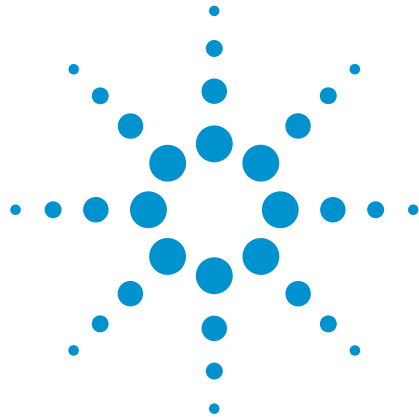


Agilent J8120A VPT501 Vehicle Protocol Tester Series 500 Testing for Timing Problems in CAN and LIN Networks Application Note



Overview

This application note explains how the J8120A Agilent Vehicle Protocol Tester (VPT501) can be utilized as a test tool enabling the identification and isolation of network timing problems which, if left undetected would compromise the reliability of the system.

Definitions

Age – Time measured for completion of an event or a sequence of events.

Arbitration – Process of determining which node is allowed to communicate on a network at a given time.

CAN (Controller Area Network) – 1 Mb/s, multi-master networking protocol.

CRC (Cyclical Redundancy Checksum) – An modular arithmetic calculation utilizing the communication coefficients and a polynomial equation fitted for minimizing the probability of undetected communication errors in the given type of communication (CAN, FlexRay, etc.).

FlexRay – 10 Mb/s, dual wire physical layer based networking protocol supporting both synchronous (required for safety critical applications) and asynchronous communication simultaneously.

Follow Up time – The amount of time measured between consecutive occurrences of a frame.

Frame (message) – the complete collection of bits constituting a communication sequence (start sequence, header, control fields, data bytes (signals), check sum, and end of frame) from a publishing node.

Function – Control mechanisms, including the calculations and logic used in defining the relationship between a logical group of correlated inputs and outputs.

Gateway Delay – The amount of time measured from when data that requires gatewaying across networks is received by the gateway node until the gatewayed data is observed on the appropriate gatewayed networks.

Gateway – a node which interfaces multiple networks and is responsible for transferring data between those networks.

Interface – A physical connection between a node and a network.

LIN (Local Interconnect Network) – 20 Kb/s, master/slave, single wire physical layer based networking protocol, primarily a sub-bus used for low speed non-critical applications.

Max Age – A design timing requirement specifying the maximum time duration allowed for execution of a specific control function.

MCF (Master Configuration File) – Database file including the network definitions for nodes, frames, signals, and the associated timing parameters used by timing checker.

Message (frame) - the complete collection of bits constituting a communication sequence (start sequence, header, control fields, data bytes (signals), check sum, and end of frame) from a publishing node.

Min Age – A design timing requirement specifying the minimum time duration allowed for execution of a specific control function.

Network – a physical communication media (often wire) interconnecting a series of nodes where communication of data parameters (signals) are used for controlling distributed system functions.

Node – An ECU that communicates on a given network or networks.

Periodic – a signal or frame which is transmitted repeatedly with a constant frequency.

Publisher (Same as Transmitter) – A node that sends a specific set of data on a network.

Publisher Delay – The amount of time measured from when the state of a sensor or input changes until the corresponding data or frame is sent on the network.

Receiver – A node that receives a specific set of data from a network.

Signal – (a) A stimulus (electrical, light, heat, other) measured by one or more nodes used in the control logic and/or calculations relating to one or more functions. (b) One or more data bits contained within a frame used for communicating a measurement value, status or command to other nodes within the system.

Signal Chain Analyzer – Codeless Communication.

State Change – A signal type that is only transmitted when there is a change in the signal value.

Subscriber (Same as Receiver) – A node that receives a specific set of data from a network.

Subscriber Delay – The amount of time measured from when data that requires a local output state change is received by a subscribing node until the output state change is observed.

System – Group of nodes interconnected through networks.

TDMA (Time Division Multiple Access) – A communication method where a carrier frequency is multiplexed (divided) into sequential time slots where single nodes must transmit the designated data.

Time out – The maximum quantity of time allowed to elapse between events, exceeding this amount of time triggers a time out flag.

Timing Checker – Codeless Communication Testing performed by VPT Timing Reference Recorder.

Transmitter (Same as Publisher) – A node that sends a specific set of data on a network.

Update Bit – a databit used as a communication flag distinguishing when a published signal value update has been made.

Update Interval – The time duration between two observed updates made to a signal.

Update Rate – The time required from a local input or sensor change until the corresponding communication signal values are observed to change.

VPT (Vehicle Protocol Tester) – Network test tool enabling codeless testing of timing parameters for age, publisher latency, gateway latency, and subscriber latency.

Network Robustness Testing

The increasing complexities of electronics in vehicles today and the foreseeable future bring about a raised focus on the importance of testing procedures and tools.

The utilization of the network bandwidth available in today's systems is of constant concern and many practiced design processes don't have reliable methods for measuring and controlling the latencies incurred from high bus loading. In fact without reliable design practices the most commonly used networks today, namely Controller Area Networks must be limited in bandwidth utilization far below 50% to improve the odds that the system behavior will be reliable enough.

One common design practice used when network bandwidths reach unreliable levels is the addition of more networks. This practice does in fact reduce the bandwidth utilization on the concerned network, but the results make the networking even more complicated. Distributing signals across multiple networks creates higher degrees of unreliability while adding processing requirements to those nodes responsible for gatewaying signal values across networks. ECU's responsible for the gatewaying of signals are often highly utilized and complex, making them easily identifiable as sources of communication latency problems.

While the complexities of networking are continuously growing, the identification and resolving of these issues through testing becomes increasingly critical. Often however, the time available for testing is not increased proportionally and there is risk the system will not be ensured adequate reliability. Ultimately though, the final manufactured products success will be measured by the consumers experience and this places substantial importance on performance of the testing processes and tools.

Agilent Technologies has addressed this growing industry need by adding the Vehicle Protocol Tester 501 to it's already extensive portfolio of test tools.

The VPT 501 utilizes a comprehensive master configuration test file which is easily generated from existing processes and data formats. The test parameters contained within the master configuration file enable the VPT501 to provide powerful testing capabilities with a minimal manual configuration effort. Testing features that enable automatic identification and isolation of timing problems through the *Network Timing Checker and Signal Chain Analyzer*.

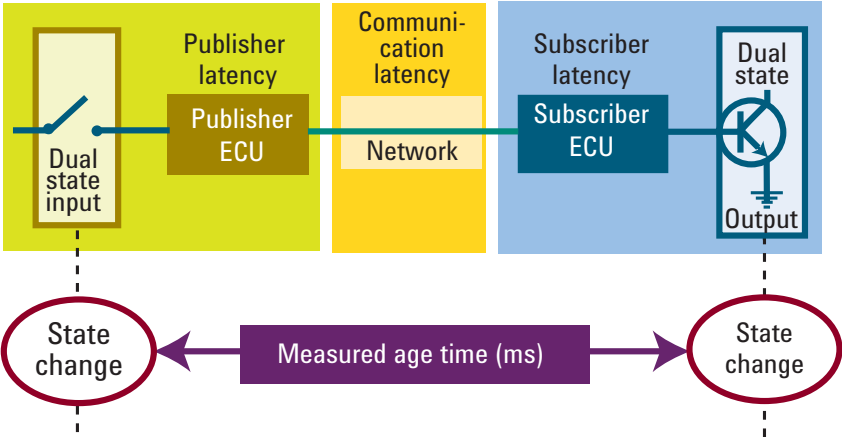
Bringing these capabilities to fruition, the VPT 501 hardware platform is a powerful processing system, deep with memory and interfaces for connection of 2 Controller Area Networks (including software selectable integrated transceivers), 2 Local Interconnect Networks, and 8 digital I/O lines. VPT 501 capabilities are also featuring standalone data logging and trigger lines which can be used for interfacing with additional equipment for correlated physical layer analysis (such as oscilloscopes and logical analyzers).

Additionally, the VPT 501 is a simple to configure test tool based on flexible scalable solutions which can be used for testing a wide variety of different test cases ranging from physical layer to protocol layer and even application layers. The skills of an experienced network troubleshooter are integrated within the *Vehicle Protocol Tester*, enabling self configuration of tests and providing the know how required for helping engineers to **efficiently identify and isolate network related problems**.

Scope of Testing

The Vehicle Protocol Tester 501 provides standardized communication tests which are automatically executed during run time and/or post processing. Timing measurements are made for frames, signals, gateways, and ECU processing, to check for variations from the system specifications.

















Figure 1: Life of a Signal



The life of a signal is depicted in Figure 1. The use of the word *signal* can be confusing, so first it is important to clarify the meaning. In understanding the signal concept, the focus should first be on what distinguishes one vehicle or system from another, namely the features and functions. Each feature is started based on activation or state change of some input or collection of inputs. This input is processed by an ECU which publishes the input as a digital value in a communication *signal*. This signal is then received by those subscribing ECU's which drive the outputs required for execution of this feature.

The Vehicle Protocol Tester provides codeless capabilities for automatically measuring those timing parameters required for ensuring reliability (shown in Table 1) for the testing components shown in *Life of Signal Figure* (shown above).

Table 1: Automatic Timing Measurement Selections

<input checked="" type="checkbox"/>  Age is smaller than required.	<input checked="" type="checkbox"/>  Signal Age timeout
<input checked="" type="checkbox"/>  Age is greater than required.	
<input checked="" type="checkbox"/>  Total Gateway Delay is greater than required.	<input checked="" type="checkbox"/>  Total Gateway Delay timeout.
<input checked="" type="checkbox"/>  Gatewayed Signal has been overwritten.	<input checked="" type="checkbox"/>  Transmitted Signal differs from Received.
<input checked="" type="checkbox"/> <input type="checkbox"/> Follow Up Time is smaller than required.	<input checked="" type="checkbox"/>  Update Interval is smaller than required.
<input checked="" type="checkbox"/> <input type="checkbox"/> Follow Up Time is greater than required.	<input checked="" type="checkbox"/>  Update Interval is greater than required.
<input checked="" type="checkbox"/> <input type="checkbox"/> Follow Up Time of Frame timeout.	<input checked="" type="checkbox"/>  Update Interval timeout.
<input checked="" type="checkbox"/>  Total Publisher Delay is smaller than required.	<input checked="" type="checkbox"/>  Total Subscriber Delay is smaller than required.
<input checked="" type="checkbox"/>  Total Publisher Delay is greater than required.	<input checked="" type="checkbox"/>  Total Subscriber Delay is greater than required.
<input checked="" type="checkbox"/>  Publisher timeout.	<input checked="" type="checkbox"/>  Subscriber timeout.

What is needed for *Vehicle Protocol Tester* to automatically make these measurements is simply the required timing definitions to be measured against and the interface connections.

Defining Test Timing Parameters

The Vehicle Protocol Tester uses a database known as the *Master Configuration File*, which contains all the typical communication database definitions for networks, nodes, frames, and signals. In addition to these parameters however, the *Master Configuration File* also contains the test timing parameters used by the Vehicle Protocol Tester for identification of timing problems.

The *Master Configuration File* communication definitions can be created through the import of CAN databases and LIN Descriptor files. Additionally, CAN databases often contain useful system information stored in containers called *attributes*. These *attributes* can also be imported into the *Master Configuration File* by utilizing the included *CANdb Attribute Mapper* utility.

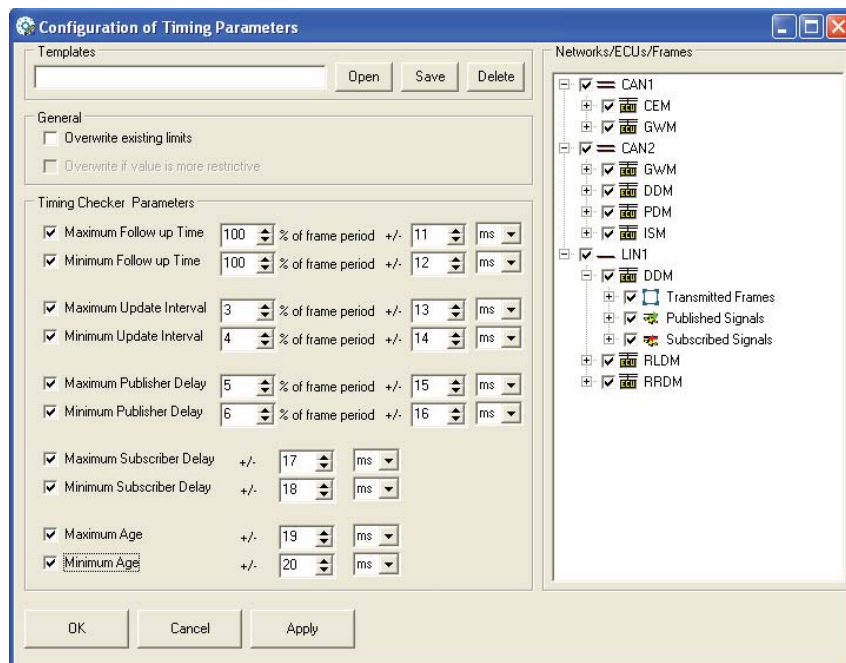
Figure 2: CANdb Attributes Mapping Editor

VPT 501 Attributes / Values	CANDB Attributes/Values	Unit / Type
Frame		
Transport Type	GenMsgSendType	
Periodic	cyclic	
Periodic	cyclicIfActive	
Sporadic	spontaneous	
Sporadic	spontaneousWithDelay	
Period	GenMsgCycleTime	ms
Offset	GenMsgDelayTime	ms
Min. FollowUp Time	Min_FUT	ms
Max. FollowUp Time	Max_FUT	ms
Signal		
Init Value	InitValue	Integer
Min. Total Pub. Delay	MinPubDelay	ms
Max. Total Pub. Delay	MaxPubDelay	ms
Min Age	MinAge	ms
Max Age	MaxAge	ms
Min. Total Sub. Delay	MinTotalSubDelay	ms
Max. Total Sub. Delay	MaxTotalSubDelay	ms
Min. Update Interval	MinUpdateInterval	ms
Max. Update Interval	MaxUpdateInterval	ms

The *CANdb Attribute Mapping Editor* provides one mechanism for bringing in test timing parameters for when these parameters can be extracted from CANdb Attributes during import of a CAN database.

Another method provided for defining the test parameters is through use of the *Configuration of Timing Parameters* utility. This utility allows the user to define test parameters for Publisher Delay.

Figure 3: Configuration of Timing Parameters Utility



The *Timing Parameters Configuration Utility* provides the simplest way for defining timing parameters within the *Master Configuration File*. This utility allows supported test timing values (frame follow up time, signal update time, publisher delay, subscriber delay, and ages) to be entered as a percentage of the associated frame or signal's period rate (0 for sporadic or event) plus/minus and offset amount. These values can then be assigned globally to the entire *Master Configuration File* data set or to a selected subset.

The timing parameters within the *Vehicle Protocol Tester* can also be set in accordance with reference timings recorded from a live ECU or System. Simply connect the device(s) to be recorded to the VPT 501 and run the measurement. Once the desired amount of data has been recorded, *Timing Checkers* built in *Reference Timing Checker* feature can be utilized for saving those parameters directly to the *Master Configuration File*.

Figure 4: Reference Timing Recorder

Timing Problem	Node	Time	Error	Required Time	Measured Time
- ABS_FRAME	ABS	123.87	Follow Up Time	250.00	319.23
Vehicle Speed	ABS	799.44	Gateway Signal Value Overwritten	na	na
Cruise Control	ACCU	1466.98	Update Interval Timeout	1000.00	na
GWM_DATA	ABS	1587.11	Total Gateway Greater Than Required	54.00	101.54
ABS_FRAME	ABS	1799.46	Publisher Delay	50.00	96.33

Using the *Reference Timing Recorder* for specifying test timing parameters can be especially useful for checking variances in the communication behavior where one system or ECU experiences intermittent problems, while another comparable system does not experience the problems.

Explanation of Measuring Age

The *Age* refers to the amount of time that is required for the completion of a function.

Illustration 1: Functional Age

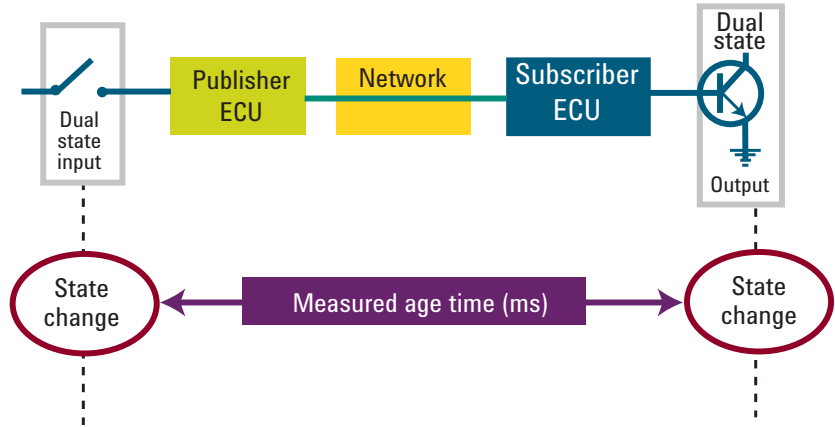


The measurement of functional *Age* is ultimately realized throughout the life of the product by the product consumers and end users in terms of responsiveness and reliability. Collectively, the *Ages* of all product functions combine to give an overall impression of a products quality and desirability.

The importance of the measurement *Age*, makes it a critical parameter for consideration by all engineers involved in the product development phases: design, implementation, and testing.

The following example illustrates the components of a distributed function that are included in an *Age* measurement.

Figure 5: Measuring Function Age



A function is initiated by a state change in an input triggering mechanism such as a switch or sensor. This input state change is then processed and conditioned by an ECU, where the results are prepared for publishing on the network for use by the subscribing ECU(s). In the function shown above, a single subscribing ECU receives the related transmitted data, which is then processed and conditioned for determination of the logical state an output is to be driven.

All functions within a system have measurable *Ages* which collectively represent a measurement of the performance and reliability for the system. Consumers and end users ultimately make judgements about a products quality and desirability based on performance characteristics related to these function *Ages*.

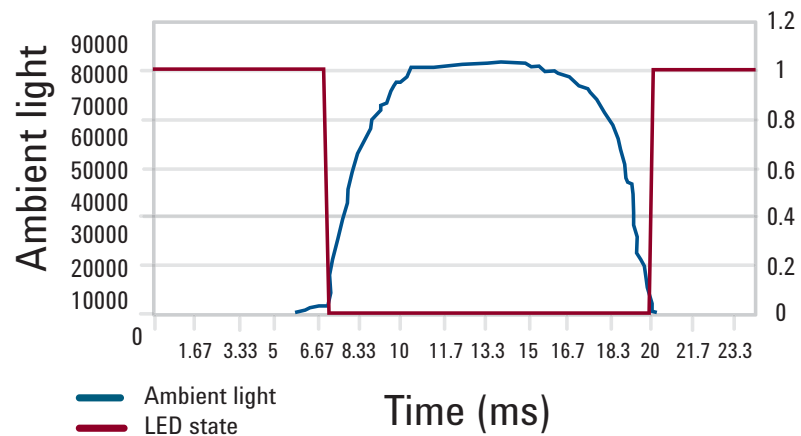
Measuring Age

Age is often a simple measurement where utilizing a test tool with monitored input lines which are connected to the inputs and outputs for the to be analyzed function. The test tool would then make a collection of *Age* measurements by comparing the time measured between the changes in function input states and the corresponding changes in output states.

Example:

Given a function where a light is to be activated when the ambient light intensity drops below 2,500 lux. For the following system sample *Age* calculations will be collected to determine the response time distribution.

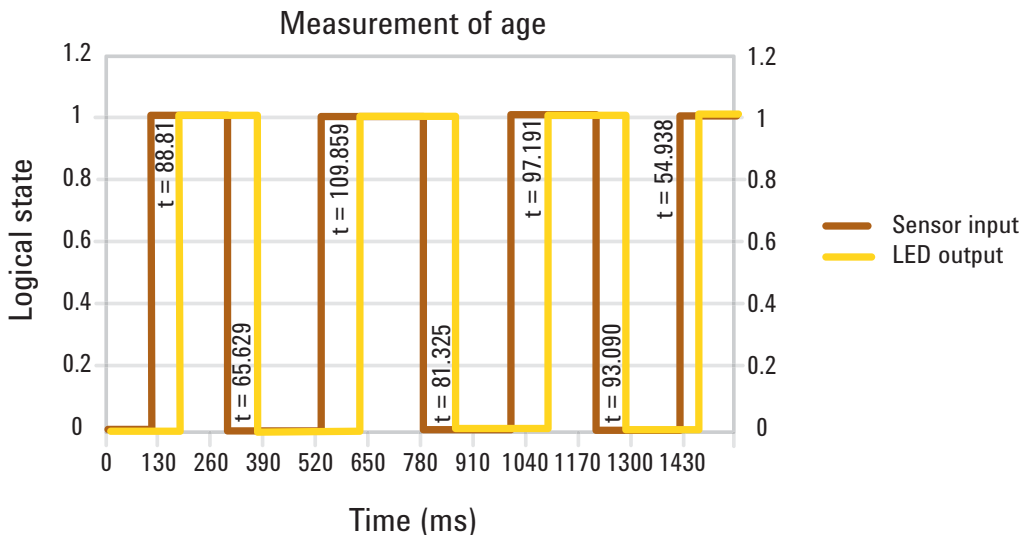
Figure 6: Light Control Function Sensor and Light Control



A sample recording is made of the light intensity for a 24 hour period with the corresponding light system response. For testing purposes a lab is to be setup where variances of the recorded 24 hour light intensity will be sampled periodically.

When collecting a set of *Age* measurements has been compiled, it is important to make enough samples to understand how the system behaves over time and under various conditions. A total population of data can never be achieved due to the time constraints of testing, however it is important to set a goal where the number of samples collected is representative of the behavior that will be observed during the life of the system.

Figure 7: Sample Age Calculations for Light Control



Initially to check the testing setup and predicated responses, a sample of 50 measurements for functional *Age* were made for the described lighting function. The sensor measures light levels which trigger the function logical output status to change between LED on and LED off. The collection of measurement *Age* data is contained in the following table:

Figure 8: Age Measurements for Light Control Function (50 samples)

Data #	Follow up time	Data #	Follow up time	Data #	Follow up time	Data #	Follow up time	Data #	Follow up time
1	88.810	11	141.414	21	119.873	31	136.635	41	123.851
2	65.629	12	98.411	22	100.362	32	119.224	42	131.164
3	109.859	13	71.790	23	99.851	33	104.493	43	136.256
4	81.325	14	71.124	24	112.097	34	110.079	44	120.277
5	97.191	15	79.530	25	94.796	35	116.430	45	102.899
6	93.090	16	143.574	26	100.444	36	124.720	46	998.906
7	54.938	17	107.297	27	100.144	37	82.125	47	99.192
8	111.755	18	63.121	28	98.523	38	108.089	48	108.757
9	67.321	19	140.506	29	79.821	39	96.489	49	127.638
10	106.703	20	72.006	30	78.074	40	98.446	50	127.348

A sample of 50 measurements is usually not adequate testing to achieve an accurate distribution model for the function response behavior over the system's lifetime, however some generalizations can still be made from this sample size.

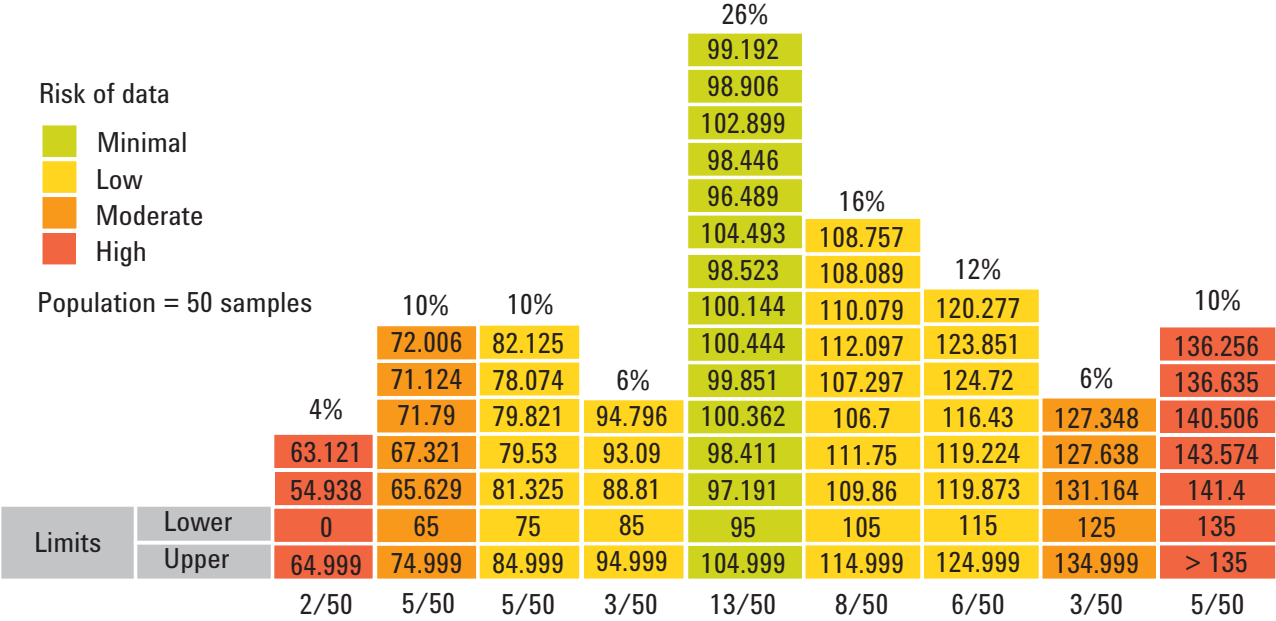
As part of the test designing task, risk factors pertaining to performance and quality must be defined for degrees of variance from the optimal desired measurement. For the lighting system currently being evaluation, the following definitions are given:

- Mean target age..... 100 ms
- < 5% variance Minimal risk
- < 25% variance Low risk
- < 35% varianceModerate risk
- > 35% varianceHigh risk

Grouping the samples by risk level, allows for quick assessment of the reliability of the system being tested.

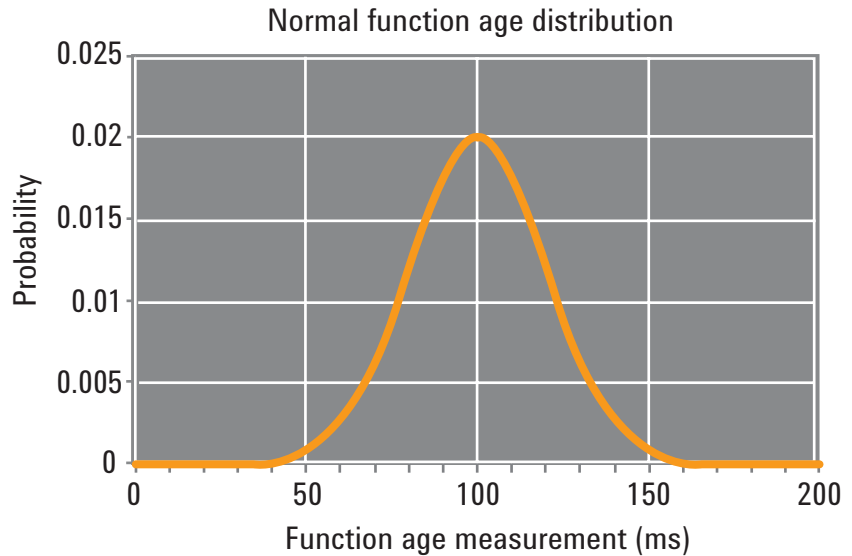
From quick analysis it is learned that 14% of the data collected is considered to be high risk and this is not acceptable from a quality perspective. This immediately flags a need for investigation of the test conditions to ensure correctness of test setup. If the test is verified as correct, then further information must be collected to identify if the problem stems from system design, implementation, or other factors. This is further described in the following "Components of Age" section.

Figure 9: Risk Assessment for Age Measurements



Now 1000 measurements are made and the population is well represented, a statistical analysis is now performed to define the following normalized distribution.

Figure 10: Distribution for Age Measurements



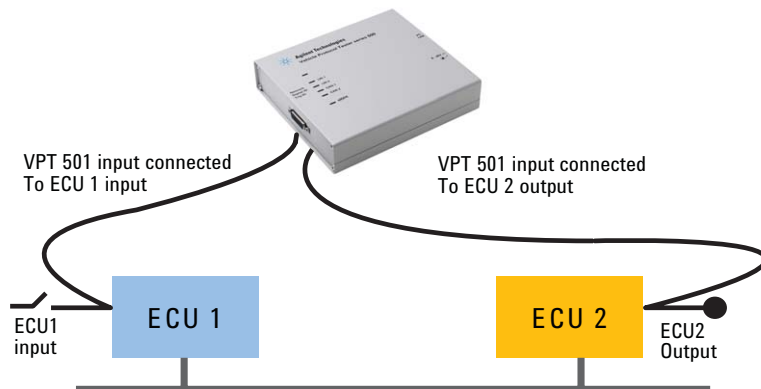
Based on the sample population, the distribution is shown above. Important statistical factors are calculated: the mean for the *Age* measurement is 100 ms and the standard deviation is 20 ms.

This information confirms there is a problem with the function under test and it clearly fails the requirements specified by the design. Now additional testing must be performed to find out the root cause of the high risk behavior and access what actions need to be taken. The scope of this testing is described in the following "Components of Age" section.

Using Vehicle Protocol Tester 501 For Measuring Age

The Vehicle Protocol Tester 501 provides inputs which can be configured for connection to system I/O as shown below.

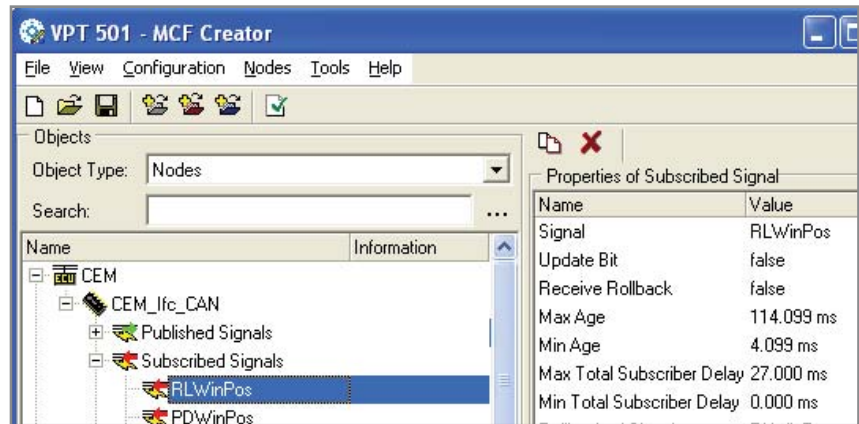
Figure 11: Connecting VPT 501 for Age Measurements



Measuring *Age* requires the VPT 501 inputs be connected to the system inputs and outputs which constitute the *Age* to be measured. This requires that at least two inputs be physically connected to the system.

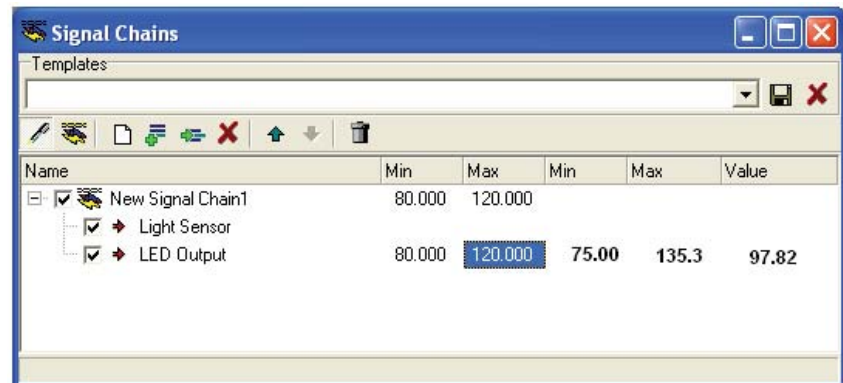
The tolerances for the *Age* value range can be defined within the Master Configuration File, where each signal is defined a minimum and maximum *Age*.

Figure 12: Master Configuration Test Parameters For Age Measurements



When Age definitions are available, the VPT Signal Chain Analyzer is codelessly configured to identify Age timing measurements where the MCF specified requirements are not being met.

Figure 13: Defining the Signal Chain for Age Measurements



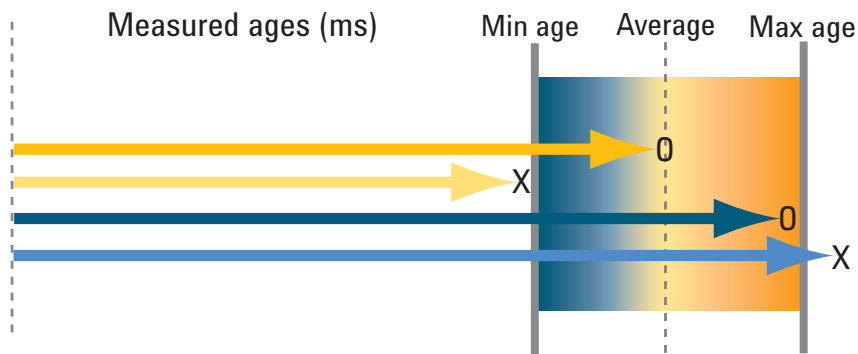
The *Signal Chain Analyzer* enables quick configuration of *Ages* measurements to be possible without requiring code. As is shown above in Figure 13, the signal chain calculates the *Age* for the light function *Age* automatically each time the Light Sensor input crosses (rising or falling) the defined threshold voltage.

Each time this measurement is made, the measured value is displayed in the value column. A history is given for what the minimum and maximum measured response times were.

For example, in the example shown in Figure 13, the tolerance limit defined for the signal chain are between 80.00 ms and 120.00 ms. Each time the input transitions past the threshold voltage, a measurement will be recorded. In this example, the shortest measured time for the signal chain to occur was 75.00 ms, while the maximum value was measured at 135.3 ms. The most recent measurement is displayed in the *Value* column and is displayed as 97.82 ms. Each time a measurement shows the signal chain falls out of the defined tolerances an error flag indicator is made through the VPT 501 analysis suite to indicate where this error condition occurred and which ECU's, frames, and signals were related.

Analysis of the collected data shows the frequency of how often the measured *Ages* fall outside the minimum and maximum requirements as shown below.

Figure 14: Measured Age Distribution



Components of Age

The measurement of *Age* is comprised of many contributing factors relating to hardware, software, and communication. Determining the cause of variability in *Age* measurements requires further measurements to be made. VPT 501 is easily configurable for making these measurements as list as follows:

Publisher Delay – The amount of time measured from when the state of a sensor or input changes until the corresponding data or frame is sent on the network.

Subscriber Delay – The amount of time measured from when data that requires a local output state change is received by a subscribing node until the output state change is observed.

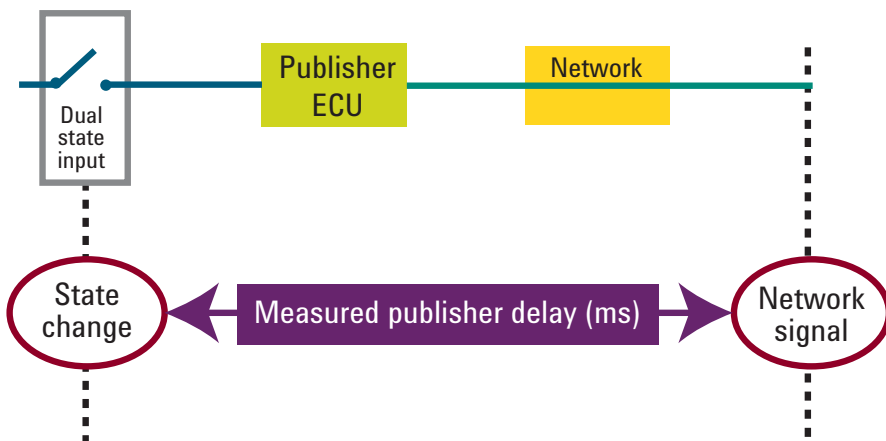
Gateway Delay (if applicable)– The amount of time measured from when data that requires gatewaying across networks is received by the gateway node until the gatewayed data is observed on the appropriate gatewayed networks.

Communication Time – The time required for sending the frame which contains the relative data for which the *Age* is being calculated.

Publisher Delay

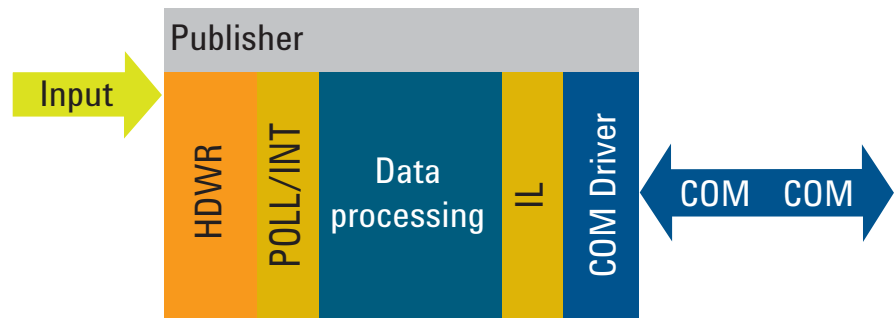
The *Publisher Delay* is defined as the amount of time that elapses from change of an input state until the reflected data change is evident on the network. Analysis of the *Publisher Delay* shows the reliability of the publishing ECU to provide communication data in response to the changing of a local input(s).

Figure 15: Publisher Delay



When measuring the Publisher Delay, behavior of the hardware interface (switch sensor), ECU architecture (software and hardware) and communication design play important roles.

Figure 16: Components of Publisher Delay



The components which contribute to the duration and variability in Publisher delay are:

Change of Input State – changing of an electrical state by a measurable increment, thus triggering the processing of a recognized state change from a switch or sensor

Hardware Filtering – the delay required in conditioning the signal through hardware circuitry before the state change is recognized by the *Publisher ECU*

Polling / Interrupt Data Handling – the delay associated with the ECU recognition method used for measuring the state of the local input

Data Processing Time – the time required for the ECU (including jitter) to utilize the new data value in all software conditioning algorithms prior to updating a new communication value in the communication driver

Communication Driver Delays – influenced by network communication design, this delay is often a function of arbitration delay and is measured as the number of frames which are allowed to transmit from other ECU's while this frame is being attempted for transmission

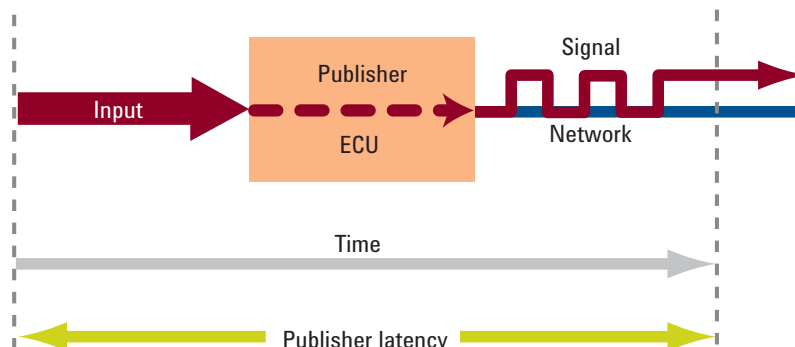
Bus Arbitration Delay – this is a product of the network communication design and

Communication of Signal Reflecting Data Change – this is a product of the physical layer characteristics (speed and health), refers to the amount of time required for successfully transmitting the frame containing the updated data value(s).

Measuring Publisher Delay

Publisher Delay is measured by calculating the time difference between the state changing of an input local to the Publishing ECU and when the frame containing the corresponding updated communication signal is successfully transmitted.

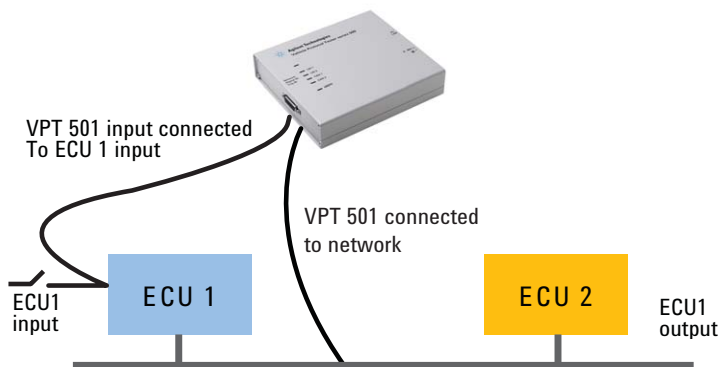
Figure 17: Publisher Delay



Using Vehicle Protocol Tester 501 to Measure Publisher Delay

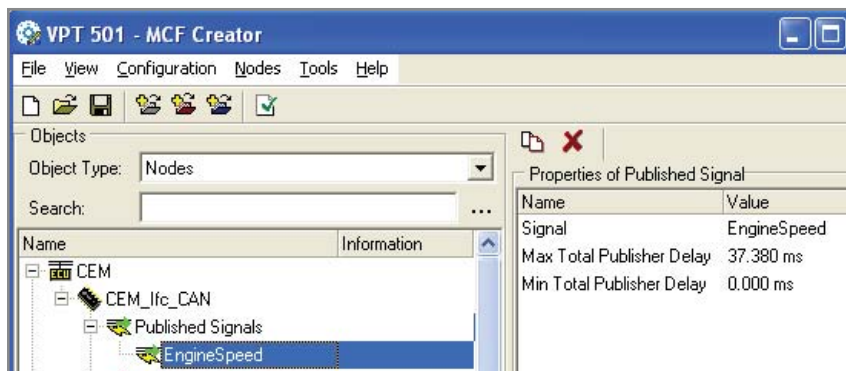
Utilizing one of Vehicle Protocol Tester's inputs in combination with a network interface enables the codeless *Timing Checker* and *Signal Chain Analyzer* features included in VPT 501 to measure *Publisher Delay*.

Figure 18: Connecting VPT 501 to Measure Publisher Delay



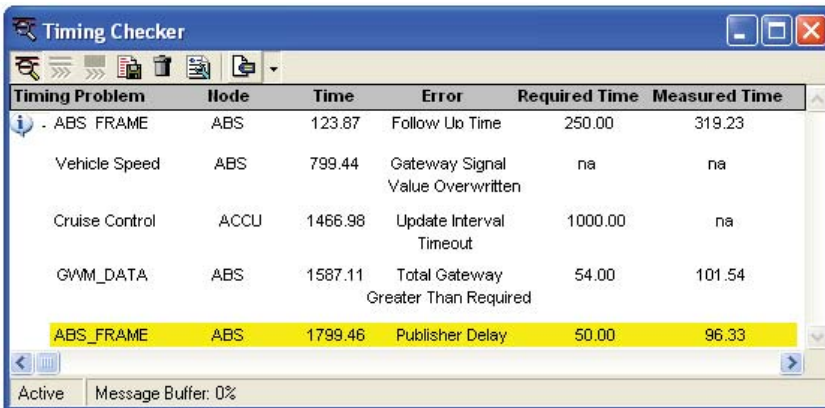
The *Publisher Latency* test timing definitions are defined within the *Master Configuration File* as shown.

Figure 19: Defining Publisher Delay Tolerances in the Master Configuration File



According to the tolerances given in this example, the publishing node is allowed between 0.000 and 37.380 ms to publish the Engine Speed signal. The VPT 501 utilizes this information while performing timing checker measurements.

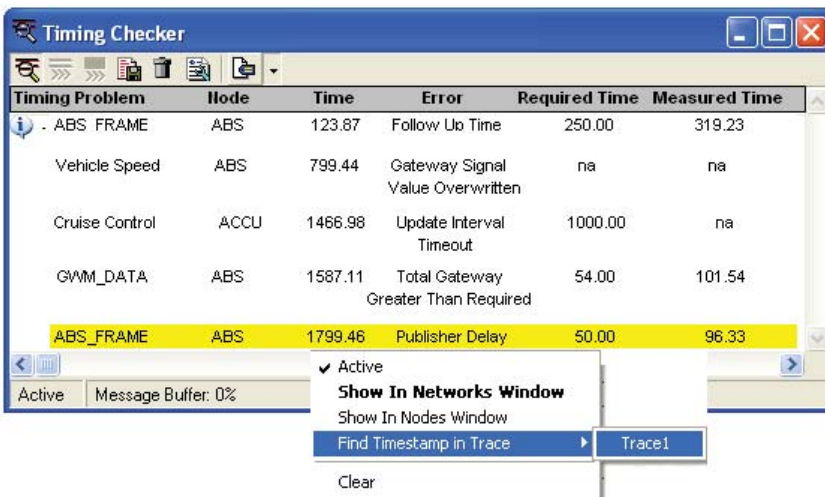
Figure 20: Identifying Publisher Delay with Timing Checker



The *Timing Checker* will show all occurrences of *Publisher Delay* violations found for the configured measurement. From Figure 20, it can be learned that at a measurement time stamp of 1799.46 ms, the Vehicle Protocol Tester identified an occurrence where the ABS required 96.33 ms for transmitting the ABS_FRAME. This transmission should require no more than 50.00 ms according to the specification.

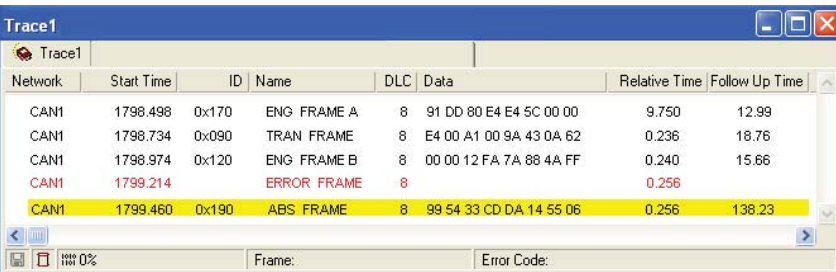
The first step in identifying the cause of this is to look at the network traffic around that time and see what contribution *communication delay* had.

Figure 21: Find Reference of Publisher Delay in Frame Trace



Right clicking on the *Publisher Delay* entry within *Timing Checker* triggers *Vehicle Protocol Tester* entry of interest allows.

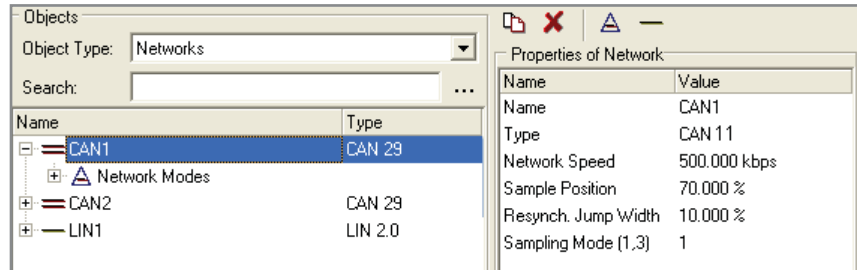
Figure 22: Analyzing Bus Arbitration Delay in the Frame Trace



The *Trace Window* shows the frames activity as it occurred chronologically on the network. The ABS_FRAME has been highlighted and now it's possible to determine what effect the *bus arbitration delay* has on the *Publisher Delay*.

Understanding the time required for transmitting a frame on the CAN1 network is of importance here. If the speed of the network is not initially known, then this information can be easily acquired from the *Master Configuration File*. Select CAN1 network under the nodes tab as follows.

Figure 23: Master Configuration File Network Speed Definition



The Network Speed is easily determined to be 500 kb/second. CAN uses stuff bits to ensure synchronization and this means that it's never predictable exactly how many bits are required to send a single CAN frame, but a typical 8 byte CAN frame utilizing 11 bit identifiers requires an estimated 125 bit times to transmit.

From this we know that 1 CAN frame requires $125/500,000 = 0.25$ ms

Using this calculation in conjunction with the data from Figure 22 reveals that this the bus was utilized continuously since the transmission of ENGINE FRAME A (id 0x170). This can be determined by calculating the difference in frame start times, which is also provided in the relative time column.

It is not known however whether this frame was really loaded into the CAN controllers transmission queue in time to arbitrate against these other transmitted frames. For test purposes though we will assume that the worst case arbitration delay was in fact true and this will yield the minimal amount of delay impacted from the other components of *Publisher Delay*.

Measuring the time difference between the start of ENGINE FRAME A and the transmission of ABS_FRAME is calculated to be:

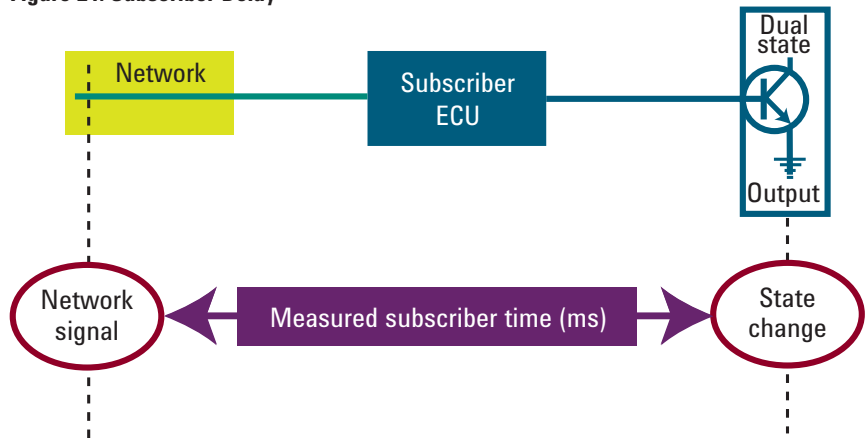
$$1799.460 - 1798.498 + .25 \text{ (1 frame transmission time)} = 1.212 \text{ ms}$$

On inspection this is only a small percentage (1.258%) of the Publisher Latency, so this is not the root cause of such a delay. Investigations must now be made of the ECU software architecture and associated CAN driver.

The *Signal Chain Analyzer* can also be configured for making *Publisher Delay* measurements similarly to the *Age* calculations. When configured, the *Publisher Latency* calculation is automatically measured when the connected input(s) are sampled with a recognized change in status.

Subscriber Delay

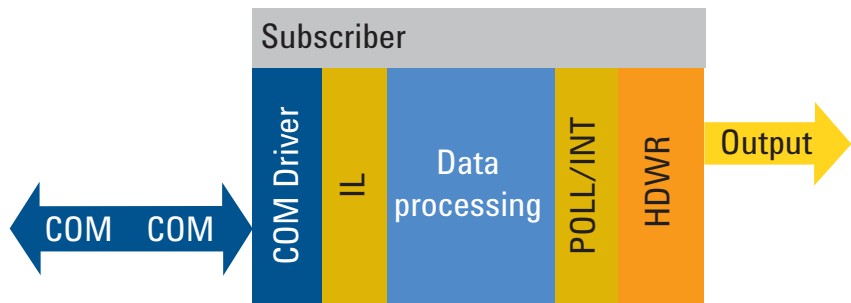
Figure 24: Subscriber Delay



The *Subscriber Delay* is defined as the amount of time that elapses from data being sent on the network until a corresponding reflected change of an output state. The components which make up this time include:

When measuring the *Subscriber Delay*, behavior of the hardware interface (Relay Output), and ECU architecture (software and hardware).

Figure 25: Components of Publisher Delay



The components which contribute to the duration and variability in Publisher delay are:

Communication Driver Delays – this delay is measured as the amount of time required for the communication driver to make newly received data values available to the application

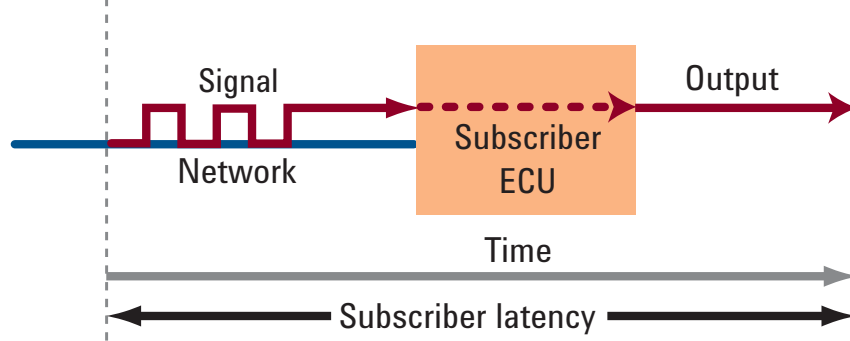
Data Processing Time – the time required for the ECU (including jitter) to utilize the new data value in all software conditioning algorithms required for driving the proper output state.

Hardware Delay – the delay introduced through the hardware circuitry.

Measuring Subscriber Delay

Subscriber Delay is measured by calculating the time difference between reception of a new communication data value(s) and when the corresponding output state(s) is achieved.

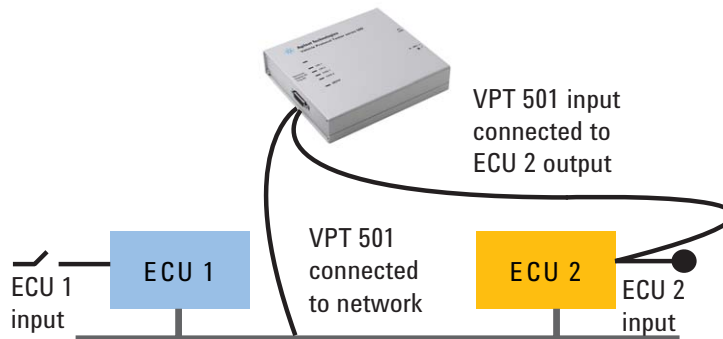
Figure 26: Subscriber Delay



Using Vehicle Protocol Tester 501 to Measure Subscriber Delay

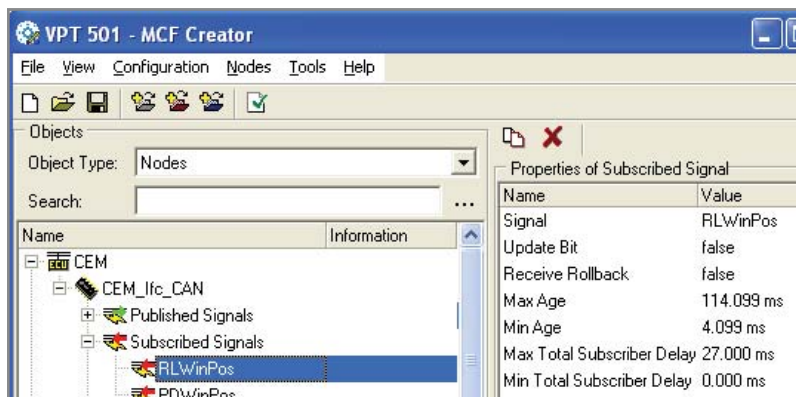
Utilizing one of Vehicle Protocol Tester's inputs in combination with a network interface enables the codeless *Timing Checker* and *Signal Chain Analyzer* features included in VPT 501 to measure *Subscriber Delay*.

Figure 27: Connecting VPT 501 to Measure Publisher Delay



The *Subscriber Latency* test timing definitions are defined within the *Master Configuration File* as shown.

Figure 28: Defining Subscriber Delay Tolerances in the Master Configuration File



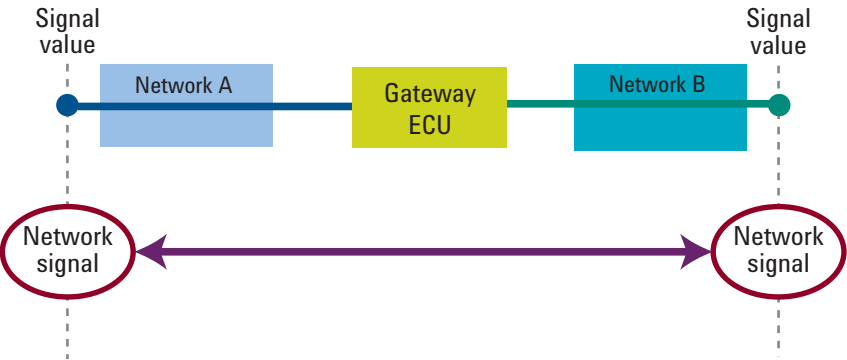
According to the tolerances given in this example, the subscribing node is allowed between 0.000 and 27.000 ms to drive a Rear Left Window Position output change when receiving such a command in the RLWinPos signal.

The VPT 501 utilizes these timing definitions utilizing the *Timing Checker* and *Signal Chain Analyzer* in exactly the same manner as shown in the previous Publisher Latency from the previous section of this Application Note.

Gateway Delay

The Gateway Delay is defined for signals that are exchanged between multiple networks. The amount of time measured between the signal’s existence on one network until it is realized on another network is calculated as the *Gateway Delay*.

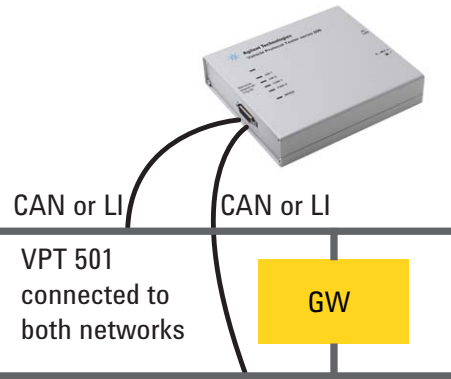
Figure 29: Gateway Delay



Gateway ECU’s are commonly based on a highly capable ECU equipped with processing power, memory, and a variable degree of interfaces. Due to the elevated prices of these ECU platforms, they are usually burdened with an extremely high load of tasks to perform. This often results in Gateway ECU’s to be a common source of communication delays and solving these issues can be extremely difficult due to the software complexity.

The first step to understanding if the Gateway ECU is contributing communication latency to the system is to perform *Gateway Delay Testing*. This type of testing will reveal how reliably the Gateway is able to transfer data amongst networks.

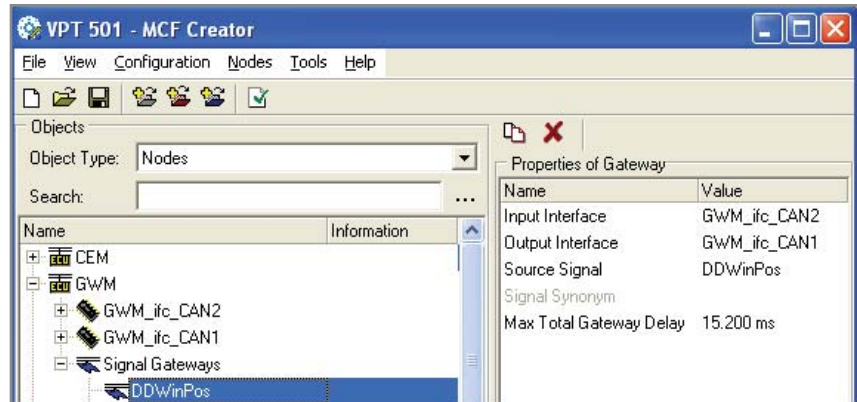
Figure 30: Connecting VPT 501 to Measure Gateway Delay



The VPT 501 provides 2 interfaces for CAN and 2 interface for LIN, which make it a good solution for gateway testing. Simply connect those interfaces which are being supported by the gateway ECU.

The *Gateway Delay* for signals are defined in the *Master Configuration File* under *Signal Gateways* view located in the Nodes view for each gateway node as follows:

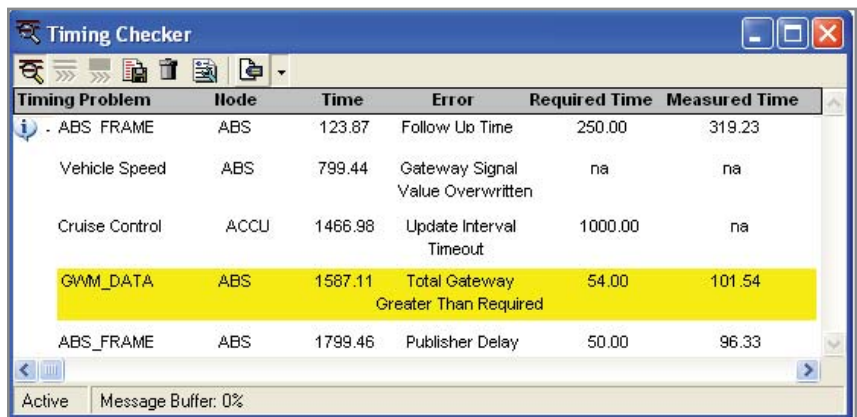
Figure 31: Master Configuration File Gateway Delay Definition



The *Maximum Total Gateway Delay* is defined in this example as 15.200 ms for the DDWinPos signal.

Once the VPT 501 has the *Gateway Delay* test timing parameters defined, the Timing Checker will automatically check the timing for every gateway signal.

Figure 32: Measure Gateway Delay with Timing Checker



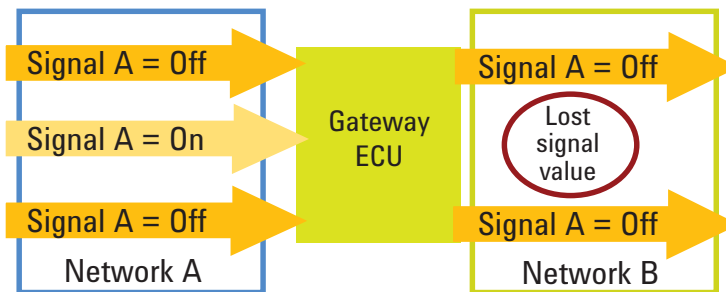
In this example, the *Timing Checker* has identified an instance where the GWM_DATA frame required 101.54 ms to gateway and the required time was 54.00 ms.

An investigation should again be made utilizing the *Frame Trace* in the situation of *Gateway Delay* to evaluate how much of this delay can be contributed to communication arbitration delay (note: LIN doesn't use arbitration).

Lost Signal Values

The *Timing Checker* will automatically check all gatewayed signal values to ensure that no signal states are lost due to multiple same type frames being sent consecutively without allowing the receiving gateway node enough time to process the information.

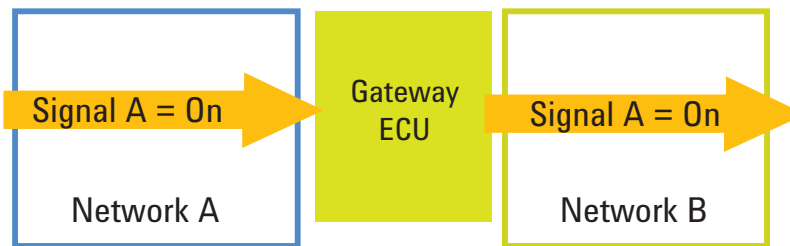
Figure 33: Gateway Lost Signal Value



Transmitted Signal Value Differs From Received

The *Timing Checker* will automatically perform a consistency check on signals being gatewayed to ensure that the value being published on one bus is equivalent to the value being received on the input bus.

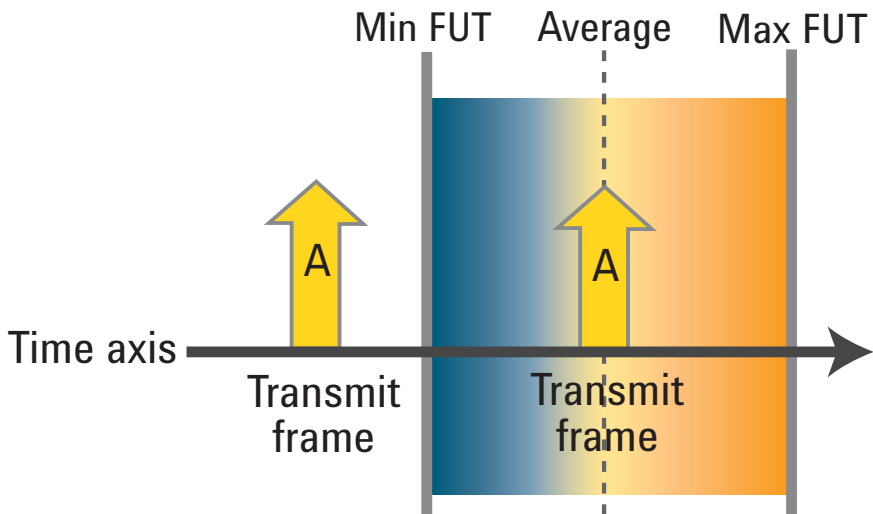
Figure 34: Gateway Transmits Incorrect Signal Value



Follow Up Times

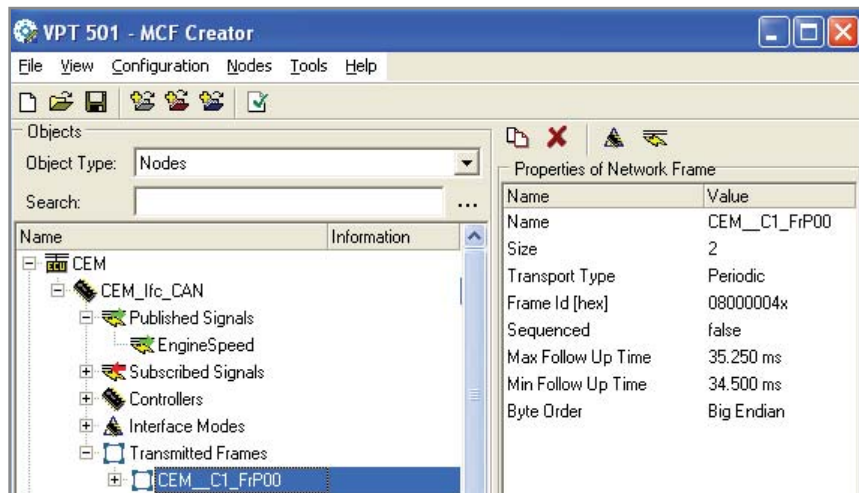
The frame *Follow Up Time* is measured as the time that elapses between two occurrences of the same transmitted frame as shown below:

Figure 35: Frame Follow Up Times



The *Follow Up Time* is stored in the *Master Configuration File* for each transmitted frame as is shown under the Nodes view.

Figure 36: Master Configuration File Follow Up Time Definitions



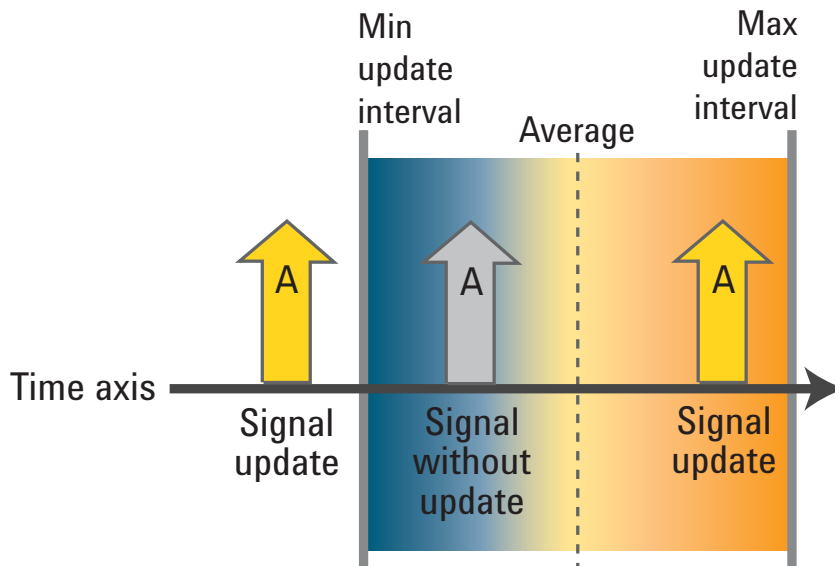
The *Timing Checker* automatically identifies all occurrences when transmitted frames have *Follow Up Times* outside of the specified requirements.

Update Interval

The *Update Interval* is the measurement between two occurrences of a common signal when updated on the same network.

The *Update Interval* value ranges are defined in the *Master Configuration File* for signals viewed under the transmitted frame view as is shown below:

Figure 37: Updated interval



The *Timing Checker* automatically identifies all occurrences when signal values are updated at rates outside of the specified requirements.

Related literature

Publication title	Publication type	Publication number
J8120A VPT 501	Data Sheet	5989-6818EN
J8115A LIN Tester	Data Sheet	5989-6817EN
J8130A VPT1000	Data Sheet	5989-7589EN
Error Injection in LIN Tester	App. Note	5989-7312EN

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Revised: October 24, 2007

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Printed in USA, February 26, 2008
5989-7971EN

