020*F* Technical Manual
- **TDS2020HM** microprocessor Hardware Manual
- **TDS2020PM** microprocessor assembler Programming Manual
- ***TDS-PC for Windows*** CD with development system, software library, website and other useful material.

Flash Forth is pre-loaded. The Program and Data sockets are supplied empty. For the 28 pin (Program) socket you will need to order EEPROM32K or 27C256. For many control applications you will need no further chips. For use in the 32 pin (Data) socket order 28SF040 512K bytes Flash chip or RAM128K / RAM512K.

16-bit Interactive Embedded Computer

Contact us if you would like a copy of any other datasheets

8-Bit Card Computer
For simpler applications in control or data logging the TDS9092 8-bit card has many similar features to TDS2020F but at a lower price.

Data Logger Module
A PCMCIA and Compact Flash solution for TDS2020F to hold large quantites of data in removable or transmittable forms.

Components For Embedded Computers
For quantity usage, a Chip Set solution for the commercial manufacturing of systems developed with either Card Computer.

Can Bus Adapter
Communicate over secure Controller Area Network to control dispersed systems. Use re-programmable intelligent nodes and a PC link. For TDS2020F or TDS9092.

Application Software Library
Descriptions of source code available to customers and Update Service subscribers - continuously being updated.

Text to Speech
If you can display it, you can speak it. Converters for text to speech in PC, card and boxed formats from RC Systems Inc.

A Promotional CD is also available containing prices, specifications, circuit diagrams, web site, TDS-PC for Windows development environment and most of the applications software library.

UPDATE SERVICE

For a yearly subscription you can be sent the latest releases of TDS library routines plus the following:

- Co-operative traditional Forth multitasker
- Pre-emptive multitasking
- Latest updates to TDS-PC for Windows
- Source code for TDS-PC for Windows
- Forth words database and indexing utility
- Source code optimisation utility
- Extended software library routines
- New additions to the library
- New Forth kernel when there is an update

Triangle Digital Services Ltd

Latton Bush Centre
Southern Way
Harlow
UK
CM18 7BL

Tel **+44 1279 639471**
Fax **+44 1279 639489**
E-mail **Business@TriangleDigital.com**
Web **www.TriangleDigital.com**

Representatives

USA & Canada
Saelig Company LLC

Tel **716 425 3753**
Fax **716 425 3835**
E-mail **saelig@aol.com**

Netherlands
Lismar Engineering BV

Tel **020 496 6026**
Fax **020 496 5174**
E-mail **lismar@compuserve.com**

Italy
Leane International srl

Tel **0521 242495**
Fax **0521 242505**
E-mail **leanepar@tin.it**