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Specification for Datacon Repeaters

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Introduction:

The Datacon system is a serial coaxial transformer isolated communication field bus system used to control ACS Datacon remote devices. It is electrically and functionally familiar to users of mil std 1553, but has a much simpler protocol. A tally of Datacon addresses on July 15, 1991 showed 2616 devices defined for active use. There are approximately 42 device types, some of which are being replaced with modern Datacon interfaces. Some of the 42 device types are power supply control, collimator jaw positioners, stepper motor positioning systems, beam profile monitors, scalers, autodets, analog signal acquisition, video multiplexing, Linac DACADS, function generators, etc. The "Datacon" system evolved over a period of 25 + years with the modernization of ACS control systems, and the use of field programmable logic, allowing the implementation of Datacon transceivers without relying on adjustments and drifting one shots or time delays. The proposed repeater is a tune-less crystal controlled implementation and repackaging of the existing and time proven Datacon repeater/multiplexer.

During their 25 + years of service, Datacon lines have undergone many configuration changes and additions, surviving long stubs and T's, as well as improper termination and grounding. Due to the robust nature of Datacon, most of these ills had minor effects on operations. This specification details the design objectives that are to be met by the new Datacon Repeaters. Existing repeaters will be taken out of service when the new ones are installed. This specification also intends to help field bus maintenance personnel determine when and where repeaters are needed in the field. Future Datacon line maintenance policy should follow this specification.

Approximately 10 miles of Datacon cable is downstream of the Datacon Masters. Cables are dispersed through many buildings and tunnels in the most unserviceable conditions. Great emphasis has been given to working with the existing cable plant. Repeaters will be used to minimize the impact on the cable plant. Only "unserviceable" cable will need to be replaced.

Purpose:

The Datacon Repeater will help resolve data errors or data losses due to loading and run length limitations inherent with the existing Datacon system. The new design will improve service life and reliability, while adding some new diagnostic LED indicators for trouble shooting the lines. Data output from the repeater must meet more stringent timing and loading conditions and inputs may have a greater range of allowed values. The new Datacon Repeater will be compliant with the more stringent timing and loading specifications called out in this document.

Scope:

The Datacon Repeater shall:

- restore amplitude of Datacon pulses meeting the "acceptable" or better input specifications
- restore pulse width, and shape of Datacon bipolar data pulses in a single pulse pair to "nominal" values called out in this specification.
- restore pulse width and shape of Datacon bipolar frame pulses, to "nominal" values called out in this specification.
- be contained in a single 1 U x 19" rack mount, catalog order aluminum extruded chassis, with internal switching power supplies, and ventilated top and bottom panels. The enclosure will have solid 0.093" thick aluminum front and back panels, with 19" rack mount ears.
- fit into the existing repeater/mux rack space but use only 1U in height.
- have 1 BNC input, transformer isolated and terminated into 93 ohms impedance.
- have 4 BNC outputs, individually transformer isolated and terminated with 93 ohms impedance.
- meet or exceed all of the requirements contained in the September 2, 1975 Specification for Datacon Signal Standards.
- have 60 volt "Sidactor" type back to back zener diode discharge protection devices on all inputs and outputs.
- withstand 1500 volts dc isolation by design

- all BNC outputs shall be frame grounded on their outer shell, making galvanic contact with the 19" rack and ground wire terminal on the AC power connector.

- The BNC Input has a choice of 0.01uF capacitive coupling to FGND , direct coupling to FGND, or no coupling to FGND.

- have a green line activity monitor LED near each downstream BNC connector, pulse stretched to 15ms.

- have a green line activity monitor LED near the upstream BNC connector, pulse stretched to 15ms.

- have red fault LEDs as follows: LTD (less than data), GTDLTF (greater than data less than frame), MIX (mixed error), and UPP (unipolar pulse), pulse stretched to 15ms and a scope trigger K-LOC output with a TTL rising edge trigger for use with a digital oscilloscope, or logic analyzer on the front panel.

- have green status LEDs as follows: DVAL (data valid), FVAL (frame valid) for upstream and downstream lines.

- use Altera EPLD logic, and a crystal oscillator.

- will fan out to, and fan in from, 4 lines. The old repeater only fans out to 3.

- not prioritize, or make use of, colliding response signals. Collisions are passed through the repeater logic as corrupted responses.

- should more than one device have the same address on fanned out branches of a single Datacon line, collisions will occur at the inputs of the repeater, causing pulse errors. The responsibility for proper addressing falls on the Datacon line maintenance manager.

Definitions:

Specification of "acceptable" Datacon signals is simplified in this document to allow the implementation of a practical standard Datacon test set which may be used to qualify all acceptable Datacon cable runs. The envisioned test is a loopback test. "Unserviceable" cable definitions are given in this specification. General cable termination, run length, and practices are outlined to familiarize readers with proper cable management, and how it pertains to acceptable Datacon error-free packet transmission.

A Datacon transceiver is capable of receiving and transmitting Datacon signals. Both transmit and receive functions must meet all Datacon Signal Standard specifications.

A Datacon master is capable of transmitting and receiving Datacon signals. The Datacon Master initiates the command or transmit packet and waits for the reply or response packet.

Downstream is in the direction that command or transmit packets travel.

Upstream is the direction that reply or response packets travel.

Datacon Devices are downstream of the Datacon Master, and are uniquely addressed. No two devices may share the same address on fanned out lines.

Dwell or dead time is the period of no signal that occurs between pulse pairs in a Datacon packet.

A Datacon pulse may not fall below the 5 volt threshold during its entire duration due to any noise or other disturbance. Should this occur, the pulse does not meet acceptable standards for inputs to receivers.

Datacon Signal Specifications:

The Datacon repeater shall be terminated internally to 93 ohms impedance.
The Cable of choice for ALL Datacon lines is RG62A/U with a characteristic impedance of 93 ohms. Other cable types are not acceptable. All lines shall be terminated at the far downstream ends with 93 ohm terminating resistors, unless connected to the input of another repeater. All Datacon Repeater inputs and outputs are terminated internally to 93 ohms. RG62A/U cable has a propagation speed of 0.84C which translates into 768 ft./μs. Using the propagation speed above a reflection on a 1000' piece of RG62A/U cable would show up 2.6 μs after the transient's leading edge. (Remember 2000' is traversed by the pulse).
No stubs are permitted or tolerated over 6" in length.
Stub length is limited to 6 inches total for each crate controller.
At no time shall the number of devices exceed 33 on a single driver. More devices require a fanout through a repeater.
At no time shall any unloaded cable length exceed 2000 feet. At no time shall any multidropped cable run exceed 1000 feet. Longer runs require a repeater every 1000 ft. Each repeater used will introduce an additional delay of 2 - 3 μS one-way and 4 - 6 μS round trip .

A Datacon line is "**unacceptable**" when any of the following are observed:
1.) Reflections are 20% of the weakest signal amplitude, or exceed the 5 volt threshold.
2.) Spurious noise is 10% of the weakest signal.
3.) Pulse width for data falls below 210 ηs at 5V or -5V when a standard test set* is used.
4.) Pulse width for frame pulse falls below 810 ηs at 5V or -5V when a standard test set* is used.
* A standard test set can be two repeaters one on each end of the transmission line which comply with the Specification for Datacon Repeaters.

(this part of the specification is **limited** and **bounded** by sampling techniques and the choice of a **20MHz** crystal.)

New Datacon Transceivers, Crate controllers, devices, or Repeaters are "**unacceptable**" when any of the following are observed:
1.) Transmit Pulse width for data is under 450 ηs or over 520 ηs between the 10% and 90% points of the pulse flat top into 100 ohms resistive or 1000 ft of RG62A/U cable with a 93 ohm terminator at the far end. TTL input pulses to driver circuitry should be 500 ηs for this test.
2.) Transmit Pulse width for frame is under 950 ηs or over 1020 ηs between the 10% and 90% pulse flat top points into 100 ohms resistive or 1000 ft of RG62A/U cable with a 100 Ohm terminator at the far end. TTL input pulses to driver circuitry should be 1000 ηs for this test. Transmit pulse widths between 521 & 949 ηs are undefined, neither frame or data pulses, and the driver does not meet specification.
3.) Pulses over 1020 ηs are undefined and may become increasingly non-linear as they approach cup core saturation, leading to droop, large transients and transistor drive failure. Drivers producing longer pulses do not meet specification.
4.) Receive data pulse widths of 210 ηs to 690 ηs at 5.5V and -5.5V into 93 ohm inputs must be received without error for 1000 repetitions.
5.) Receive frame pulse widths of 810 ηs to 1590 ηs at 5.5V and -5.5V into 93 ohm inputs must be received without error for 1000 repetitions.
6.) The above means that receive pulse widths between 700 & 800 ηs are undefined, neither frame or data pulses and must not be detected as frame or data pulses.

Old Datacon Transceivers, Crate controllers, devices, or Repeaters are "**unacceptable**" when any of the following are observed:
1.) Transmit Pulse width for data is under 350 ηs or over 500 ηs at 10 or -10 V into 93 ohms
2.) Transmit Pulse width for frame is under 1000 ηs or over 1200 ηs at 10 or -10V into 93 ohms
3.) The above means that transmit pulse widths between 501 & 999 ηs are undefined, neither frame or data pulses.
4.) Pulses over 1200 ηs are undefined and will saturate the cup core leading to droop and transistor drive failure.
5.) Receive data pulse widths of 350 ηs to 500 ηs at 5V and -5V into 93 ohms must be received without error.
6.) Receive frame pulse widths of 1000 ηs to 1200 ηs at 5V and -5V into 93 ohms must be received without error.
7.) The above means that receive pulse widths between 501 & 999 ηs are undefined, neither frame or data pulses.

Datacon Repeater Definitions:

(Definitions are necessary to limit the scope of possible interpretations, as well as clarify 25 years of accumulated expression!)

This specification for repeaters will supersede all previous specifications for Datacon devices for devices that wish to be compliant to the higher repeater standard.

The September 2, 1975 Specification for Datacon Signal Standards and the March 14, 1973 Signal Specifications and Transceiver Operation for DATACON II System are reprinted and attached. Alterations were made in the 1975 spec. to supersede all previous specifications. No alterations are made to the 1975 spec., only additions for practical data reliability monitoring and practical measurement. Some of the additions are to limit new device variations for transmitted signals and provide real measurable and testable limits on receiver operation. Additions became necessary when sampling of the Datacon packets was first used, and to clarify a dead zone between frame and data pulses. The values specified assume the use of a 20 MHz crystal controlled sampling frequency. The additions are specified in ideal or "nominal" values, and maximum and minimum "acceptable" values only. No specification for a max., min., or nominal "dwell" or dead time between Datacon pulse pairs is made in the 1975 specification only to be limited at 100 μs for the entire packet. Any dwell time above the nominal 1 μs should be discouraged. All voltages in the new specification are measured from AC "ground" or AC coupled zero voltage. There will be only one positive threshold and one negative threshold without hysteresis for measuring acceptable signal quality. This approach is used because digital oscilloscopes can be triggered to catch "out of spec." signals using these values, and EPLD logic and comparitors made to detect out of specification signals. Pulse fault monitors in the repeaters will use these values to trigger external oscilloscopes or logic analyzers.

Since there are many quality issues with data packets on transmission lines, a test set must be devised which automatically measures all relevant characteristics of the pulse train on any transmission line in a repetitive way to determine it's fitness and error rate. Pseudo random code testing is recommended with two Datacon Repeater transceivers. A final test using the loopback capability of the Datacon Master Test Set should also show no errors for a lengthy testing time. The test is to be conducted on a suspect transmission line with a loopback Datacon transceiver on one end terminated with 100 ohms resistive, and a Datacon master on the other end. This loopback test is currently implemented on the Hulliger Motor Positioning System Upgrade.

Some important concepts about Datacon signals:
1.) An ideal or nominal Datacon signal should have no net DC components averaged over the bipolar pulse pair (DC free). This is necessary to avoid saturation of the Datacon line transformers. To avoid a DC component, the amplitude and duration of each transmitted pulse in the pulse pair must be exactly the same but of opposite polarity. For example, a transformer will saturate and distort a pulse train if the width of the positive pulses exceeds the negative pulses. An "acceptable" variation is 5%. Larger variations are unacceptable.

2.) Low frequency bandwidth is limited in the transformer so that the pulses must not exceed 1020 ηs to avoid saturating the magnetic pot core of the transformer. The transformer may also saturate if there is any DC components as in item 1 totaled over the entire pulse train. Old datacon drivers routinely operate in this region and may have pulses of 1200 ηs or more in the non-linear, near saturation area of the B - H curve.

3.)Interwinding leakage inductance introduces flyback pulses on the push pull amplifier transistors. These pulses are normally shunted with zener diodes to prevent avalanche

breakdown of the push pull drive transistors. Litz wire can be used to farther reduce transformer leakage inductance and the corresponding flyback pulses.

4.) Transformers are terminated with 300 ohms on each winding of the new Datacon Repeater to distribute the termination through the transformer to provide the least transient behavior on all the windings. The parallel impedance of the transformer lowers the numerical equivalent 100 ohms of resistive termination to approximately 93 ohms impedance which matches the RG62A/U cable characteristic impedance closely. The 93 ohm termination reduces the amplitude of reflections to a minimum. It should be noted that both open and 50 ohm or less terminations will cause a significant reflection which will cause pulse errors if the line is several feet or more in length. Lack of termination or open termination will cause a pulse slightly reduced in amplitude with the same polarity to be reflected back. A short circuit or 0 ohm termination will cause a pulse slightly reduced in amplitude but of opposite polarity to be reflected back. 100 ohm terminators are close enough to 93 ohms that the minor mismatch reflections cause no detectable pulse errors.
The PRCGC (pseudo random code generator / checker) which is built into the repeater, shall be used to qualify a line as "acceptable" with the following guidelines:

"Unacceptable" cable are to be made acceptable by use of proper interconnections, terminations, and repeaters.

"**Unserviceable**" cable is any cable that will not pass repetitive "acceptable" error-free Datacon packets using the PRCGC function built into the Datacon Repeater. The test is comprised of a repeater transceiver at both ends of the questionable cable, with one repeater working as a generator and the other working as a checker. No data or frame errors should be detected in 4, 5 minute testing intervals using both data and frame pulses and generating and checking in both directions. Unserviceable cable may have once passed acceptable error free Datacon packets but no longer does so because of physical damage, improper interconnections or routing (such as long stubs or branching, non RG62A/U cable, and improper connectors) , and faulty or improper impedance devices connected to the cable. A perfectly healthy new cable can be "unserviceable" due to excessive length alone! Maximum cable length and loading is 1000 ft. with 33 device loads and one 100 ohm terminator with each device load meeting the minimum 3000 ohm input impedance spec.

Transmission packets are in groups of 35 bipolar rectangular pulse pairs which must meet the standards put forth in the September 2, 1975 specification which is fully endorsed by this specification.

A bipolar frame pulse pair and bipolar data pulse pair is represented in Fig 1 and Fig. 2 below.

Fig. 1 is a RESPONSE frame, key, and first data bit, and Fig. 2 is a Command frame, key and first data bit.

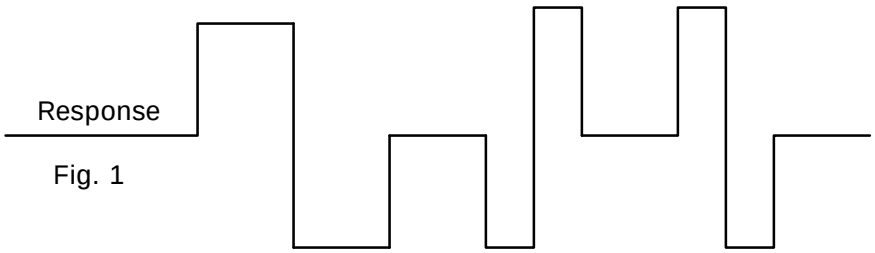


Fig. 1

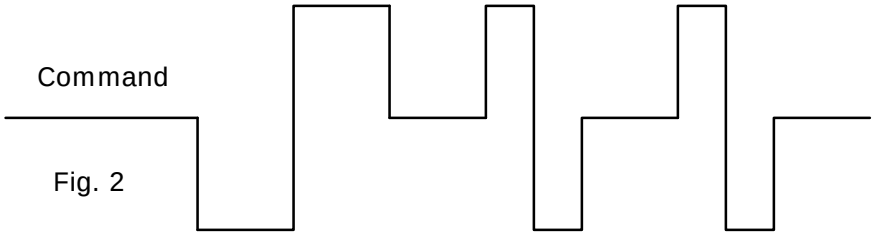


Fig. 2

A command or transmit packet is a frame pulse pair followed by 34 data pulse pairs generated by a Datacon Master, traveling downstream to a Datacon device. The frame pulse in a command packet always starts with the negative pulse followed by the positive pulse. (Fig. 2)

A response packet or pulse train is a frame pulse followed by 34 data pulses generated by a Datacon device, traveling upstream to a Datacon master. The frame pulse in a response packet always starts with the positive pulse followed by the negative pulse. (Fig. 1)

The first pulse pair in each packet is the frame pulse and is distinguishably wider than all other pulses. A leading positive or negative pulse determines whether it originated from the Datacon master as a command packet or if it originated from a Datacon device as a response packet. Frame pulses starting with a negative pulse followed immediately by a positive pulse belong to command packets, frame pulses starting with a positive pulse followed immediately by a negative pulse belong to response packets.

The second pulse pair is the key bit and is always opposite in polarity to the frame pulse.

Pulse pairs 2 to 35 are considered data pulses. Pulse pairs 3 to 35 carry digital information used by Datacon devices. Pulse pair 2, the key bit, is discarded by the Datacon receiver interface, it is only used as a marker to signify that the last bit has been shifted into the receiver shift registers, and when of opposite polarity to the frame pulse pair, it qualifies the frame and key pulse pairs as valid allowing the receiver to enable its data shift registers. The key pulse pair always contains a logic "1".

The 35th pulse pair is the parity pulse and its logic value is derived by summing modulo 2 all bits from 3 to 34. Sometimes referred to as odd parity.

To make things interesting, a positive pulse followed by a negative pulse is a logical one for a command packet (first data bit after the key bit in Fig. 2) but a logical zero for a response packet

(first data bit after the key bit in Fig. 1). A negative pulse followed by a positive pulse is a logical zero for a command packet but a logical one for a response packet.

The Datacon Repeater by design has terminations of 93 ohms internally on all BNC connectors. A repeater will have nominal signal characteristics which are crystal controlled to limit variations in signal timing to less than 0.1%, without any tuning for the life of the repeater. The repeater must accept all signals between and including the maximum and minimum signals outlined in this specification for inputs without error. The repeater must generate nominal signals with less than 0.1% variation at all its outputs without error determined by repetitive testing. The repeater shall restore signal amplitude, power, rise time, fall time, noise level, pulse widths, and zero DC components to the nominal values in this specification with any "acceptable" signal inputs as so defined by this specification. The repeater will not restore inter-pulse-pair timing for incoming pulse trains that have more time between pulses than the nominal output pulse timing, but will expand pulse trains to nominal timing for input pulse trains that are faster than nominal pulse timing using its internal FIFO. The input pulse pairs must be within input "acceptable" standards for any output pulse pair to be generated. Pulse width variation in the acceptable standards are measured from the threshold (+-5V) on the leading-most edge of each pulse pair. Note: a Datacon device which generates error free output when connected to a Datacon standard test set in repetitive loopback tests is not vindicated of any wrong doing just because its outputs fall within the very forgiving input signal allowances of the test set. The output pulses must still meet the Datacon Specification for signal standards. The repeater is designed to accept a large input range of signal pulse width variation to compensate for line conditions, loading and noise. Signals may deteriorate below acceptable standards at the receiving end of the cable due to the cable length, loading, termination, or any combination of cable deficiencies. These deficiencies can be resolved by using a repeater or correcting the loading, termination, or routing which caused the problem. Packet transmissions requiring 100 μS or more are outlawed in the September 2, 1975 specification. Faulty (or out of tune) downstream crate controllers that violate the old specification and do not function in the new system must be corrected at the source no matter how painful this may be!

note: all the following technical specifications are given into 100 ohms resistive for simplicity, and apply over temperature, and aging for the life of the product. There is currently no hysteresis built into the new Datacon receivers using the 75107B RS232 receiver IC as a pulse detector, as specified in the 1975 receiver specification.

Specification for existing Datacon receiver inputs:

	data pulse detect threshold, hyst.	**time, @ volts**	**dwell**
min.	+-4V, 500mV	200 ηs*	?
nom.	+-5V, 500mV	500 ηs, 5V	?
max.	+-6V, 500mV	?	?

	frame pulse detect threshold, hyst.	**time**	**dwell**
min.	+-4V, 500mV	?	?
nom.	+-5V, 500mV	?	?
max.	+-6V, 500mV	?	?

input impedance not to fall below 3000 ohms from 60 Hz to 2 MHz, unless terminated at 93 ohms such as a Datacon master or Datacon Repeater.
inputs must function for pulses of +-20V peak to peak.
inputs must tolerate without burnout +-35V peak to peak.

Specification for existing Datacon transmitter outputs:

	data pulse threshold	**time @ volts**	**dwell**
min.	+-10V	350 ηs, ?	550 ηs*
nom.	?	500 ηs, ?	1000 ηs
max.	+-21V	500 ηs, ?	?

	frame pulse threshold	**time**	**dwell**	**end receive to begin transmit**
min.	+-10V	1000 ηs	550 ηs*	6 μs
nom.	?	1000 ηs	1000 ηs	?
max.	+-21V	1200 ηs	?	300 μs

* from March 14, 1973 Signal Specifications and Transceiver operation for DATACON II System, EP&S Technical Note. This information was omitted in the 1975 spec.

Specification for New Datacon receiver inputs, 1000 operations without error in loopback test set:

	data pulse detect thresholds	**time, measured at**	**dwell**
min.	+-4.5V	210 ηs, 5V	210 ηs, below 5V
nom.	+-5V	500 ηs, 5V	1000 ηs, below 5V
max.	+-5.5V	690 ηs, 5V	3 μS, below 5V

	frame pulse detect thresholds	**time, measured at**	**dwell**
min.	+-4.5V	810 ηs, 5V	210 ηs, below 5V
nom.	+-5V	1000 ηs, 5V	1000 ηs, below 5V
max.	+-5.5V	1590 ηs, 5V	unlimited, below 5V

input impedance not to fall below 3000 ohms from 60 Hz to 2 MHz, unless terminated at 93 ohms such as a Datacon master or Datacon Repeater.
inputs must function for pulses of +-20V.
inputs must tolerate without burnout +-35V.

Specification for New Datacon transmitter outputs into 100 ohms resistive:

	data pulse voltage output into 100 ohms	**time @ 10% & 90%**	**dwell**
min.	+-15.5V	450 ηs	950 ηs
nom.	+-16V	500 ηs	1000 ηs
max.	+-21V	520 ηs	1020 ηs

	frame pulse voltage output into 100 ohms.	**time @ 10% & 90%**	**dwell**	**end receive to begin transmit**
min.	+-15.5V	950 ηs	950 ηs	1.6 μs
nom.	+-16V	1000 ηs	1000 ηs	3.2 μs
max.	+-21V	1020 ηs	1020 ηs	300 μs

* from March 14, 1973 Signal Specifications and Transceiver operation for DATACON II System, EP&S Technical Note. This information was omitted in the 1975 spec.

transmitter maximum dwell voltage 2.5V peak into 100 ohms resistive for 100 ηs (overshoot and undershoot) , 1mV DC thereafter.
receiver must tolerate 0.25V continuous dwell voltage, and 5V of overshoot for 100 ηs, during operation of loopback tests without data error.
The above thresholds are not to be crossed more than once per pulse.

Rise and Fall transition time for inputs on receivers terminated with 93 ohms impedance shall not exceed 140 ηs for any and all of the following transitions 0 to +5, 0 to -5, +5 to -5, -5 to +5, +5 to 0 and -5 to 0.

Datacon drivers compliant to this new specification must meet stringent rise and fall transition times under over-load and nominal load circuit conditions. Over-load is 10 ohms resistive, and nominal load is 100 ohms resistive. Output pulses must meet the following standards:

Rise and fall transition times for drivers compliant to the Datacon Repeater specification shall be 50 ηs or less between 10% and 90% of peak pulse amplitude as measured across 100 ohms resistive. The peak pulse swing must be at least 15.5 volts sustained at the flat top of the pulse.

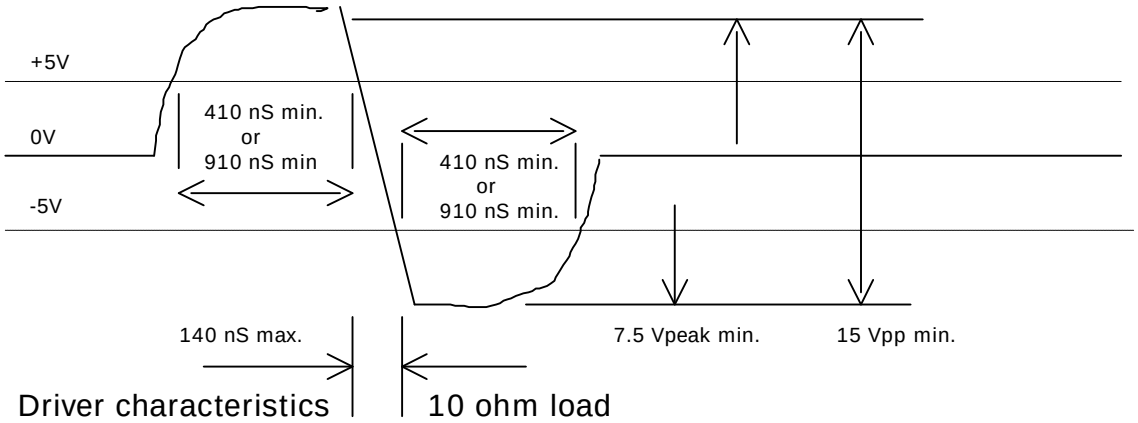
Rise and fall transition times for drivers compliant to the Datacon Repeater specification shall be 140 ηs or less between +5V and -5V as measured across 10 ohms resistive. (over-load conditions)

Pulse width for drivers compliant to the Datacon Repeater specification for data pulses shall be a minimum of 450 ηs between 10% and 90% of peak pulse amplitude as measured across 100 ohms resistive.

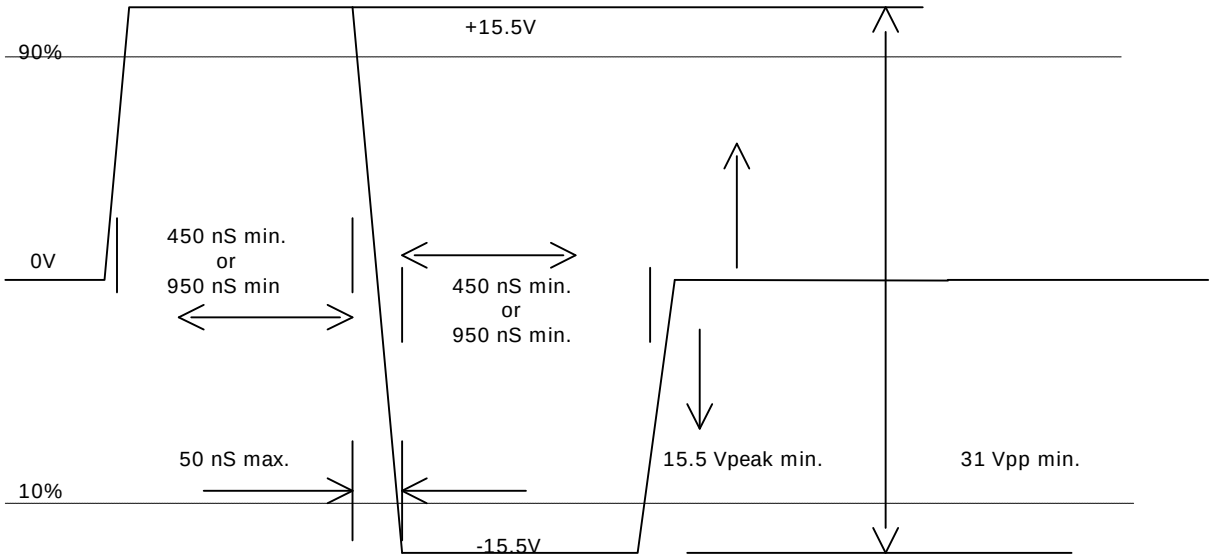
Pulse width for drivers compliant to the Datacon Repeater specification for frame pulses shall be a minimum of 950 ηs between 10% and 90% of peak pulse amplitude as measured across 100 ohms resistive.

Pulse width for data pulses for drivers compliant to the Datacon Repeater specification must be a minimum of 410 ηs between -5V and +5V as measured across 10 ohms resistive.

Pulse width for frame pulses for drivers compliant to the Datacon Repeater specification must be a minimum of 910 ηs between -5V and +5V as measured across 10 ohms resistive.



Driver characteristics 10 ohm load



Driver characteristics 100 ohm load