CAN implementation on Terrier

Graham Taylor CEng, MIET, BAE SYSTEMS, Land Systems

TITAN©, TROJAN© & TERRIER© vehicles are the latest generation of Engineering Vehicles entering service with the British Army. TITAN© and TROJAN© are both based on the heavily armoured Challenger 2 hull having a large degree of commonality with their forebear and leant heavily on existing sub-assembly designs. CANBus was integrated into the vehicles' electronic architecture to facilitate the trials programme. TERRIER© is an entirely new design and with it came the opportunity to integrate the latest technologies into a versatile, lightly armoured, highly manoeuvrable, tracked engineering vehicle. TERRIER© has a completely new and unique chassis and integrates COTS components over a wide range of functions. From the initial design CANBus was selected as the control bus architecture, with MilCAN as the preferred protocol. TERRIER© utilises multiple CANBus segments functionally segregated for Power Management, Command & Control, Special-to-Role and Automotive related operations. As an additional robustness measure, dual-redundant CANBus segments have been integrated in key areas.

1 MilCAN overview

MilCAN as a deterministic CAN protocol is ideally suited to the tough environment experienced by engineering vehicles. Having the simplicity of a look-alike J1939 frame, adopting the MilCAN A protocol means that relatively un-sophisticated nodes may be integrated onto a segment, minimising development timescales which are an imperative for the short-production runs afforded by many UK military projects. This coupled with the fully deterministic behaviour of the protocol and the natural robustness CANBus, enables the overall vehicle system behaviour to be optimised for performance at an affordable price.

2 MilCAN protocol

Conforming to ISO 11898-1, the 29-bit extended identifier of MilCAN is arranged into a number of fields to include a 3-bit priority, and Main Function, Sub-Function and Source Address of 1-byte each. This enables the design authority to determine the performance of system by manipulating the priority of each message on the bus according to the guaranteed deterministic data latency and also to manage bus loading. The data load is message dependant and may be upto 8-bytes. The MilCAN protocol supports multi-frame messages normally reserved for non-time critical data.

MilCAN supports a fairly simple Modes of Operation 4-state sequence. After a Power-On, Reset, loss of Sync Frame or on exiting their System Configuration state, each node enters Pre-Operation where they remain quiet until a valid Sync Frame or Enter System Configuration message is received. On receipt of a Sync Frame devices enter their Operational Mode, exit from which is by Reset or a significant loss of Sync Frames.

Another feature of MilCAN A is the resilience afforded by multiple redundant bus master arbitration with the highest priority message on the bus providing a sync message with a frame count.

3 MilCAN hardware requirements

Of course these advantages do come with some impact on the hardware. Although MilCAN may be run on standard CAN 2.0 hardware an efficient implementation particularly for the Sync Master, requires a very accurate oscillator to bit-timing, galvanic isolation for the CAN transceivers, and a chip set that supports prioritised queuing with no re-transmission on error.

The full set of specifications is available from the http://www.milcan.org/ website

4 TITAN© & TROJAN©

The development programme for the electronic architecture for the Engineer Tank System comprising TITAN© bridge-layer and TROJAN© engineering vehicle was undertaken prior to the publishing of the MilCAN data-link layer, however the ETS engineering team was aware of the importance MilCAN standard had within the military Vehicle Systems Integration working group http://www.vsi.org.uk/, and adopted the protocol before it was ratified.

VSI proposed various electronic architectures for different types of military platforms, with engineering vehicles ranked as being of medium complexity.

5 Vehicle systems integration

Here extensive use of MilCAN for interconnection of subsystems is recommended. In the example two MilCAN subnets are shown interconnected via bridges to a MilCAN backbone. The use of MilCAN in this way allows the architecture to be partitioned on a functional basis since each subnet can perform a different function e.g. automotive, power distribution or control. Bridges are used to limit the traffic onto the MilCAN backbone and effectively limit data throughput on the backbone as the architecture is enhanced. The backbone only carries the traffic that is either essential for subnet to subnet interaction, import or export via BOWMAN – the military communications system, or to carry data for use at the BOWMAN User Data Terminal.

Where the subnet to subnet data carrying capacity is great or where sub-systems connected directly to the backbone require higher data throughput than MilCAN can provide, then a high bandwidth technology such as Standard or Gigabit Ethernet is recommended.

6 CANBus on TITAN© & TROJAN©

The CANBus on ETS was used primarily for data-logging during the extensive vehicle trials programme. The single segment bus was essential to the gathering of data from custom units such as the Driver's & Commander's Control Panels, Display Panels, Power Pack Control Unit, Hydraulic Control Unit, Bridge Launch Control Panel and Indirect Vision Video Control Systems for off-line analysis during Reliability Growth Trials.

7 CANBus on TERRIER©

When the TERRIER© Contract was awarded, the teams developing ETS & TERRIER© were each part of competing organisations. With the well publicised acquisitions within the UK Defence industry both teams find themselves still operating from separate sites but now interacting as a single organisation. It's a tribute to the efforts of MilCAN working group that both teams completely independently opted to employ it as the protocol to meet their CANBus needs.

The TERRIER© light engineering tractor is designed around a completely new and novel chassis optimised for mobility and survivability in the indirect battle zone. With a clean slate to work on, the development team took the opportunity to follow the VSI guidelines, albeit non-mandatory, in the architecture of its vetronics.

During the Product Definition phase prior to contract award, the aim of the team proposing the initial vetronics architecture, was to integrate as many of the vehicle's electrical sub-assemblies onto one or other of a set of inter-linked CANBus segments maintaining strict functional segregation. 5 CANBus segments were initially identified namely automotive, power-management, C2 Command & Control, DbW Drive-by-Wire and finally STR Special-to-Role.

8 TERRIER© - MilCAN enabled functions

The disposition of electrical units associated with the Automotive and Power management segments was relatively easy as each segment was fully in the domain of individual sub-contractors. Additionally electronic assemblies on the engine and power distribution and already were linked by a serial bus structure.

There was no real advantage to be gained in seeking to migrate from the J1939 on-engine CANBus over to MilCAN. In fact there was a major risk to the program if that avenue was to be pursued as the proposed engine already had a well proven pedigree using J1939 and the development costs of changing were astronomical. However it was proposed that the Power Pack Controller would be modified to include a MilCAN interface to bridge to the Drive-by-Wire segment.

The Integrated Logistics Support community was also able to give this decision their blessing as both J1939 and MilCAN use the ISO 11898 bus so common diagnostic toolsets could be used.

Similarly, the proposed Power Management sub-system was already based on a serial bus structure. However in this case neither the Command bus nor the Control bus was based on CAN and the sub-system already needed a significant amount of development before it was fully militarised. So the decision was taken to move to MilCAN for both of its buses.

The rest of the electrical units were associated with the 3 remaining segments and discussions with the manufacturers were begun where a MilCAN interface was not part of their initial offering.

The Award of Contract for TERRIER© in July 2002 helped to focus the technical discussions with the suppliers of electrical sub-systems. Some were already convinced of the benefit and were of themselves already offering MilCAN interfaces. Some were open to persuasion albeit with technical support from the team, and some others were unable to offer MilCAN as their interface.

Of this last group, the main reason appeared to the availability of hardware and software COTS solutions for MilCAN, as they had little or no detailed electronic design expertise within their organisations.

TERRIER© uses COTS sub-systems where feasible, the sub-systems themselves using COTS industrial controllers. Where the sub-contract expertise was in electrical assembly and programming rather than original electronic design, or the offering was based on an already well developed commercial product there was, quite understandably, a reluctance to change.

9 TERRIER© – CANBus architecture

When faced with such an intractable position the only practical way forward was to provide the necessary interface from another sub-assembly and bridge onto the MilCAN where necessary. This in turn compromised the "ideal" architecture originally proposed and a number of trade studies were undertaken as the disposition of the units changed their CANBus associations according to the interfaces available.

The trade studies were quite intensive being driven by the ILS team and covered the complete set of issues through the product's Life Cycle.

The trades strongly informed the outcome of the final vetronics architecture. The number of CANBus segments was reduced to 4 and the functions of the Vehicle Computer and Drive-by-Wire Controller were combined with additional RS422 ports.

One of the biggest risks to a serial-bus based Vetronics Architecture is the integrity of the data buses. This was of particular concern on TERRIER© as the mechanical analysis of the hull had identified peaks of high vibration when using the rock-hammer or when running at high speed over concrete roads. Electronics can be protected from the worst of the problem by a combination of modal analysis during the design of the sub-assembly chassis combined with the and / or the judicious use of anti-vibration mounts. However cabling and hull penetrations for connectors do not have all the same options open to them.

For a new structure such as TERRIER© the full set of vibration modes of every plate comprising the hull is impractical to analyse in sufficient depth prior to building the prototype. To help mitigate the risk that the CANBus would be unable provide an adequate quality of service under all conditions, it was proposed that mission critical buses would be made dual-redundant unless there was a body of evidence to the contrary.

The power pack, comprising engine, transmission & final drive has its own AV mounts and although it generates a fair amount of vibration, the on-engine CANBus was of sufficient pedigree and maturity to remain single. The 3 remaining CANBus segments were possible candidates to be dual-redundant. The most mission critical of these is the Power Management segment and this was already proposed with fully dual-redundant controllers and power distribution network.

The Drive-by-Wire and Special-to-Role Controllers were fitted out with MilCAN bridges each acting as secondary bus masters for the other, so a reasonable level of fault tolerant robustness was inherent in the bus structure. To further mitigate risk given the number of unknowns, the decision was taken to implement the C2I and Special-to-Role buses as dual-redundant segments also.

10 TERRIER© - MilCAN bus interconnect

Cabling multiple segments of dual-redundant CANBus has its own issues. Various topographies are suggested by the MilCAN specifications and there are many stakeholders in the decision. Suppliers, designer, integrators, connector & cable manufacturers, trials team, maintainers, supportability all had some impact on the outcome. The ILS team undertook a trade-off study resulting in a combination of through-unit cabling and T-junctions that was the adopted solution. A major limiting factor was the 1M-bit data rate that puts a tight constraint on the lengths of the cable spurs and segments. In some cases this caused a re-think on the part of suppliers as to the disposition of the CANBus transceivers within their equipment.

11 MilCAN - Vehicle system development

During the Project Definition phase, CANBus networks, nodes running MilCAN protocol were modelled using COTS software tools. This continued into the Development phase for progressive functional testing and integration of the various sub-systems using emulators and prototype equipment as it became available. However the real-time demands of the CANBus system soon outpaced the capacity of the emulation PC platforms and migration to performance testing real hardware was only possible using dedicated COTS microcontrollers for the Network Managers, Sync Masters & Bridges.

12 MilCAN - Network manager & bridge

By the conclusion of the Project Definition phase it was evident that no available COTS hardware would of itself be able satisfy all of the key network functions and hence the development of a PCB to satisfy these roles was budgeted.

The design was based upon a VME board format, mainly for convenience as this was the processor backplane of the STR & DbW Controllers where the Bridge & Network Manager resides. Located at a Bridge point, a pair of microcontrollers with on-chip, multi-channel, CAN controllers were arranged on the board each to govern one of the CANBuses. The opto-isolated CAN transceivers were supplied from separate on-board DC-DC converters and the two microcontrollers had separate data paths to a RISK communications processor. This is responsible for transferring MilCAN data across a Dual-Port RAM to the VME bus to & from the application software.

This architecture was able to deliver very accurate bit-timing, synchronisation and data throughput as well as deriving additional system integration benefits as the MilCAN protocol is handled entirely within the board relieving the applications processor of this low-level task.

Robustness of the network is enhanced by the cross-coupled microcontrollers residing in separate sub-assemblies acting as sync master, network manager and data-bridge for one the dual-redundant MilCAN segments as well as being the secondary bus master for another segment.

13 Vehicle trials programme

The TERRIER© prototype is still in the throws of an exhaustive trials programme with the 4 demonstrator vehicles presently being built with an identical vetronics architecture. The performance analysis of the CANBus architecture is underway, but has many more months to run before a conclusion is reached. Early signs are that the CANBus design is conservative and for the series production models dual-redundant cabling for all of the MilCAN buses as may not be necessary. Further analysis and risk mitigation trades will follow to determine the final configuration adopted.

References

[1] MilCAN Specifications
http://www.milcan.org/
[2] Vetronics System Integration
http://www.vsi.org.uk/
[3] VSI Standards & Guidelines
http://www.vsi.org.uk/standards/index.html