# iXblue

# Introduction to iXBlue RF drivers and amplifiers for optical modulators

### Introduction :

iXBlue designs, produces and commercializes optical modulators intended for a variety of applications including : optical telecommunications, pulsed lasers, fiber sensors, RF over fiber …

Each application involves a specific modulation format :

- Optical telecommunications most often require digital modulation. As an example, non-return-to-zero (NRZ) format results in long sequences of 0 and 1 symbols distributed randomly with time.



- Pulsed laser requires periodical pulses generation, showing short rectangular shape or arbitrary waveform, and applied with a long duty cycle.



- RF over fiber (RoF) & radar signal processing require analog modulation. The signal shows random amplitude variations, generally around a microwave carrier.



All the above modulation signals are delivered by specific electrical generators. The optical modulator then converts as faithfully as possible these electrical signals into optical signals.

Optical modulators are declined under three main families:

- Amplitude modulator of Mach-Zehnder type,
- Phase modulators,
- I&Q modulators (Dual Parallel Mach-Zehnder modulators nested in a larger combiner circuit)

These modulators are all characterized by their **half-wave voltage Vπ**. For amplitude modulators, it corresponds to the voltage required to switch from the On-state to the Off-state. For phase modulators, the Vπ is the necessary voltage to obtain a $\pi$ phase modulation. The $V_\pi$ parameter indicates generally the voltage required range to get the best dynamic modulation.

The $V_\pi$ parameter of modulators is typically in the range of 4 to 6 V.

Most of the test equipments and generators are designed to deliver voltage much below this value. Typically, a PRBS (Pseudo Random Bit Sequence) generator or an AWG (Arbitrary Waveform Generator) delivers a peak-to-peak voltage ranging from 400 mV to 1000 mV. If directly applied to the modulator, such a low level signal would result into a poor modulation efficiency, showing a low dynamic range and a reduced signal-to-noise ratio.

Therefore, it is generally mandatory to amplify the electrical signal so as to reach optimum amplitude before applying it to the modulator electrodes. This is the function of the **RF modulator driver**.

**Modulator driver presentation :**

The modulator driver is a high bandwidth amplifier built with a cascade of MMIC's (Monolithic Microwave Integrated Circuit) based on the Gallium Arsenide (GaAs) technology and on a distributed amplifier topology, designed to drive an optical modulator in the best suited conditions.

iXBlue designs these amplifiers, the passive microwave PCB, all the biasing electronic for cold-start operation and the package. iXBlue takes a particular attention to the packaging. The latter is optimized to manage the heat dissipation and to avoid internal cavity resonant frequencies. Mechanical design allows these modules to be easily connected to the iXBlue modulators. For ease of use and safety, a single +12V DC voltage is necessary to operate the driver. An additional voltage $V_{amp}$ can be applied for fine adjustment of the gain.

A heat sink is highly recommended for heat dissipation, the driver's performance being degraded at higher temperature.

The RF connector type depends on the aimed data rates or bandwidth (BW). Our drivers, comes with:

- SMA connectors for BW ≤ 12.5 GHz
- 2.92 mm / K connectors for BW from 12.5 GHz up to 30 GHz
- 1.85 mm / 2.4 mm / V connectors for frequencies above 40 GHz and for 40 Gb/s and above data transmission.



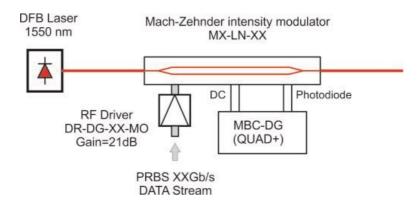*DR-AN-20-MO 20 GHz analog modulator driver*

Next paragraphs give more information about the four main types of modulator drivers offered by iXBlue. They also give explanations about the differences of design between them**.**

**DR-DG-XX-MO-NRZ series :**

DR-DG series modules are digital drivers. Their main application is fibre optic digital communications for which the On-Off Keying (OOK) format based on non-return to zero (NRZ) is the most common modulation format.



*Typical set up for digital modulation*

*Gain:*

The **DR-DG-XX-MO** series drivers allow amplifying an incoming data stream with a 0.5 V peak-to-peak voltage up to 6 $V_{p-p}$. Such a voltage is suitable to drive the modulator at its half wave voltage $V\pi$. The voltage amplification coefficient is x12, i.e. the voltage gain expressed in dB is 10.5 dB and the power gain of the driver is **21dB**. The gain is tunable via an additional voltage.

*Bandwidth:*

XX is the bandwidth in GHz for the targeted operation data rate: 10, 20, 28 or 44Gb/s. The DR-DG-XX-MO has a high frequency cut-off equivalent to the aimed data rate (10 GHz for 10 Gb/s). The high frequency cut-off is not smaller than 0.8 x data rate. The low frequency cut-off is kept as low as possible, typically 50 kHz, in order to transmit the low frequencies of the signal (long series of 0 or 1).

All iXBlue drivers are AC-coupled, meaning they don't transmit nor amplify any continuous signal or very low frequencies of the signal. A DC-block internally set at the output of the modules avoids the driver to deliver a permanent bias voltage that would be then converted into a DC-current in the modulator.

Thus, the average output level is always set at zero. For a voltage of 6 Vpp, when the data stream is balanced between 0's and 1's, then the maximum voltage is +3V and the minimum voltage is -3V.
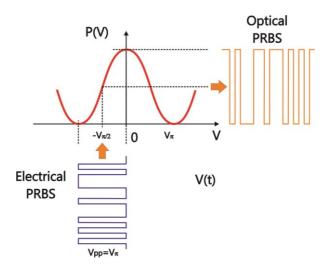
*Electrical 10 Gb/s data stream with $V\pi$ peak-to-peak voltage applied to a modulator to generate a high SNR 10 Gb/s NRZ optical data stream*

*Saturation:*

"MO" stands for Medium Output voltage. The driver is designed so that the saturation of the amplification corresponds to the aimed operating peak-to-peak voltage (approximately equal to the $V\pi$ of the modulator). When combined with the sinusoidal shape of the modulation transfer function of the modulator (figure above), it allows a full dynamic range output modulated signal with much reduced overshoots, and showing a high Q factor and high **SNR** (Signal to Noise Ratio) factor.

*Other parameters:*

For the DR-DG series, the other characteristic parameters are the rise time and the fall time, SNR, peak-to-peak jitter and RMS jitter.

The iXBlue drivers data sheets provide detailed technical information about the electrical bandwidth, the electrical return loss, the output voltage versus the $V_{amp}$. They gives also examples of eye diagrams.

**DR-DG-XX-HO-NRZ series**

The DR-DG-XX-HO series drivers are also dedicated to digital communications. They differ from the MO series by the higher peak-to-peak voltage that can be delivered. The HO letter stands for High Output voltage.

New high data rate fibre optics communications modulation formats (DPSK, DQPSK & QPSK) require modulating with a peak-to-peak voltage of twice the $V\pi$ of the modulator. If the $V\pi$ of the modulator is 6 V then, the peak-to-peak output voltage of the driver should reach 12 V. To make this possible, the driver must integrate three stages of high output power MMIC's.
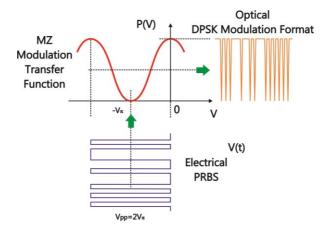
*Electrical 20 Gb/s data stream with 2 x $V\pi$ peak-to-peak voltage applied to a modulator to generate a high SNR 40 Gb/s DPSK optical data stream*
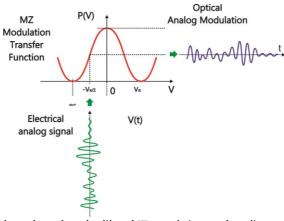
Compared to the DR-DG-XX-MO, the linear gain in amplitude is twice, i.e. an extra 6 dB in power. The gain of the driver is thus typically **29 dB**, and the saturated power typically **+26dBm**.

The heat management and dissipation become even more critical with HO series and the use of a heat sink is therefore mandatory.

### DR-AN-XX-MO series

The DR-AN-XX-MO series drivers address the analog applications. In such applications, the incoming signal is a random signal in amplitude and frequency around a microwave carrier. The combination of driver and modulator should convert this signal without distortion and without excess additional noise.

In order to do so, the amplifier must have a high saturation level. It means that it has to perfectly reproduce the incoming signal with an amplitude level nearly equal to the linear part of the modulator sinusoidal transfer function, thus avoiding distortion from the modulator.



*Electrical analog signal with < V☐ peak-to-peak voltage applied to a modulator to generate a faithful optical reproduction*
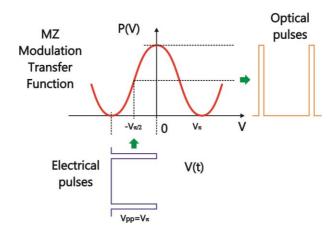
The optimization of the DR-AN series modules is therefore focused on the linearity and the 1 dB compression point ($P_{1dB}$), whereas the optimization of the DR-DG series is focused on output signal parameters such as cross point, SNR and jitter.

The 1 dB compression point of DR-AN-XX-MO series is about +23dBm, higher than the power level required for the modulator full modulation ($V\pi$). This guarantees a large dynamic range with improved linearity. The modulator non linearity will then be the only limitation factor.

The level of the electrical signals that have to be amplified, for instance signals coming from antennas, can be very low. Thus, the analog amplifier must exhibit a high gain, typically 30 dB, that is significantly higher than the gain of the DR-DG series. The driver being used with relaxed frequency requirements, the low cut-off frequency can be higher than with DR-DG series, and is increased up to typically 100 kHz.


### DR-PL-XX-MO

Pulsed modulation requires specific drivers. The DR-PL series modules are designed for this application.



*Pulse electrical signal with $V\pi$ peak-to-peak voltage applied to a modulator to generate optical pulses with high extinction*


The DR-PL series drivers are designed to amplify low-level electrical pulses to a peak value of typically the $V\pi$ of the modulator. The typical set up usually intends to generate high extinction ratio optical pulses. The requirements for the DR-PL drivers is to maintain the rectangular shape of the input electrical pulses and to be transparent to both the pulse duration and the duty cycle, the latter being potentially very low. This is obtained by a specific configuration of the MMIC chips that allows to obtain a sufficient gain without ripple and overshoots, and reaching the saturation level at the same time.

The low frequency cut-off can be optimized on requirements to reach very low pulses repetition rate. This can be useful in particular application such as amplification of pulse burst. The rise and fall time of the DR-PL series drivers are typically 40 ps, which allows us to produce short duration pulses of 0.1 ns. The operating pulse width can be extended to 100 ns.