Application Note

Anritsu

PAM (Pulse Amplitude Modulation) Signal Generation for QAM Transmission

MP1800A Series

Signal Quality Analyzer

1. Market Trend

The market explosion in cloud computing services and smartphones has caused urgent issues with core network and server transfer capacities for network service providers.
As shown in Fig.1, core network transfer rates have doubled in 18 months while server I/O transfer rates have doubled in 24 months.
This rapid expansion in transfer capacity in optical fiber communications has been achieved using digital coherent technology by applying digital signal processing technology first commercialized in the wireless field. In recent years, 100G Ultra Long Haul transfers using this technology have been achieved using DP-QPSK (Dual Polarization Quadrature Phase Shift Keying).
Future multiplexing technologies for increasing large-capacity transfers even further are focusing on QAM (Quadrature Amplitude Modulation), which performs multiplexing on both the phase and amplitude axes. Since (in QAM technologies) 2^NQAM offers increased Nth frequency usage efficiency compared to the normal OOK (On Off Keying), it is the focus of active R&D as a prospective technology for configuring future large-capacity core networks.

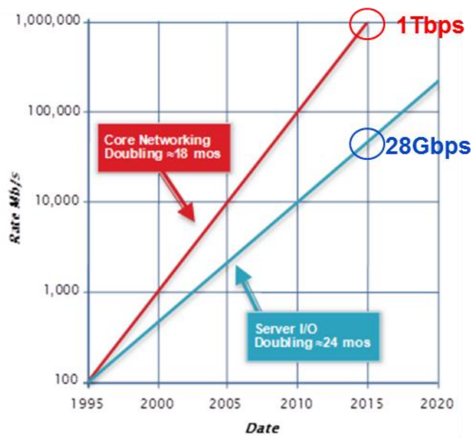


Fig.1 IEEE 802.3 HSSG bandwidth demand projections

Fig.2 shows a typical digital coherent block diagram.
It describes generation of the reference signal by replacing DSP (Digital Signal Processor) and DAC (Digital to Analog Converter) units with the Multi-channel PPG (Pulse Pattern Generator) units.

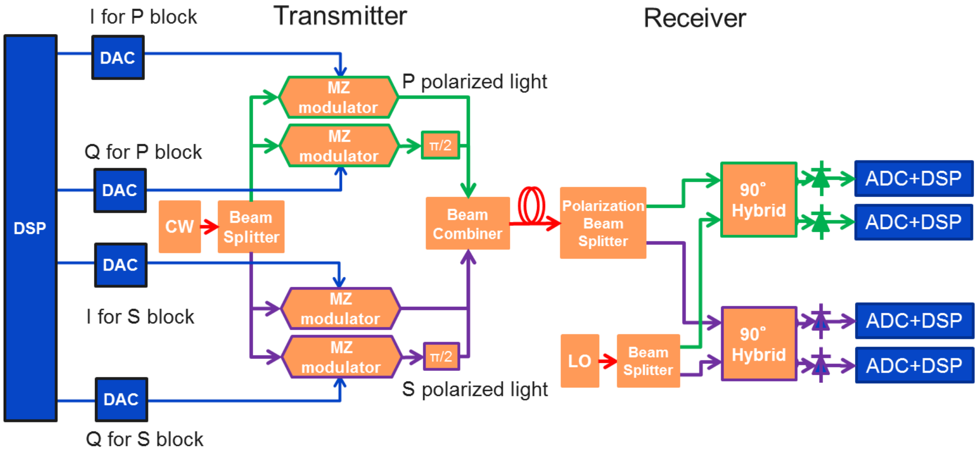


Fig.2 Typical digital coherent TRx block diagram

2. PAM4 Signal Generation for Dual DP-16QAM using Multi-channel PPG

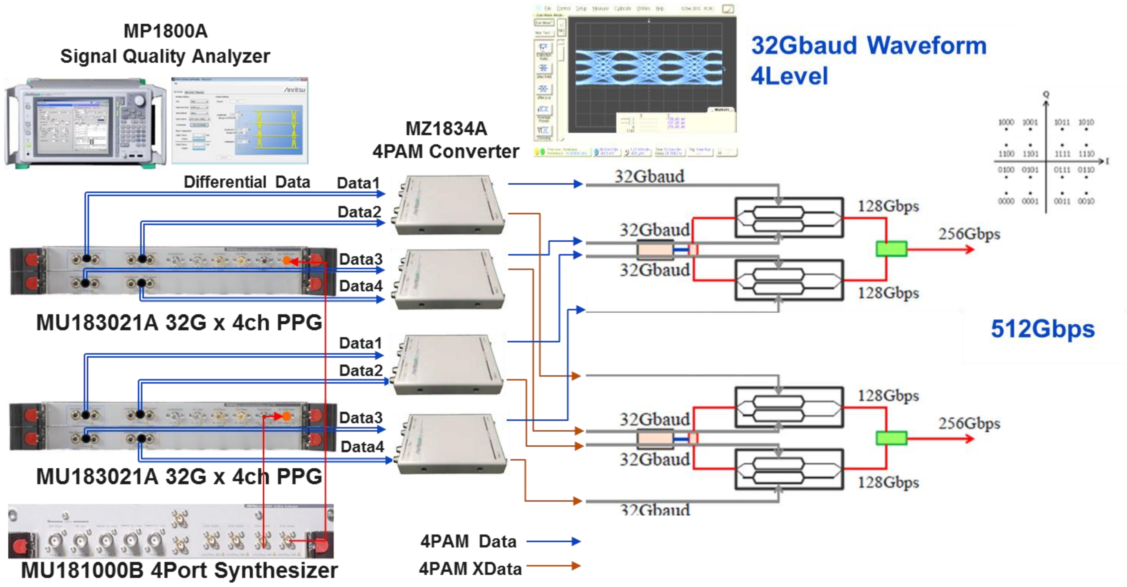
2.1. Dual DP-16QAM (PAM4) Equipment Configuration

Fig.3 shows the measurement configuration for the Dual DP-16 QAM technology as one candidate for 400G Ultra long-haul transmission using a multi-channel PPG as an example. 16-QAM transmission requires generation of a PAM4 signal (4-level pulse amplitude modulated signal) to drive the optical phase modulator. The example in Fig.3 shows a set-up composed of the MP1800A main frame, two MU183021A 32G 4ch PPG units and a MU181000B Synthesizer. Data1 and Data2 as well as Data3 and Data4 of each of the two PPGs are combined with MZ1834A 4PAM Converter to produce the PAM4 signal.

Generation of a high-quality PAM signal requires PPGs with the following features:

1) Good output signal quality (low jitter, low waveform distortion, sharp rise and fall times)
2) Tunable output amplitude over wide range for adjusting signal output amplitude after Power Divider
3) Tunable Data output phase

It is possible to use power combiners and cables, however, assuring the signal quality requires use of fixed attenuators to suppress cross reflections between Data1 and Data2 (Data3 and Data4) as well as coaxial cables with good phase-matched high-frequency characteristics at signal coupling. MZ1834A ensures enough isolation between Data Inputs. J1551A Phase Matched Pair Cable provides fine delay matching.



Model	Name	Quantity	Note
MP1800A	Signal Quality Analyzer	1	
MP1800A-015	4 Slot PPG/ED	1	
MU183021A	28/32 Gbit/s 4ch PPG	2	
MU183021A-001	32 Gbit/s Extension	2	
MU183021A-013	4ch 3.5-V Data output	2	
MU183021A-030	4ch Data Delay	2	
MU181000B	4 Port Synthesizer	1	
MZ1834A	4PAM Converter	4	
J1551A *	Phase Matched Pair Cable	8	Skew <3ps, PPG to MZ1834A
K222B *	K(f)-K(f) Adapter	16	

Fig.3 Dual DP-16QAM Tx block and instrument configuration

*: Cables for connecting with DUT are not included.
If the 4PAM Converter is connected to the PPG using cables, two K222B units must be used. Additionally we recommend using the J1551A coaxial Skew Matched Cables (skew <3 ps) to suppress phase differences caused by differences in cable lengths. Phase differences between channels can be adjusted using the PPG Delay function.

2.2. PAM4 Signal Generation Method

The following section describes the specific signal generation method.

1) Combination setting is used to match the signal generation timing between the multi-channel PPGs. Depending on the customer usage conditions, one of the following three MU183021A 32 Gbit/s 4ch PPG signal generations modes (Independent, Combination, CH Synchronization) is selected (Fig.4)

- **Independent:** Each Data output can be set to an independent pattern and the signal generation timing is also independent.
- **2ch, 4ch Combination:** At the 2ch setting, the pattern is generated like serial data when a 2:1 MUX is connected to the PPG output.
- **CH Synchronization:** Each Data output can be set to an independent pattern but the pattern is generated so that the Start bits are matched.

Usually, when coupling the same pattern at the Power Divider, because there is a weak pattern correlation after coupling each of the Data1 and Data2 (Data3 and Data4) signals, a half-cycle shifted pattern must be generated for PRBS. Additionally, assuring measurement reproducibility requires maintaining the same bit relationship even when powering-up and changing the frequency. Combination 2ch CH Sync is selected to meet these requirements.

2) Each PPG output is set. The output amplitude for each of Data1 to Data4 is set and the Delay is set to minimize the waveform jitter after signal coupling. The PAM Control Software enables easy setting of swing amplitude and EYE proportion (Fig.5).

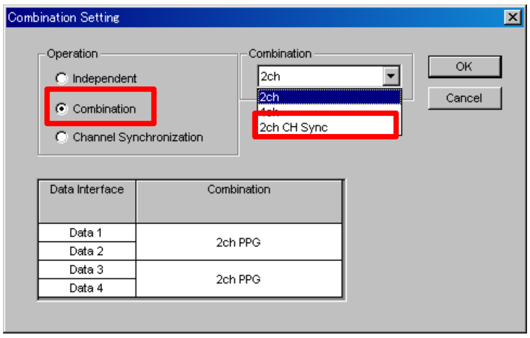


Fig.4 Combination setting

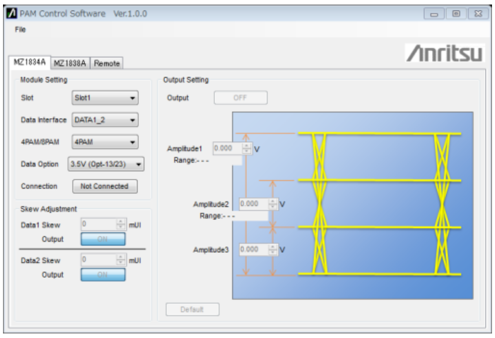


Fig.5 Output setting

2.3. Typical PAM4 Waveforms

Fig.6 shows PAM4 waveforms at typical Baud rates. It is clear that these waveforms have a good open Eye with low jitter even after the PPG output Power Divider.
In addition, this configuration supports adjustment of the PAM4 overall amplitude as well as equalizing the center and upper/lower Eye, and setting the amplitude difference by setting the amplitude for Data1, 2, 3 and 4.

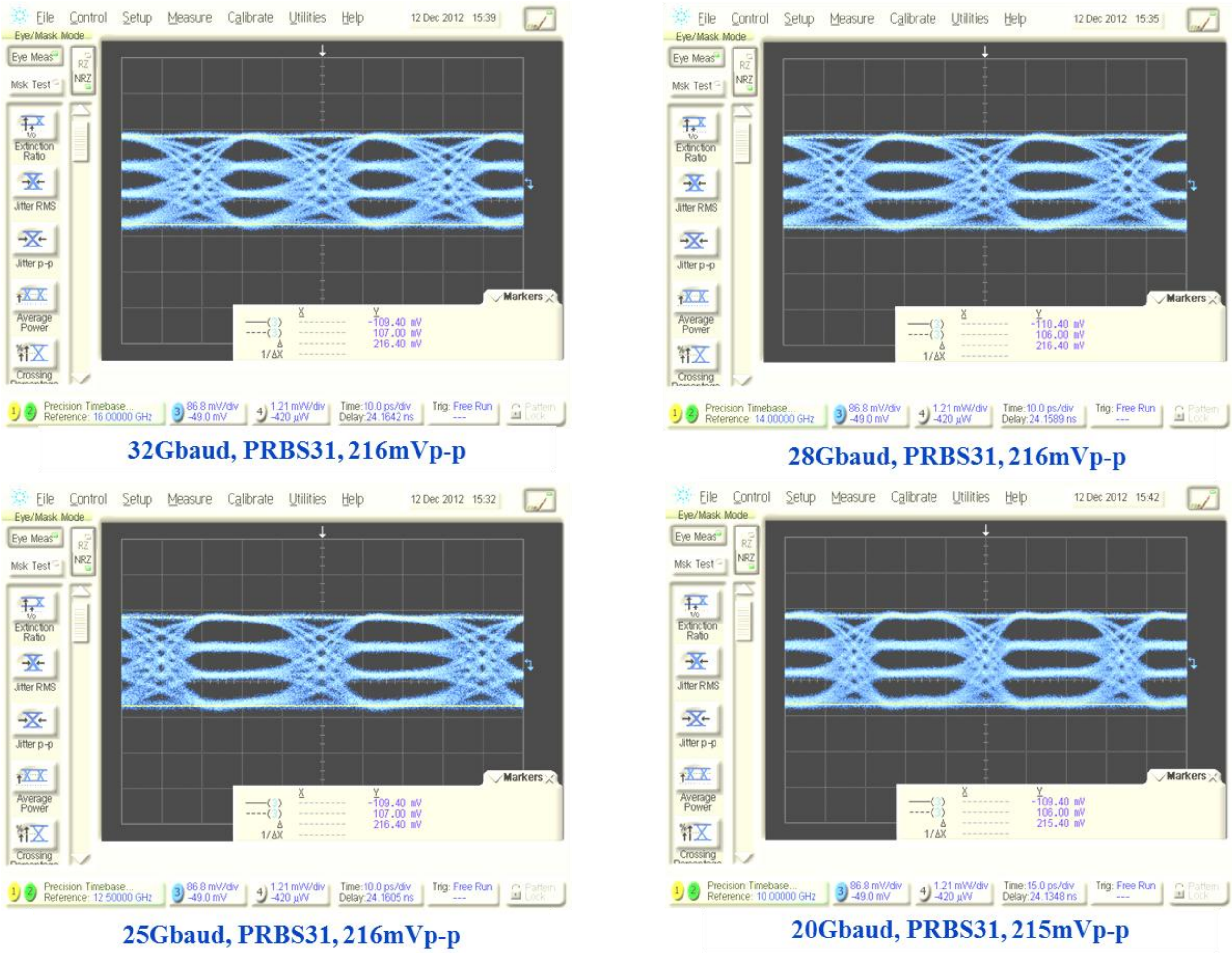
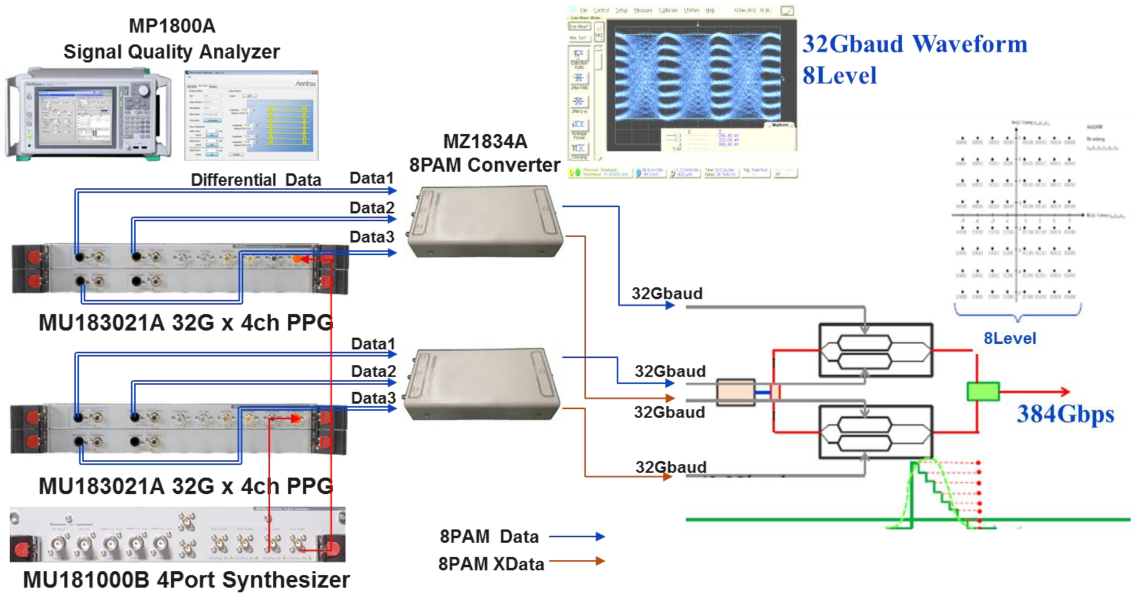


Fig.6 Typical PAM4 waveforms

3. PAM8 Signal Generation for DP-64QAM using Multi-channel PPG

3.1. DP-64QAM (PAM8) Equipment Configuration

Similarly, Fig.7 shows the measurement configuration for the DP-64 QAM technology using multi-channel PPGs. DP-64QAM tranmission requires generation of a pulse-modulated PAM8 signal to drive the optical phase modulator. The difference from PAM4 signal generation is that an 8-level pulse-modulated signal is generated by coupling Data1, Data2, and Data3. MZ1838A ensures enough isolation between Data Inputs. In addition, adapting J1551A Phase Matched Pair Cable provides fine delay matching.



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MU183021A-013	4ch 3.5-V Data output	2	
MU183021A-030	4ch Data Delay	2	
MU181000B	4 Port Synthesizer	1	
MZ1838A	8 PAM Converter	2	
J1551A	Phase Matched Pair Cable	6	Skew <3ps PPG to MZ1838A

Fig.7 DP-64QAMTx block and instrument configuration

3.2. *Specific PAM8 Signal Generation Method*

The following section describes the specific signal generation method.

1) Combination Setting is used but unlike the description in section 2.2, 4ch Combination is set instead (Fig.8)
   Since each of the Data1, Data2, Data3, and Data4 PRBS patterns must be shifted by one-quarter cycle at 4ch Combination, there is a weak pattern correlation when Data1, Data2, and Data3 are combined.

2) Each PPG output is set. The output amplitude is set for Data1 to Data3 and the Delay is set to minimize the waveform jitter.

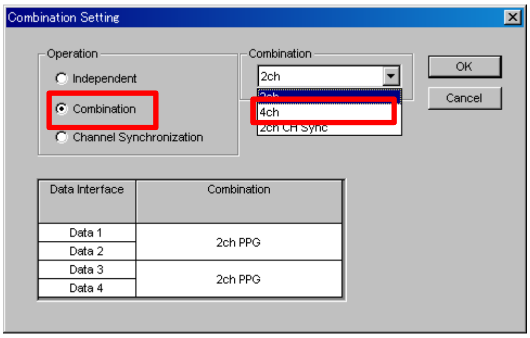

Fig.8 Combination setting

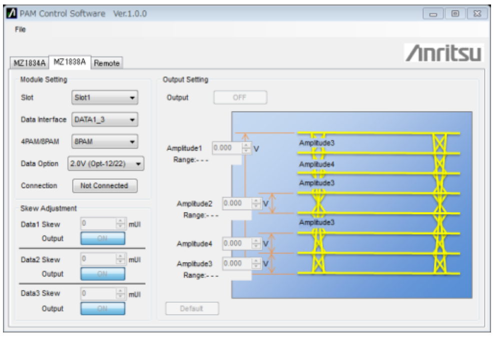

Fig.9 Output Setting

3.3. *Typical PAM8 Waveforms*

Fig.9 shows the PAM8 waveforms at typical Baud rates. Like PAM4, it is clear that good open Eye waveforms with low jitter are obtained even after PPG output signal coupling. Moreover, the overall amplitude of the PAM8 waveform can be adjusted by setting the amplitude of Data1, 2 and 3.

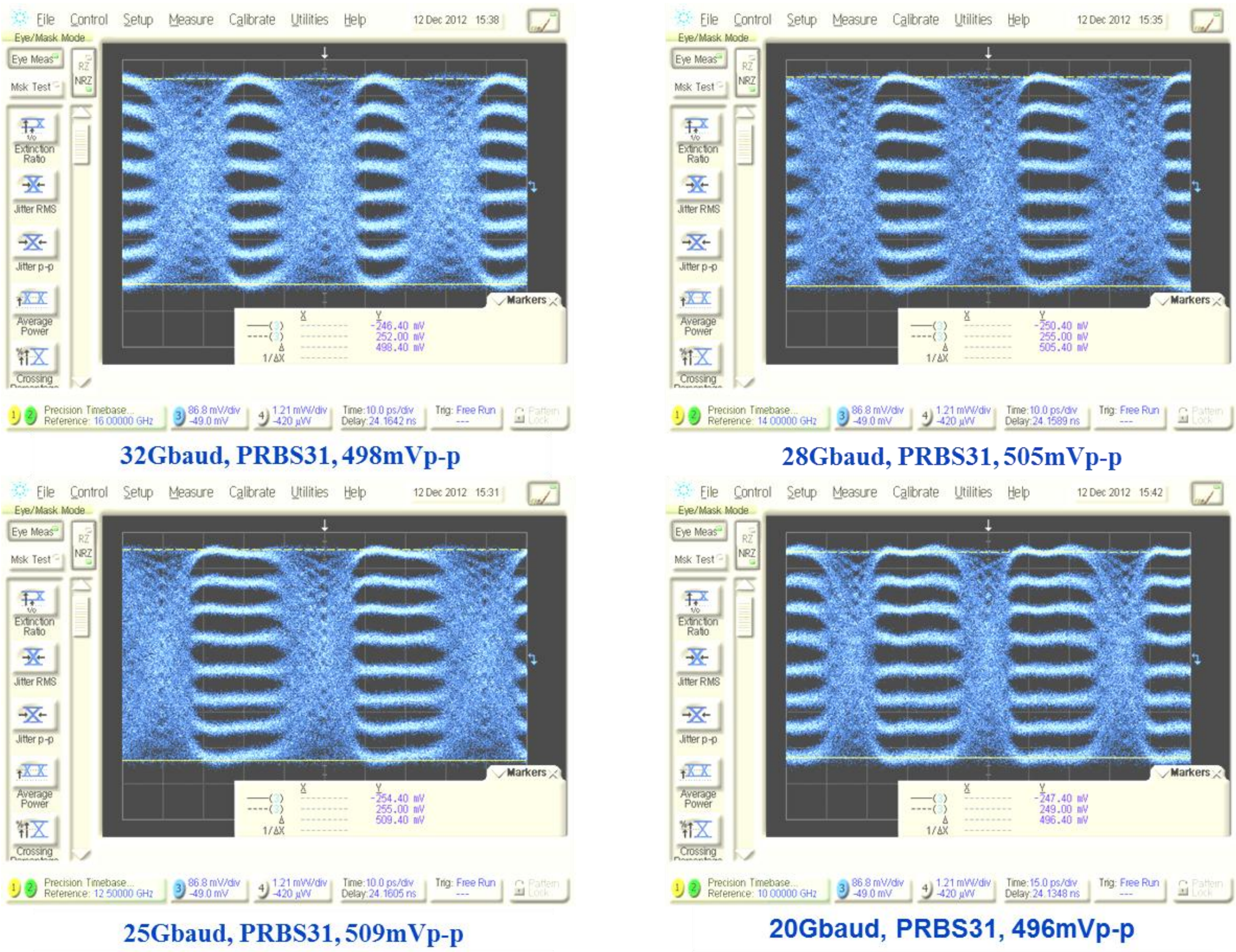

Fig.10 Typical PAM8 waveforms

4. Summary

These materials describe generation—and related points—of PAM4 and PAM8 reference signals using multi-channel PPGs for R&D of QAM transmission methods offering the promise of large-capacity core networks. The DSP and DAC used in current R&D are replaced by multi-channel PPGs and the setup is not only used in QAM transmission R&D but also supports various other applications, such as DP-QPSK transmission technology. Anritsu measurement solutions support new ways for resolving problems in achieving even faster and larger capacity future communications.

Specifications are subject to change without notice.

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No. MP1800A_PAM-E-F-1-(3.00) 公知 Printed in Japan 2013-12 MG